MODIFICATION AND APPROVAL

OF

MINE RESCUE SUPPORT MACHINE

FINAL REPORT

Contract Number 200-2017-94151

Prepared for CDC-NIOSH by:

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SUMMARY

Under previous research efforts, a prototype proof-of-concept machine was developed, that could assist mine rescue personnel with rescue and recovery efforts, by performing tasks that currently require grueling manual labor, and thus improve safety, by reducing the physical exertion and exposure risks associated with the job at hand. The prototype machine was a compact diesel engine powered track loader operated via radio remote control. Participation of the mine rescue community was an integral component of the design and development of this prototype machine. This machine was designed to meet the needs and requests expressed by mine rescuers, and there was a general optimism that this machine could become a useful tool for mine rescue teams, reduce the exposure risk to mine rescue personnel, and expedite rescue and recovery operations.

In order for the prototype machine to be used by mine rescuers in actual rescue and recovery events, it was deemed necessary for the design to meet the standards set forth by MSHA for permissible areas. It was therefore the major objective of this project to apply for the necessary MSHA approvals for the machine. Substantial redesign of the original prototype was performed under this project. Further development of the original prototype was necessary to not only meet the requirements for MSHA approval, but also to improve the design based upon operator feedback from those who will use the machine. Consideration was also given to improvement of functionality, mine-worthiness, and practicality, with any design changes to the prototype.

The project timeline was substantially affected by the redesign process, changes to the approval application and evaluation process, as well as the availability of components, but also, the COVID-19 pandemic. Significant delays arose due to

personnel shortages and limitations of work schedules, both for the contractor and the government, made necessary by measures taken to mitigate the spread of the virus.

This report discusses the work performed and results achieved during this project, and details the machine design changes and the applications for MSHA approvals, as well as the progress of the approval processes for these applications.

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NOMENCLATURE

A&CC	Approval and Certification Center
AGM	Absorbent Glass Mat
AM	Ante Meridiem
ATEX	Atmospheres Explosibles European Union Directive
BTU	British Thermal Unit
CAN	Controller Area Network
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CO2	Carbon Dioxide
COR	Contract Officer’s Representative
COVID-19	coronavirus disease of 2019
cu in	cubic inch
DOC	Diesel Oxidation Catalyst
DPM	Diesel Particulate Matter
℉	Degrees Fahrenheit
FAB	Fresh Air Base
Ft-lb	foot-pound
GHz	GigaHertz
gpm	Gallons per minute
HDSDI	High Definition Serial Digital Interface
hp	horsepower

in and “	Inch(es)
” H_20	Inches of Water Column
IR	InfraRed
ISO	International Organization for Standarization
lbm	Pound Mass
LHD	Load Haul Dump
LiFePO4	Lithium Iron Phosphate
LS	load sense
MEO	Mine Emergency Operation Group
MHz	MegaHertz
mm	millimeter
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
O2	Oxygen
OEM	Original Equipment Manufacturer
%	Percent
PLC	Programmable Logic Controller
PM	Post Meridiem
ppm	parts per million
psi	Pounds per Square Inch
PTO	Power Take Off
R	Rankine
RCA	Radio Corporation of America

RPM	Revolutions Per Minute
UL	Underwriters Laboratories
US	United States
Wh	Watt-hour
WV	West Virginia
XP	Explosion Proof

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BACKGROUND

Under previous research efforts, a prototype mine rescue machine was designed and built for the purpose of assisting mine rescue personnel in mine rescue and recovery efforts. Comments offered by the mine rescue community were an instrumental part of the prototype design and development process. The machine prototype was well received by mine rescue personnel, who expressed a cautious optimism that it would benefit mine rescue and recovery work by not only improving the rate at which laborious tasks could be accomplished, but also by reducing exposure of personnel to potential hazards, thus improving safety. Successful demonstrations of the prototype machine indicated that it could be developed into a valuable tool for mine rescue work. In order for the machine to be useful to the mine rescue community in its designed purpose, it was decided that the machine needed to meet the requirements of permissible equipment as established by MSHA. Continued development and testing of the prototype was also necessary to improve machine performance. Figure 1 shows a picture of the prototype mine rescue machine, and an operator wearing mine rescue apparatus, at a demonstration conducted by CDC NIOSH at the Doll’s Run Mine Training Facility of West Virginia University.

Figure 1 - MICROTRAXX™ Mine Rescue Support Machine Prototype

Whereas MSHA approval of the machine was a necessary requirement before it was practical to use in a mine rescue situation; the primary purpose of this project was to pursue the approval process. The initial prototype machine was built with the intention of submitting the design for permissible approval, but it was discovered that there were design alterations necessary to meet approval requirements. There were also multiple approvals needed for the machine, some being dependent on attaining approval of subsystems and components. The machine approval also required approvals of a diesel engine, diesel power package, diesel electric system, and explosion proof enclosure. Where possible, designers attempted to use components with existing approval to reduce or eliminate the need for individual component approvals.

Changes to the approval process were implemented by MSHA after the start of the project. MSHA announced that the practice of issuing multiple correction notices for application documents or test apparatus would be substantially limited as compared to procedures used in the past. This policy change was necessary to "improve the efficiency and effectiveness of the approval application evaluation process." The change directly affected this project as the new policy substantially limited the ability of the applicant to correct discrepancies in documentation, and some confusion and adjustment was involved in the policy implementation. The change made the consultation and preliminary review process much more useful and important, and changed the timeline for submitting the approval application documentation while corrections and alterations were made.

While some machine modifications were made directly to the existing prototype for testing and improvement purposes, additional machine subsystems, such as a diesel power package, were fabricated separately for testing purposes to facilitate the approval process. The approval testing process can be very destructive to the tested devices, and therefore building separate test systems kept a functional prototype machine available during the project.

During initial prototype development, operators indicated that alterations to the remote-control system were desirable to improve operator interface and machine controllability, and also that data feedback from the machine to the controller would be beneficial. These adjustments include control alignments and positioning, as well as proportional control adjustment to improve fine control. A specific request was to review function operators to reduce operator effort in locating control position(s) while under apparatus and wearing gloves. Improvement to the reliability and range of wireless control would increase the functional area in which the machine can work. Broadcasting a video stream from the machine, as well as other pertinent data, would make it possible for information from the machine to be sent to the command center. A request was also made to “increase the number of engine starts available before on-board air was depleted,” this request led designers to develop a hydraulic starting system, in which an accumulator was used to energize the starting motor, and it was recharged by the hydraulic pump on the machine.

Changes in the machine design were evaluated based on necessity both for performance improvement and / or regulatory requirement. The goal for designers with any change was to improve the overall design and not sacrifice performance. Space saving measures and component realignments were used to improve serviceability and add valuable space for access, storage, or additional features to the machine. Most importantly, the machine must be mine worthy, and therefore the durability of the machine was considered an important part of any design change.

Initial Project Planning

The project commenced on 14 August 2017, and a kickoff meeting was requested. This meeting was held at the CDC NIOSH Bruceton Laboratory on 29 August 2017 at 11:30 am with representatives of CDC NIOSH and the contractor in attendance. Project protocols, scope of work, and timelines were reviewed. A discussion was held regarding demonstration opportunities, and it was emphasized, that should such opportunities arise, the project could benefit from raising awareness in the mine rescue community and improve familiarization with operators. It was further reviewed and discussed that the contract does allow for some demonstrations for said purpose, and that, at the option of CDC NIOSH, demonstration opportunities should be acted upon when they are deemed to be of benefit to the project.

After the kickoff meeting, the group met with MSHA MEO representatives to discuss their experience(s) with the existing prototype machine and any design changes that were desired. The group expressed that the machine did not require significant changes but did have some requests and recommendations.

A concern was expressed with the air start system and the limited supply of air held by the on-board tank, which restricted the number of times the engine could be started. It was suggested that on board charging of the air tank would be an improvement over the current design of charge via external source. It was mentioned that, in more than one instance, the air start valve had stuck in the on position and depleted all on-board air during a single engine start sequence. A suggestion was made to include an air compressor on the machine to charge the system. It was agreed that the contractor would investigate alterations to the machine design that would alleviate this concern. A request was made to further adjust the bucket lift and tilt speeds as they were perceived to be too fast for smooth control. Widening the bucket outside of the machine envelope was mentioned as desirable for future machines. Remote or automatic throttle up and down control were mentioned as being beneficial to machine operation to prevent stalling the engine, and allow for idling when the machine was not in motion. Machine control was discussed and it was mentioned that the operator found the tablet style control to be difficult to use. One reason cited for this was not having a positive way to "feel" the center of controls for tram and bucket, which caused the operator to spend time looking at the screen for control location, and not being able to watch and be aware of the machine. Operators expressed that a joystick or lever would be desirable for machine controls. It was also mentioned that a video output feed from the machine compatible with RCA or

HDSDI video protocol was desirable for transmission of machine data to the command center.

It was decided that Rohmac would be permitted to take possession of the prototype mine rescue machine after the meeting, to begin Phase I design work; and to allow for a demonstration meeting with MSHA A&CC representatives, such that they could see the machine and discuss the permissible approval process needs.

The aforementioned meeting was scheduled, and on 27 September 2017, the prototype machine was taken to the MSHA Approval and Certification Center at Triadelphia, WV, to meet with MSHA personnel and discuss the machine and the project with them. Representatives from CDC NIOSH, MSHA MEO, and the mechanical and electrical safety divisions of MSHA A&CC were in attendance. During this meeting, design features of the diesel engine power package and the electrical control system were discussed and demonstrated. The desire to attain permissible approval for the machine was discussed, and the test procedures and performance requirements were discussed as they related to the machine design. Key points that were discussed included the engine exhaust system, engine intake, air compressor requirements, on-board battery, changeable fuel tank, surface temperature control, braking requirements, alternator, and Intrinsically Safe standards. Reactions to the prototype machine were generally positive, and there were no serious problems identified that would prevent the design from being considered for approval.

During this meeting, consultation from A&CC representatives as permitted by 30 CFR 36.3 was discussed, which provided for design questions to be answered before submitting approval applications for a machine. Designers were encouraged to utilize this valuable tool as a benefit to the approval process. It was later discussed and decided that, while the consultation process may extend the dates for submittal of approval applications from originally anticipated project timelines, the benefit gained in avoiding possible deficiencies far outweighed any delay to the original project schedule, and at the time it was believed that this may in fact expedite the approval process for the machine.

PHASE I REDESIGN FOCUS AREAS

An evaluation of several machine systems was performed in consideration of design alteration. A basic overview of the design features that were considered for change are discussed herein. One of the first features on the machine, that improvements were requested for, was the starting capacity of the pneumatic system. Significant concern was expressed over the existing design, that did not recharge the on-board air as the machine operated. When the air supply was depleted, the machine would not start, and further, there were instances during engine start sequences where the start valve stuck in the on position, and exhausted the on-board air supply. The reasons for not including an on-board compressor to recharge air were thoroughly discussed during the prototype process. Of primary concern was the possible operation of the air compressor in a compromised atmosphere; it was believed that this could compress certain gases that may cause hazardous, or otherwise undesirable, situations. This led designers to consider another alternative.

It was decided to replace the pneumatic engine start and control system with a hydraulic system. This method, along with changing to a hydraulic rather than pneumatic safety shutdown system, also allowed designers to remove the pneumatic system entirely. From a design standpoint, the pneumatic starter required a relatively large volume of air to start the engine. Hydraulic starters tend to be more compact and provide more torque and higher speed to improve engine starting, and generate less noise than some methods. With the hydraulic system, the air tank was replaced by a smaller accumulator that is recharged by the hydraulic pump. An on-board hand pump is used to charge the accumulator in the event the system pressure is depleted. On the shutdown control circuit, some of the pneumatic controllers were also compatible with hydraulic fluid and thus were able to be used in the revised design.

In response to the request for automatic throttle control, designers found and implemented a spring return hydraulic cylinder throttle control that opens the throttle when system pressure increases and returns to idle when the system is on standby pressure. Whereas the system pressure tends to fluctuate as different functions are activated, a flow control valve was added to hold pressure in the throttle circuit and keep the engine at speed for a short time before allowing the idle return, to reduce variations in engine speed. A spring return cylinder that operates on the safety circuit pressure was also used to control engine shutdown in place of the pneumatic cylinder previously used.

Space saving and component locations were evaluated for improvement. One of the difficult realities of the compact size of this machine design is that change to one area of the machine affected the entire machine layout, and moving one component often required that another component be moved as well. Removal of the pneumatic system components was the most significant reduction in space requirements achieved under this project. Another space saving measure involved the intake manifold and intake flame arrestor. Designers sourced a flame arrestor from a reputable mining equipment manufacturer; this new arrestor was significantly smaller than the original prototype, and permitted a redesign of the intake manifold that made the intake more compact and simpler to manufacture. Other space saving design features involved relocation of the hydraulic valve bank, and a mono-block design for the hydraulic engine start and safety shutoff control valves, relocation and packaging of the fire suppression system components to a removable tray that improved service access, and redesign of the engine gage panel.

The electrical system was also revised to improve space requirements, serviceability, and incorporate MSHA approved components to simplify the approval process. Initial discussions held with MSHA representatives led designers to move the battery, used to power the remote-control system and hydraulic valve coils to start the engine, outside of the permissible enclosure. This change would allow the battery to be removed and recharged without opening the enclosure, and reduce the volume needed inside of the explosion proof enclosure. Battery location and chemistry became a subject of much debate and design consideration, as detailed later in the report. A modularization / streamlining of components inside of the enclosure was also performed to use space more efficiently and improve access for testing and troubleshooting. Addition of intrinsically safe sensors to monitor the machine conditions and report data to the operator was also evaluated, and while electronic sensors may add value and make it possible to incorporate a digital display of parameters on the machine that could replace the gage panel, and possibly send data to the remote operator, it was decided that this would add complication to the approval process and would be better approached with a modification after initial approval is achieved. An MSHA approved alternator was sourced for the power package. The size of the alternator made it necessary to add a through shaft drive to the hydraulic pump with an overhung load adapter to drive and locate the alternator on the flywheel end of the engine. The intake flame arrestor redesign, described earlier, contributed to allowing sufficient space to mount the alternator in this location.

After commencement of this project, the contractor was informed by the prototype radio remote control manufacturer, that they would not produce an MSHA approved radio with a different operating frequency than their standard 900 MHz band, which MSHA MEO had adamantly requested designers to avoid. A request had been made of this manufacturer to produce an approved radio operating in the 2.4 GHz band, and preliminary discussions indicated that said radio would be available for this project. Upon notification to the contrary, an attempt was made to source an alternative radio control system. A manufacturer of a radio remote control system, that was approved by MSHA after the initial prototype mine rescue machine was developed, was found and contacted. Initial discussions with the manufacturer seemed to be productive and it appeared that they would be able to provide an approved system in the 450 MHz band for the mine rescue machine, however, the process was terminated in October 2018 when the contractor was informed by this manufacturer that they would no longer be able to provide their MSHA approved radio system to the US market. Later, another radio remote control system manufacturer was discovered that offered promising technology, including wireless video transmission and extended range operation. This manufacturer indicated a willingness to pursue MSHA approval for their control system, and at such time as this system would be approved for use it would merit consideration as an alternative control system for the mine rescue machine. The primary reason for pursuing a radio remote control system alternative was to attempt to find an already approved system that would operate outside of the 900 MHz frequency band to avoid any possible interference with the communication system utilized by MSHA MEO. However, a suitable device that meets these criteria was not found, so it was necessary to utilize an approved 900 MHz system built by the original prototype radio manufacturer during this project. The process of looking for an alternative radio remote control system was one of the unexpected delays encountered during this project that contributed to the necessity of an extended timeline, and as mentioned, new technology could become available at any time that may merit change to the mine rescue machine system.

Most of the design and revision work performed during this project involved the exhaust treatment system. Preliminary testing and discussion with MSHA representatives revealed that the original prototype system would not meet approval requirements without modification. Surface temperatures on the unit appeared to be within the requirements, but it was learned that coolant exiting the water jacket around the exhaust manifold and filter chamber could not exceed 212 °F, and that the original design would not pass with temperatures that were observed during preliminary tests. The cooling system was discussed, and splitting the coolant flow into a parallel system or reversing the flow of coolant to go through the exhaust system first, were mentioned as possibilities to reduce the temperature of the coolant. The contractor believed that the existing ports into the water jacket on the exhaust system were restricting flow and modified and tested larger ports. It was also discovered that the available volume of water in the mixing chamber needed to be increased to meet an 8-hour run time requirement. Methods of increasing available water volume were discussed, including use of a make-up water system that would replenish water in the mixing chamber as it was used, which could help meet the capacity requirement without enlarging the existing device. Testing was performed with additional water volume in the exhaust mixing chamber, by installing a riser pipe in the dpm filter chamber and turning the exhaust exit pipe up to reduce condensation loss, to determine an approximate water consumption rate.

It was also discussed with MSHA, that during the approval tests, methane is added to the intake of the engine, and that this can increase exhaust temperatures approximately 50 °F; and that in addition to coating the system surfaces with a temperature sensitive paint that melts above 300 °F, thermal imaging scanners would be used to identify hot spots on the power package. Additional discussions on the design were held and a suggestion was made to consider a "dry exhaust system" design instead of the water mixing system. The differences between a mixing system and a dry system are that the mixing system passes the engine exhaust through a volume of water, which cools the exhaust and quenches any spark or flame, whereas the dry exhaust cools the exhaust without mixing with a cooling fluid, this requires the addition of a flame arrestor since the exhaust is not quenched. As the water mixing chamber acts as a flame arrestor, the gradeability of the machine was of concern. With the mixing chamber design, it was necessary that the exhaust be submerged by water in all operating conditions, and the prototype mixing chamber design would have limits imposed on machine gradeability. Ultimately, in July 2018, it was decided to redesign the exhaust to utilize a dry system approach. Due to the time necessary for the redesign of the exhaust system, a no cost time extension for Phase I was requested and granted. The exhaust box redesign testing process is discussed later in this report, several design iterations were performed and tested.

Of note, the MSHA consultation / preliminary review process provided a means for designers to change designs and test prototype units without the risk of failing costly approval tests, and the associated time investment to perform tests away from the manufacturer's facility, further, it was learned that prototypes and test units are permitted to be fabricated using mild steel instead of stainless steel (required in certain exhaust areas by MSHA) for approval testing purposes, these were valuable cost saving measures which facilitated the approval process.

HYDRAULIC SYSTEM REDESIGN

Several changes were necessary in order to change the pneumatic start and control system to a hydraulic control system. The air tank was removed from the machine and replaced by a 2.5-gallon hydraulic piston accumulator. The size of the accumulator was recommended by the hydraulic starter manufacturer. The accumulator is recharged by the hydraulic pump after startup, also, an on-board hand pump can be used to charge the accumulator when the engine is not operational. A ball valve is used to close the accumulator to keep pressure from leaking off when the machine is parked for extended periods. The accumulator was located under the exhaust system beside the engine, Figure 2 shows the installation. The hand pump installed on the front corner of the machine is shown in Figure 3.

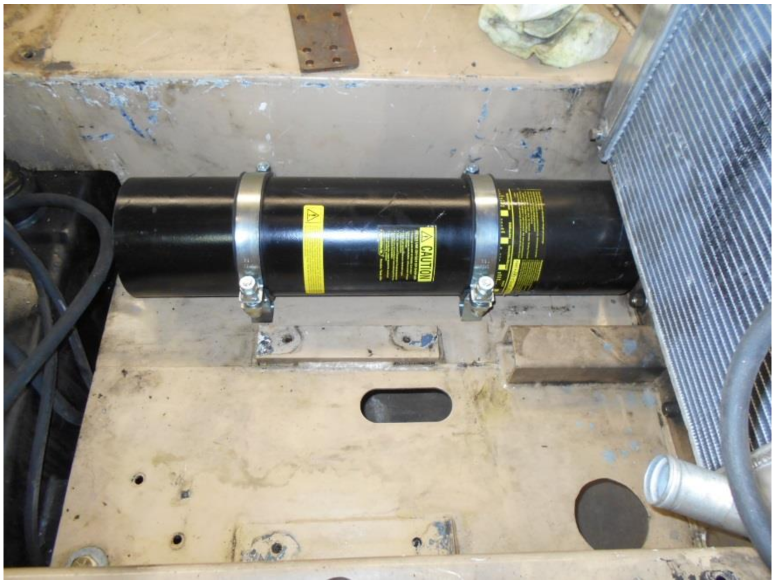
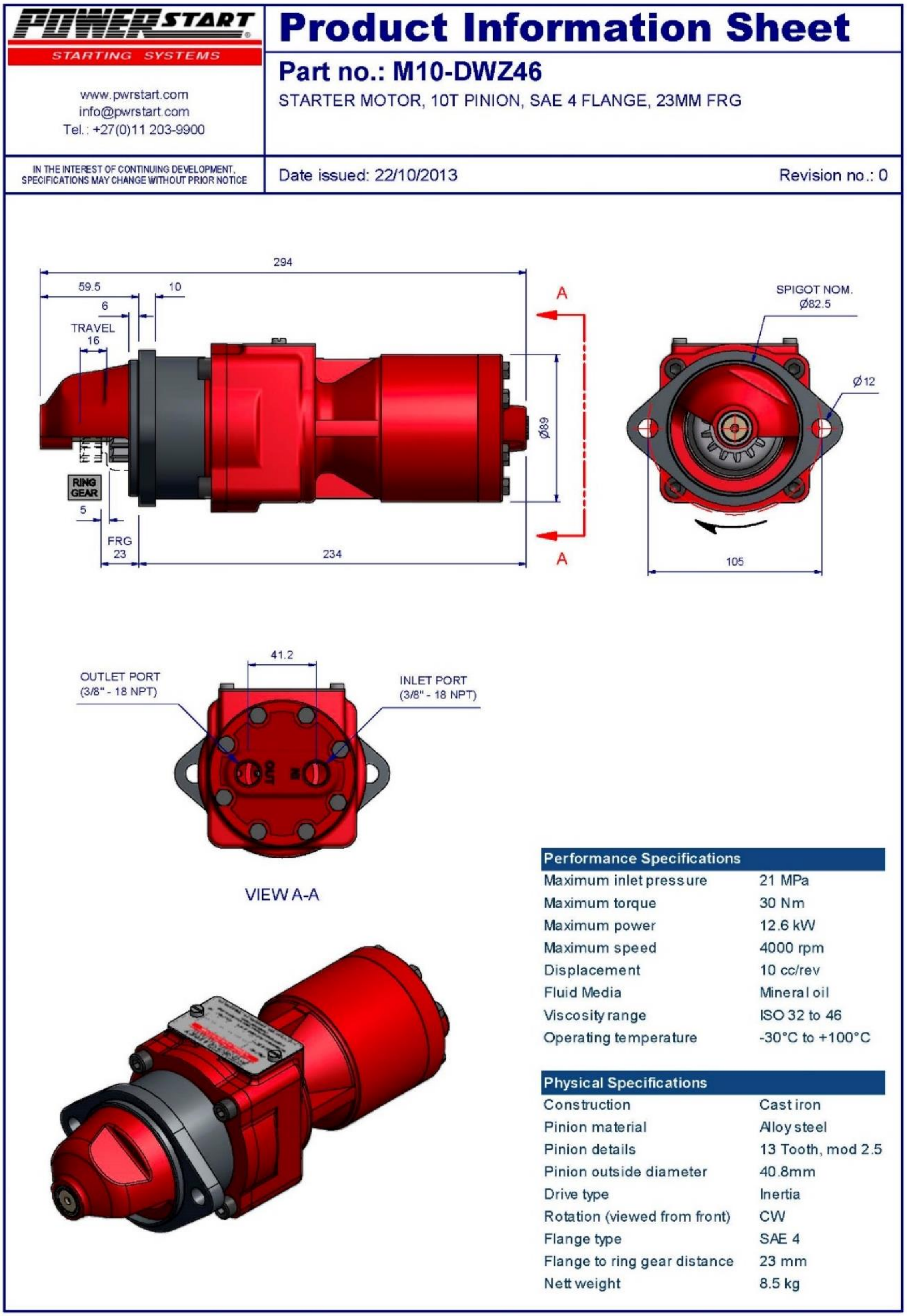


Figure 2 - Accumulator Installation

Figure 3 - Hand Pump Installation

The pneumatic starter was replaced with a hydraulic motor starter. A data sheet on the hydraulic starter is shown in Figure 5. The starter requires approximately 10 gpm fluid flow to operate. The accumulator charge of 3000 psi provides up to 10 seconds of cranking effort. The hydraulic starter is more compact than the pneumatic starter, a comparison photograph of each component is shown in Figure 4, with the hydraulic starter on the top and pneumatic on the bottom.

Figure 4 - Hydraulic and Pneumatic Starter Comparison



Product Information Sheet

Part no.: M10-DWZ46

STARTER MOTOR, 10T PINION, SAE 4 FLANGE, 23MM FRG

www.pwrstart.com
info@pwrstart.com
Tel.: +27(0)11 203-9900

IN THE INTEREST OF CONTINUING DEVELOPMENT, SPECIFICATIONS MAY CHANGE WITHOUT PRIOR NOTICE

Date issued: 22/10/2013

Revision no.: 0

Performance Specifications	
Maximum inlet pressure	21 MPa
Maximum torque	30 Nm
Maximum power	12.6 kW
Maximum speed	4000 rpm
Displacement	10 cc/rev
Fluid Media	Mineral oil
Viscosity range	ISO 32 to 46
Operating temperature	-30°C to +100°C

Physical Specifications	
Construction	Cast iron
Pinion material	Alloy steel
Pinion details	13 Tooth, mod 2.5
Pinion outside diameter	40.8mm
Drive type	Inertia
Rotation (viewed from front)	CW
Flange type	SAE 4
Flange to ring gear distance	23 mm
Nett weight	8.5 kg

Figure 5 - Hydraulic Starter Data Sheet

The pinion and pilot on the hydraulic starter were different than the engine manufacturer's design, therefore, a new mounting plate was fabricated to mesh the starter to the flywheel. The pilot for the hydraulic starter was larger and the center moved away from the flywheel center approximately 5mm radially and 20 mm horizontally, while lowering approximately 40 mm vertically, as compared to the original position. Prior to fabrication, a three-dimensional model of the starter was evaluated with the model of the engine. Figure 6 shows a drawing comparison of the original and new starter mounting plates. Figure 7 shows a picture of the starter mounted on the engine with the new mount plate. A small modification was also performed to the pump mount bellhousing in order to match the new mount plate.

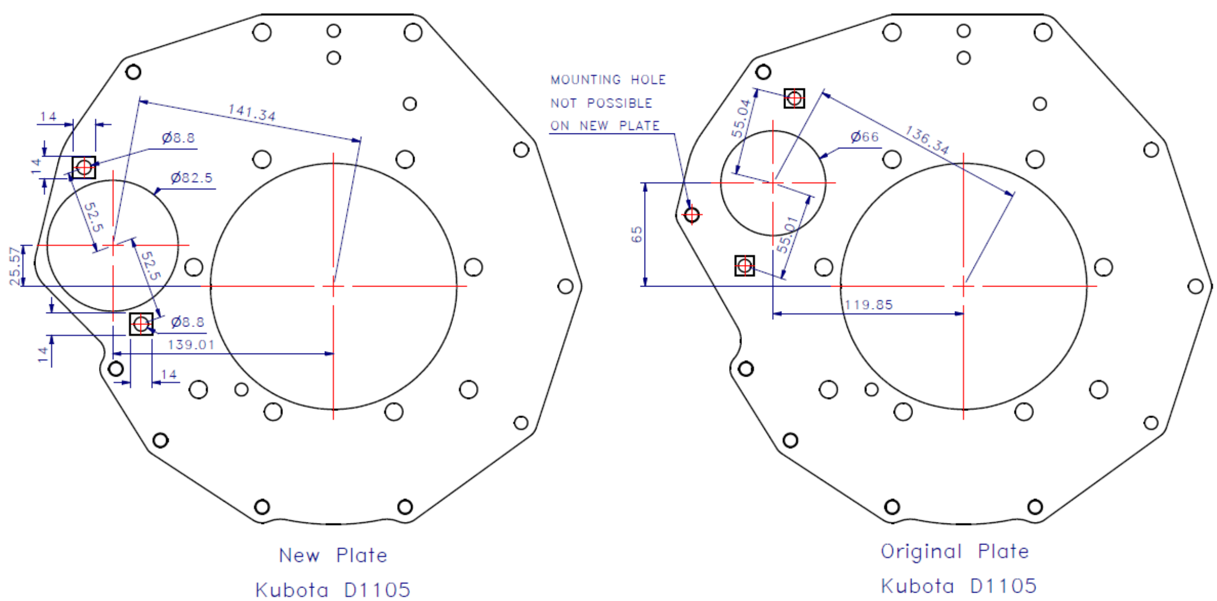


Figure 6 - Starter Mount Plate Design Comparison

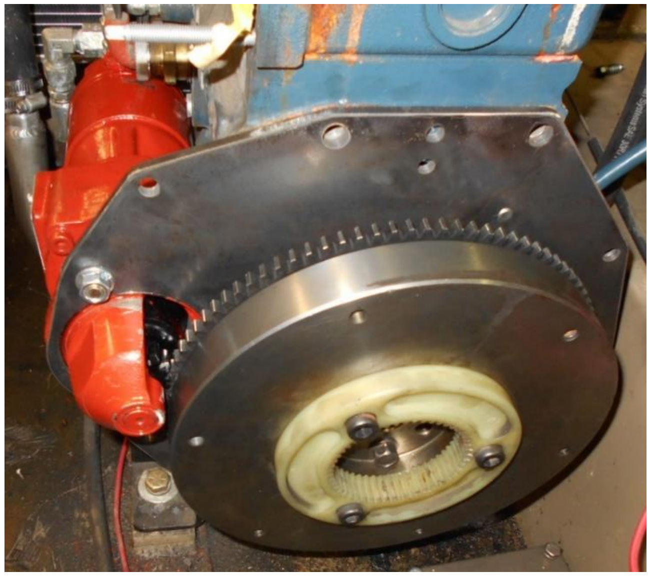


Figure 7 - Hydraulic Starter on Engine

To control the hydraulic starter and the safety shutdown circuit, a manifold was designed. A rough schematic of the start and safety circuit with this manifold prototype is shown in Figure 8. On the left-hand side of the figure, the engine driven hydraulic pump, and the starter motor on the engine are shown. A charging valve was used to replenish the on-board accumulator for restarting ability. The charging valve sends a load sense signal to the hydraulic pump in order to demand pressure and drive pump output. The function valve stack for operating machine tram and loader functions was not shown on this diagram. This valve stack also used a load sense signal to stroke the pump. A shuttle valve was installed to allow the load sense line from either the function valve stack or the engine control manifold to demand flow from the pump. Pressure from the accumulator feeds the control manifold for startup. Two pilot operated valves are used to control the starter motor output. One is the start command valve that gets pilot pressure from a manual, or electric operated solenoid valve for remote control actuation. The second is the start interlock valve that is externally connected to the hydraulic pump pressure, this shifts the valve and prevents actuating the starter with the engine running.

The override and stop valves are contained in this manifold, and are also operated by pilot from a manual or electric solenoid operated control valve. In the initial design, the pilot signal was sent from manual override to hold the override as well as the stop valve. In the event that the on-board battery was depleted, this provided a method to start the engine. At that point, the alternator would begin charging, and the control system could be energized to hold in the stop valve, then the override could be released and the machine could be operated. The pilot operated override valve acted in the same fashion as the pneumatic valve it replaced, it pressurized the safety circuit and bypassed the engine oil pressure valve, until the oil pressure built up and held that valve closed. The safety shutdowns were simplified in this drawing, but their function, instead of venting to atmosphere, as done in the pneumatic system, was to drain the safety pressure to tank for shutdown. The safety system actuated a spring return cylinder that was connected to the fuel shutoff lever on the engine fuel pump. Pressure reducing valves were used to lower the system pressure of 3000 psi to 350 psi for the electric solenoid pilot actuators, and 116 psi for the safety shutdown circuit, which was the maximum allowable pressure on some of the shutdown devices. The hydraulic manifold provided benefit to the machine design by reducing the space required for controlling the start and safety circuits, as compared to the original pneumatic system, instead of three separate valves for Start, Start Control, Start Interlock, Stop, Override, and pressure regulating functions, these function valves were all incorporated in a single manifold assembly. Another benefit of this design was that it used the same MSHA approved electric solenoids as the function valve assembly, thus reducing the spare parts needed to maintain the machine, and further, eliminating the need to attain MSHA approval for the electro-pneumatic control valves that were used on the original machine prototype. Figure 9 shows a picture of the prototype hydraulic manifold, while Figure 10 shows the installation of the manifold valve and function valve stack on the new mounting shelf design. The manifold block occupied the space previously held by the function valve stack, and the function valves were moved up and toward the loader end of the machine. As a side note, the hydraulic hoses for the tram motors and loader cylinders were replaced with smaller diameter hoses and fittings, and pressure lines were routed through a protective hose conduit. It was discovered that the existing hoses were larger diameter than necessary for the flows involved, and that they were exhibiting abrasion wear, therefore, the smaller diameter hoses and conduit were used to alleviate the abrasion issue.

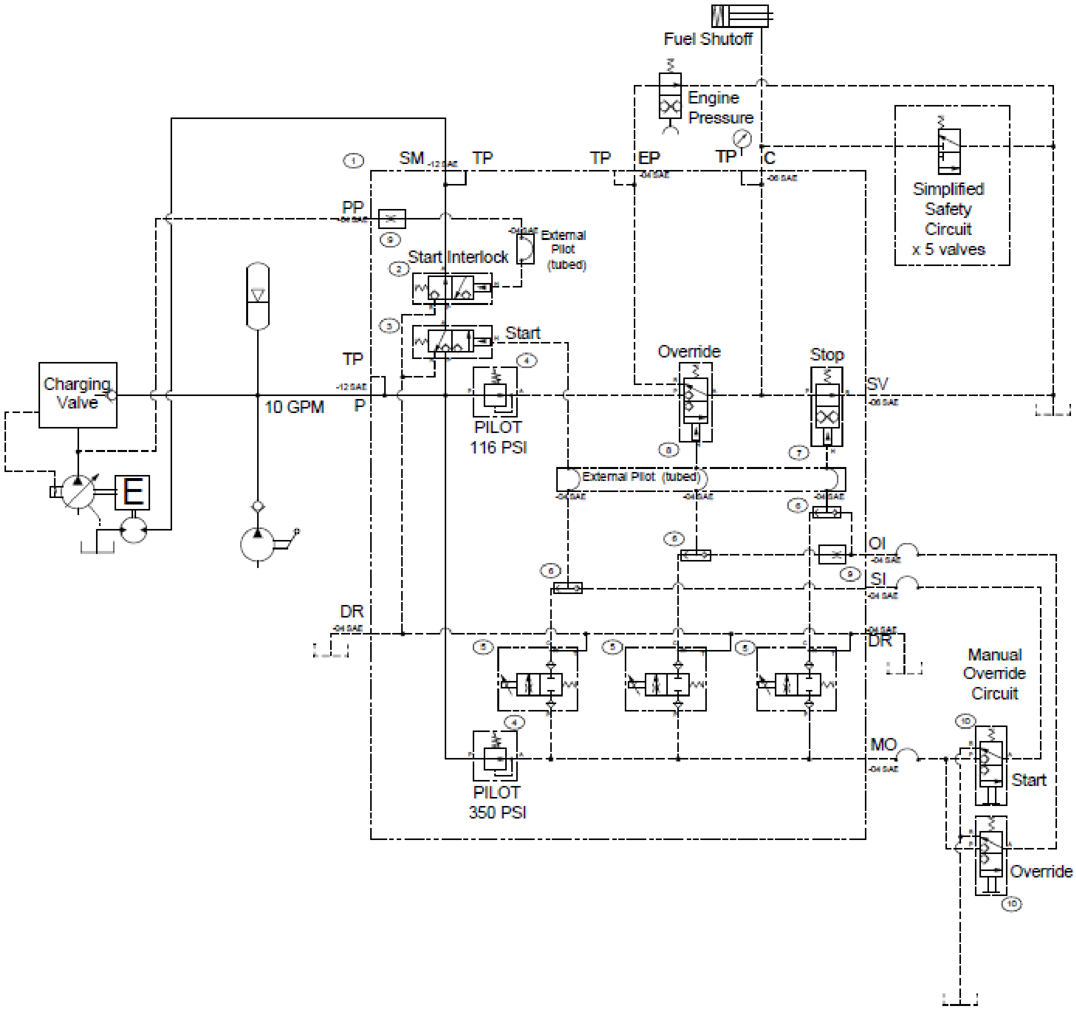


Figure 8 - Hydraulic Start Control Circuit Schematic

Figure 9 - Hydraulic Start and Safety Control Manifold

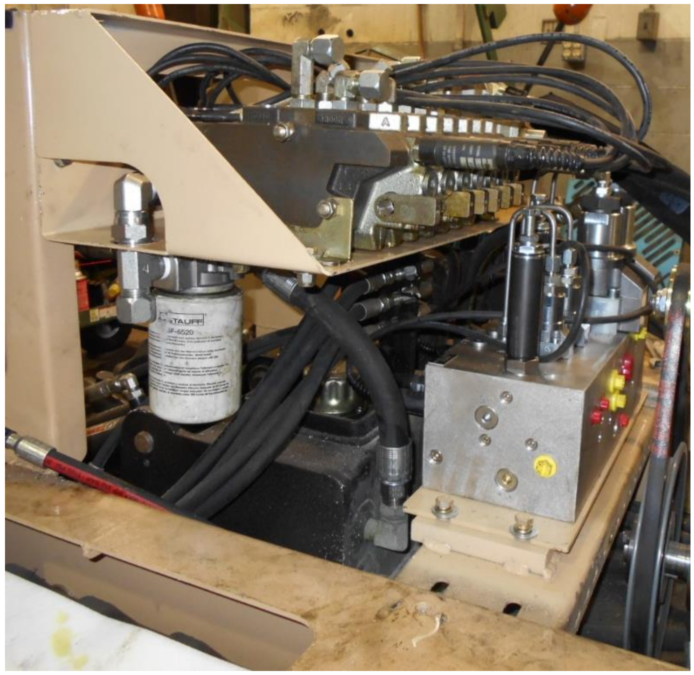


Figure 10-Hydraulic Valve Installation

Figure 11 shows the installation of the manual control valves used to start and stop the machine. On the left side was an enable valve, which pressurized the downstream control valves for the engine start, and then override, shown respectively left to right. At the far right was a stop valve, and the emergency intake shutoff pull handle was also mounted as shown.

Figure 11 – Manual Control Valves

Figure 12 shows a picture of the spring return hydraulic cylinder used to shut down the engine by actuating the fuel shutoff arm on the fuel pump. The fuel pump arm was held open by a spring during normal operation. Initially, designers wanted to use the same actuator for both throttle and shutoff functions for parts commonality. However, it became necessary to source a separate component for the shutdown cylinder. The safety shutdown system pressure was dictated by the maximum allowable pressure of the shutdown control actuators for engine and exhaust temperature. The 116-psi pressure was very low by any standard for hydraulic actuators and cylinders and thus a special device was required to meet design criteria for this system. The cylinder was attached to the shutoff arm via cable, and the spring return on the cylinder held the shutoff arm in a closed position. When pressure was applied to the safety circuit, the cylinder retracts, and the fuel shutoff arm opened via its own spring force. This feature allowed the cylinder to have more stroke than necessary for the shutoff arm travel, which allowed the cylinder volume to act as a small accumulator. This helped to have extra volume available, as when the override was released and the engine oil pressure shutdown valve was connected to the safety circuit, small losses were incurred; as well, small leaks could be endured and prevent engine shutdown until it was called for by the operator or a shutdown device.

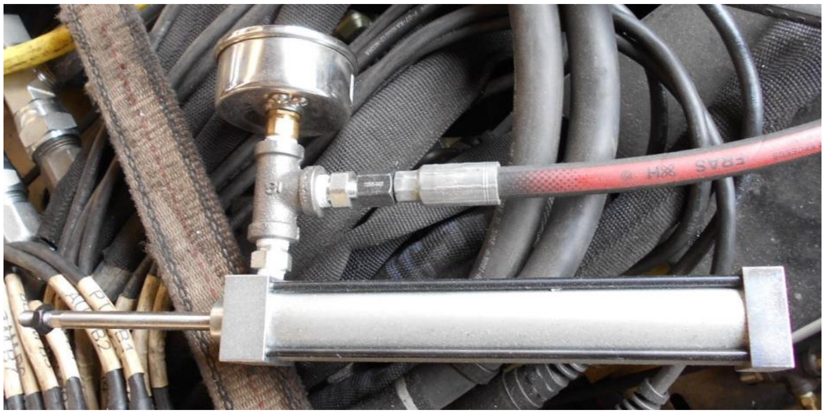


Figure 12 - Engine Shutdown Cylinder

Throttle was controlled by a hydraulically operated spring return throttle valve, that actuated when the hydraulic pump pressure increased from standby. This provided the automatic, on-demand throttle response that was requested by mine rescuers. A flow control valve with a free flow in the opposite direction was installed to allow the pressure to throttle up the machine quickly, and slow the return to idle to even out engine operation. A picture of the throttle device mounted on the machine is shown in Figure 13.

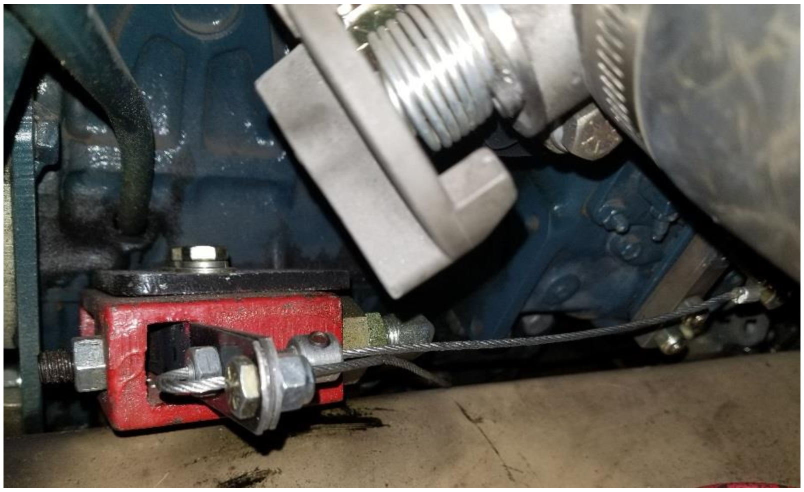


Figure 13 - Hydraulic Throttle Controller

HYDRAULIC SYSTEM TESTING AND DEVELOPMENT

Testing and development of the hydraulic system identified several unexpected problems, that required a time-consuming iterative process of design and component change, and follow-up tests to achieve a functional system. Hydraulic component availability was a significant contributor to the time requirement of this process.

One of the first issues observed was that the accumulator charging valve called for hydraulic pressure from the pump while the engine was cranking and attempting to start. This load was such that it prevented the engine from starting. Further, the increase in pressure was sufficient to activate the start interlock valve and stop the starter from cranking. The start interlock was one method specified to prevent sparks in the event the starter would engage while the engine was operational. An alternative method used an anti-spark starter gear, which was added to the future starter specification.

To test the accumulator charging valve, the load sense line from the charging valve was separated from the main hydraulic pump circuit and plugged. The hydraulic start system was cycled many times to determine that engine start was reliable. To recharge the accumulator after startup in this configuration, a loader function was operated against the relief to call for pump pressure until the charging valve filled the accumulator and switched off. After determining that the load sense (LS) signal from the charging valve was at fault, a pilot operated hydraulic valve was installed to stop the load sense line from reaching the pump until standby pressure was developed. Originally this valve was installed as a dump valve between the ls shuttle valve and the pump to send the ls signal to tank. Pressure from the start circuit was used to pilot the dump valve, and the sub-system function was tested, and the engine was able to start; the accumulator would then charge after engine startup. Observations from later additional testing however, caused designers to change the valve setup.

The accumulator charging valve used a pilot operated spring return valve to send a LS signal to signal the hydraulic pump to call for pressure and bring the pump on stroke. This normally happened when the accumulator pressure fell below the charge preset value of 2200 psi, which occurred at engine startup. If the LS signal reached the pump before the engine started, it effectively prevented the engine from starting as it is tried to start against a load (as previously described). After initial installation of the dump valve, testing indicated that any leakage of the LS line, or on the accumulator side of the accumulator charging valve, caused the charge valve to be unable to shift and charge the accumulator properly. To eliminate the possibility of leakage through the dump valve, it was replumbed as a blocking valve to the LS line of the accumulator charging valve. In this configuration, the valve stops the LS signal from going to the pump until the standby pressure shifts the valve open. To further control the delay, and ensure the engine is started before calling for the pump to produce pressure, an orifice was installed to slow the pilot pressure from opening the blocking valve.

Upon startup, the accumulator pressure depleted, and fell to 0 psi, when the charging valve did not bring the pump on stroke quickly. A problem was encountered where the engine shutoff control cylinder would lose pressure and extend when the accumulator pressure fell to 0 psi. It was originally thought that this was due to a leakage and loss of pressure at the valve inlet, so a check valve was installed at the safety manifold inlet, in an attempt to hold the cylinder in place. This did not correct the problem, so a trial and error testing process ensued.

The hydraulic control valve block for the start and shutdown circuits used pilot operated valves for the Start, Override, and Stop Functions. Pressure reducing valves in the valve block supplied pilot pressure to the MSHA approved electric solenoid valves, the manual control valves, and the safety shutdown circuit. Initially, the inlet pressure to the valve block was supplied by the accumulator. Through testing and research, it was learned that the MSHA approved electric control valves used approximately 0.5 gallons per minute when energized. The original system design for the remote stop function valve, used by the remote-control operator to shut down the engine, was such that the solenoid needed to be energized to hold the stop valve closed in order to keep pressure in the safety circuit. When the solenoid was deenergized, the safety circuit oil would drain and the shutdown cylinder would extend. The oil usage of the energized stop valve, along with any other leakage in the valve block, was sufficient to prevent the accumulator charging valve from calling for the pump to charge the accumulator. Upon startup, the accumulator pressure would fall to zero unless the charging valve shifted and called for pressure. When the accumulator pressure fell below 300 psi, the Stop valve pilot pressure was lost and the safety shutdown circuit drained. It was also discovered through testing, that once the accumulator was charged with the engine running, the oil usage by the electric control valve depleted the accumulator and caused the pump to come on stroke to recharge the accumulator; this cycle pattern was on for ten seconds, off for forty-five seconds. These discoveries dictated that changes to the system were needed.

A test was performed with a parallel path from the pump to the safety control valve block inlet, using check valves and a ball valve to allow the accumulator to start the engine, and then isolate the accumulator from the pump and safety valve. The engine was started and the valve closed, the pump supplied oil to the safety valve and the accumulator charging valve called for oil, but the pump was unable to build enough pressure to fully charge the accumulator and turn the charging valve off. Through a series of tests, it was determined that there was sufficient drainage in the safety control valve after startup to prevent the pump from building enough pressure to charge the accumulator. A needle valve was installed in the pump line to the safety valve inlet and it was successfully able to limit the flow to the valve to allow the accumulator to charge, and maintain the pilot pressure necessary to hold the shutdown cylinder in the on position. The manually operated test hardware was replaced with a pilot operated shift valve and flow orifice that switched the safety valve from accumulator supply to pump supply once standby pressure was developed. Initial tests on this valve installation were successful with starting the engine, charging the accumulator, and holding the shutdown cylinder open.

After further testing and evaluation, it was ultimately decided that changing the operation of the remote stop valve would benefit the machine, making it more reliable and energy efficient. Instead of the coil being energized to send the pilot signal to the stop valve, to hold it closed to prevent safety pressure from going to tank, the valve was changed to normally closed, such that the coil was energized to send the pilot signal to open the valve, and drain safety pressure. This not only eliminated the use of available energy to keep the valve closed, but also increased the expected life of the remote stop coil and prevented the machine from becoming disabled in the event of a coil malfunction. Another consideration for using this method involved manual machine startup with a depleted on-board battery. In order to start the machine, the safety circuit must be pressurized, with the stop valve normally open, the manual override would have to be held until the engine started, the alternator energized, and the control system was activated, in order to keep the engine operating. With the normally closed remote stop valve, the manual override plumbing was simplified, and it could be released immediately upon engine start. The valve on the prototype machine was changed in December 2019. The electrical logic for the remote stop circuit was also redesigned to energize the coil when a stop command was received or radio signal was lost.

Figure 14 shows the hydraulic schematic for the machine. The start and safety control manifold previously described was located on the left side of the drawing, with the safety shutdown devices in the upper left corner. The engine and exhaust temperature actuators, as well as the fire suppression shutdown actuator were the same as used on the original prototype with pneumatic control. The engine oil pressure actuator was changed to a 26:1 pilot-operated two-position valve, which was more compact, simpler to install, and had less leakage potential than the valve used in the original prototype. The function valve bank and hydraulic drive components were shown in the upper right, and these components were not changed. The hydraulic pump, accumulator, charging valve, hand pump, and throttle control were shown near the center of the print, along with the additional pilot operated control valves that were previously described. Certification statements required by MSHA were listed on the right side above the title block, and description of the braking system was included in the top center. This print was part of the Part 36 machine approval application.

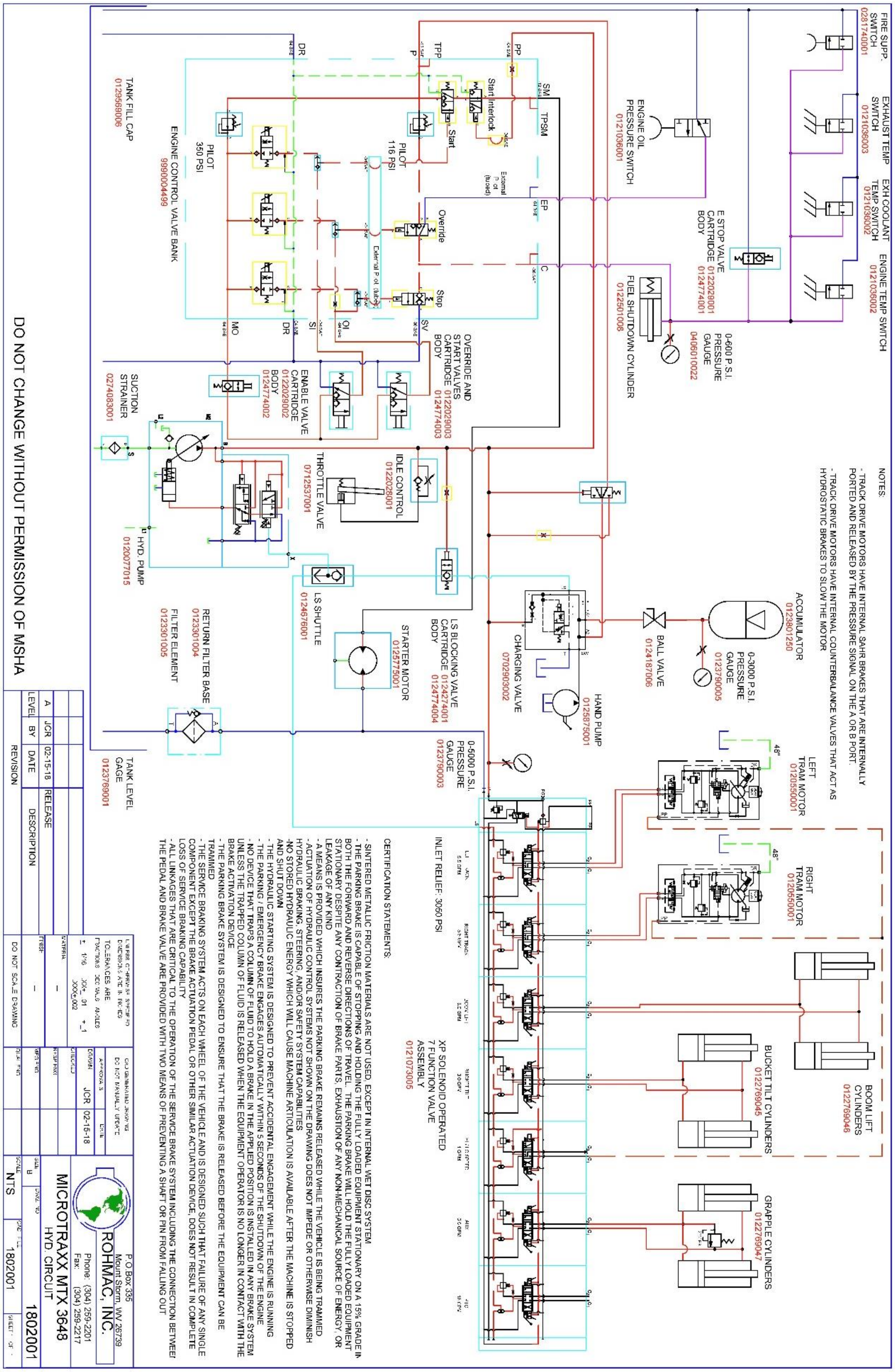


Figure 14 - Hydraulic Print

WATER COOLED EXHAUST SYSTEM TESTING AND DESIGN

Preliminary tests of the diesel power package were performed by the contractor to evaluate performance. On 13 October 2017 a test was performed to determine if there were any surface temperatures that would exceed 302 °F. Indictor paint was applied to surfaces of the exhaust and engine head prior to the test. This paint coating would melt at temperatures above 300 °F.

Figure 15 shows the paint applied to the exhaust system on the machine. Also visible are thermocouples that were installed in the exhaust coolant exit and the exhaust gas exit to monitor temperatures. An Infrared temperature gun was also used to monitor temperatures during the test.

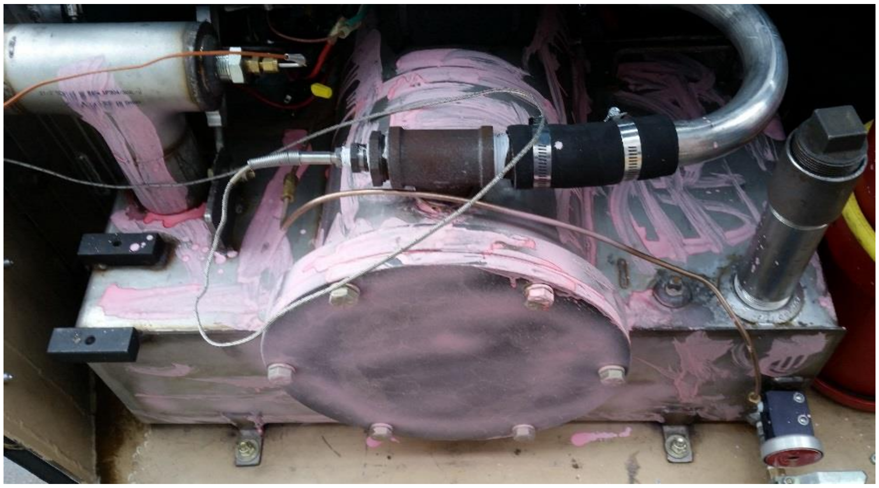


Figure 15 - Temperature Indicator Paint Applied to Exhaust

To induce a load on the engine, a hydraulic loading device was attached to the PTO circuit on the prototype mine rescue machine. The device adjusted the pressure to load the hydraulic circuit and had a water-cooled heat exchanger to remove heat from the fluid. A dial pressure gage was used to measure system pressure, and an inline flowmeter indicated the flow rate.

Figure 16 shows the load test device connected to the mine rescue machine prototype. The device was on a cart in the bucket of the machine, the control valve and oil cooler are visible on the left-hand side of the picture. To test the machine, the control was placed in manual mode, PTO was engaged, throttle was opened to maximum, and the pressure on the circuit was raised to the maximum attainable point before the engine became overloaded and began to stall. The engine was held at 2900 rpm, and the hydraulic circuit measured 19 gpm at 1100 psi.

Figure 16 - Load Test Device Attached to Machine

This first test was performed for one hour with the DOC/DPM Filter installed in the exhaust. This was designed to simulate the test that would be performed by MSHA during approval evaluation. Data recorded during the test included thermocouple temperature readings, Engine Oil Temperature, Exhaust Backpressure, and maximum temperatures seen near the exhaust manifold and on the DPM filter lid with the IR gun. Table 1 shows the data collected during this test, and it is charted in Figure 17.

Time	Exh Gas	Exh Coolant	Eng Oil	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F
20	150	212			
30	154	221	175	219	250
40	154	223	180	218	254
50	154	226	190	226	251
60	152	228	193	231	260

Table 1 - 13 October 2017 Surface Temperature Test Data

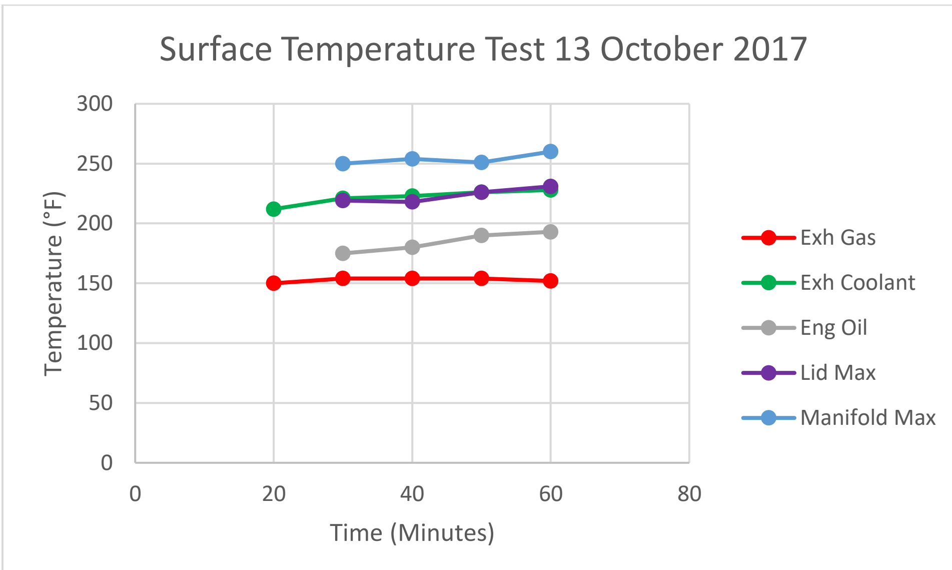


Figure 17 - 13 October 2017 Test Data

The data shows that Exhaust Gas Temperature stabilized around 155 °F, while Exhaust Coolant Temperature rose to nearly 230 °F. It was later learned that the maximum coolant temperature allowed by MSHA anywhere on the power package was 212 °F. The maximum temperatures observed on the DPM Filter Lid and Engine Exhaust Manifold area were 230 °F and 260 °F respectively. Engine Oil temperature was also recorded, and it rose to approximately 195 °F during the test. None of the temperature sensitive paint applied to the engine and exhaust components was observed to melt during the test. The backpressure recorded during the test was high, nearly 50" H_20. The contractor determined that this was an indicator of a clogged DPM filter. It was believed that while the machine was involved in several short demonstrations, and loading for transport, that soot had collected during cold engine starts and idling periods, without increasing the filter temperature sufficiently to clean itself. Therefore, the filter was removed for cleaning. On 18 Oct 2017, additional tests of the machine were performed.

The first test attempted was a cooling water consumption test. MSHA required that the exhaust mixing tank have an eight-hour supply of water while operating the engine at 1/3 load. To perform this test, the minimum load was applied to the engine with the load test unit at 500 - 550 psi and 18 gpm with the engine operating at 2950 rpm. With the exhaust filter removed, the backpressure was much lower. Fuel Consumption was also recorded during the test, using the tank mounted gage. The Exhaust Gas and Exhaust Coolant Temperatures were also recorded using the thermocouple reader. Table 2 shows data recorded during the test.

Time	Fuel Gage	Backpressure	Intake Restr	Exh Temp	Exh Coolant	Eng Oil
AM		Inches of Water		°F	°F	°F
8:20	3/4	8	9	136	169	Low
9:20	1/2	5	9	135	177	150
10:10	1/4			133	181	160

Table 2 - 18 October 2017 Water Consumption Test Data

At approximately two hours into the test, the usable water in the exhaust mixing chamber was depleted and the low water level float shut down the engine. The mixing chamber was refilled with 4 gallons of water, equating to a rough consumption of 2 gallons per hour. Approximately ½ tank of fuel, or 3 gallons, was consumed during the test, equating to approximately 1.5 gallons of fuel per hour. The fuel gage, however, did not provide precise measurement, so the fuel consumption was an estimate only. After this water consumption test, it was decided to perform a surface temperature test with the DPM filter removed from the system to assess any changes that may be observed as compared to operation with the filter installed. The surface temperature test was started at 11:20 AM, the engine was set to 2950 rpm, and the load was 1250 psi at 19 GPM. The Exhaust Backpressure and Intake Restriction were 7" H_20 and 9" H_20 respectively. At approximately five minutes into the test, a leak was observed at the radiator cap, the test was paused to fix the leak, and restarted at 11:40 AM. Table 3 and Figure 18 show the data collected during the test.

Time	Exh Gas	Exh Coolant	Eng Oil	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F
10	157	220	160	206	256
20	156	225	180	230	266
30	156	230	190	244	269
40	156	234	200	255	

Table 3 - 18 October 2017 AM Surface Temperature Test

At approximately forty-five minutes into the test, the engine shutdown. The cause of shutdown was likely the depletion of the exhaust cooling tank water, and, when restart was attempted, it was also observed that the engine coolant shutdown sensor had opened. The exhaust mixing chamber was refilled, and coolant was added to the radiator.

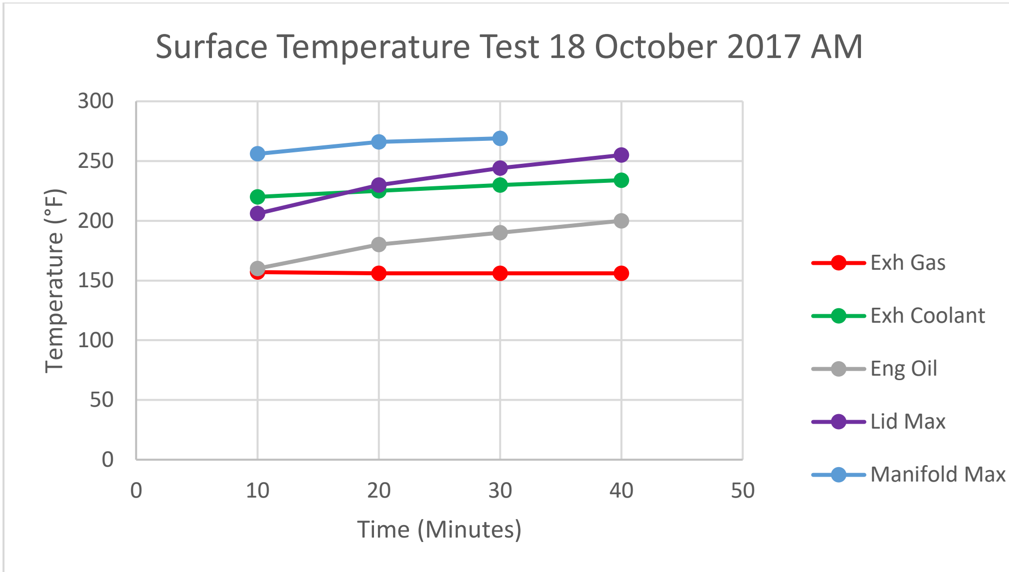


Figure 18 - 18 October 2017 AM Surface Temperature Test Data

The data shows that the Exhaust Gas Temperature remained steady around 155 °F while the exhaust coolant temperature rose to approximately 235 °F. The maximum observed temperature on the lid was 255 °F, which was an increase over the test with the dpm filter installed. The manifold temperature also rose to 270 °F. In the afternoon, a second test was performed. To prevent shutdown, water was added, a gallon at a time, to the exhaust mixing tank during the test. The test started with the engine at 2900 rpm, 19 gpm and 1100 psi load. The load was increased to 1250 psi during the first twenty minutes of the test, but the engine began to stall, and load was reduced and reset, over the course of the next twenty minutes, to 1200 psi for the remainder of the test. The test ran for ninety minutes in total. Table 4 and Figure 19 show the data recorded during the test. The exhaust gas temperature was stable again at 155°F, while the exhaust coolant temperature was stable around 230 °F. The engine oil temperature reached 200 °F, the maximum observed temperature on the lid was 244 °F, and the maximum manifold temperature was 276 °F. Once again, no melting of the temperature sensitive paint was observed.

Time	Exh Gas	Exh Coolant	Eng Oil	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F
10	151	204	135	165	243
20	158	225	170	209	263
30	155	235	185	232	247
40	153	220	190	229	264
50	154	220	190	230	261
60	152	226	190	232	268
70	156	230	195	239	257
80	154	230	200	241	276
90	156	232	200	244	269

Table 4 - 18 October 2017 PM Surface Temperature Test

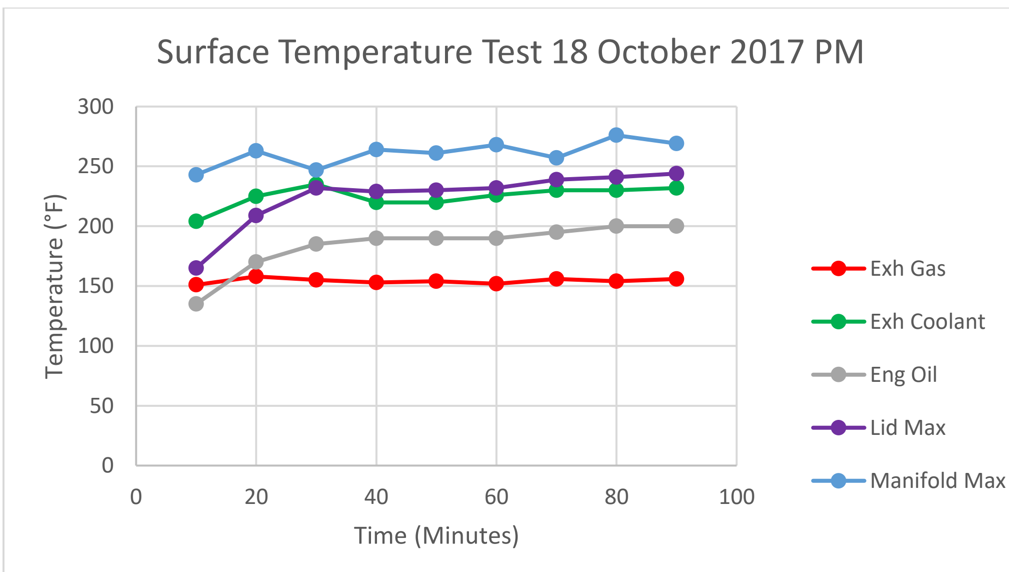


Figure 19 - 18 October 2017 PM Surface Temperature Test Data

In order to test additional water volume in the mixing chamber, some minor modifications were made to the existing prototype. A pipe fitting was welded to the exhaust exit from the filter chamber. This allowed a riser pipe to be installed such that the water level could be raised, to perform testing, without risking exposure of the exhaust manifold or filter to water. Figure 20 shows the riser pipe modification to the exhaust chamber. This modification allowed the exhaust system to be tested with approximately three more gallons of water than originally designed. Additional water could not be added as exhaust gas pressure pushed it out of the exhaust tailpipe.

Figure 20 - Exhaust Box Riser Pipe Modification

A delay to the testing process was encountered when the hydraulic load test unit became disabled, which prevented full load testing of the engine. The replacement parts were not readily available, and the unit was not restored to service until May 2018. However, the eight-hour water consumption test, only required 1/3 of maximum engine load, and therefore investigators believed that this test could be simulated. In order to induce load, the PTO circuit was activated through a restrictive hose. The goal of this test was to determine approximate water consumption for the expected exhaust system redesign. Table 5 contains data recorded during the water consumption test.

Time	Fuel Gage	Exh. BP	Intake Restr	Exh Temp	Exh Coolant	Notes
		Inches of Water		°F	°F	Start approx 3 gallon over previous fill
11:00	3/4	10	10			Cold Start PTO on
11:30	9/16	8	9	132	160	
12:00	3/8	6	10	130	157	
12:30	1/4	5	10	129	157	hyd overheat, PTO off
13:00	1/8	5	10	110	125	Refill Fuel
13:30	F	5	10	114	132	
14:00	7/8	4	10	110	123	
14:30	3/4	3	10	111	125	
14:50						Shutdown Low Water

Table 5 - Water Consumption Test Data

The water consumption test began with a cold start of the machine at approximately 11:00 am. The fuel tank gage read approximately ¾ tank. The engine was at full speed, 3000 rpm; exhaust backpressure and intake restriction both measured 10" H_20, and the usable water was approximately seven gallons, which was three more gallons than the amount that originally filled the scrubber tank after a low water shutdown.

Fuel was refilled at 1:30 pm. Review of the fuel readings during the test show that the fuel usage was most nearly ¼ tank per hour. As the gage was not an exact measurement of the total tank volume, the fuel usage was estimated to be approximately 1.75 gallons per hour. The Backpressure column indicated a steady decrease as the water in the scrubber tank was consumed. Intake restriction remained steady through the test.

At 12:30 pm, the hydraulic fluid heated and expanded to the point that it began pushing out of the hydraulic tank vent. From this point forward, the PTO circuit was turned off and the engine was operated at high idle with parasitic loads only (cooling fan, alternator, hydraulic pump standby). Without a hydraulic fluid cooler, such as used on the load test device, extended hydraulic induced load testing was not sustainable.

The exhaust gas temperature and the coolant temperature at the exhaust water jacket exit were recorded during the test. With the PTO engaged, the exhaust temperature averaged 130°F, and with the PTO off it averaged 111°F. The Coolant with the PTO engaged averaged 158°F, this is worth noting as it was steady at this level ninety minutes after the start of the test. An attempt was made to open the coolant passage that was believed to have become constricted when fittings were welded to the water jacket. During the previous water consumption test, the coolant temp at this location had exceeded 180°F after this amount of time.

At approximately 2:50 pm, the engine shutdown on low mixing tank water. The water consumption estimate for this test was seven gallons in four hours, or 1.75 gallon per hour. This was comparable to the result of the previous test which used approximately two gallons per hour. Based upon these data, designers estimated that two gallons per hour should be used to size the water volume needed for the exhaust system redesign.

Upon completing repairs to the load test device, load testing was again performed on the prototype machine, to determine the maximum exhaust coolant exit and exhaust system surface temperatures. Also evaluated was a change to the exhaust system coolant exit passage, which was made larger in an attempt to lower the coolant temperature in the exhaust system water jacket. On 18 April 2018, a test was performed starting at 3:10 pm. The ambient temperature during this test was 50 °F, and the engine was operated at 3000 rpm with a hydraulic load setting of 17 gpm at 1000 psi. The calculated load created by the hydraulic pump in hp was 1000 psi * 17 gpm / 1714 = 10 hp. Table 6 shows tabulated data as recorded during the test. Data was recorded on fifteen-minute intervals during the test. At the end of one hour, the load was increased slightly and the exhaust coolant exit temperature exceeded 212 °F within a few minutes. After ten minutes the test was concluded, and it was noted that the manifold temperature neared 300°F. Figure 21 shows a line graph of the temperature data points recorded during the test. The data shows that the temperatures were relatively stable after a warm up period, and a small increase was observed near the end of the test when the load was increased. The exhaust gas temperature was very stable and did not exceed 157 °F. The exhaust coolant temperature warmed to approximately 205 °F during the test and was a maximum of 223 °F after the load increase. The maximum surface temperature recorded on the lid was 205 °F and the Manifold maximum was 296 °F after the load increase. Backpressure data shows the consumption of cooling water during the test as the backpressure dropped from 10" H_2O to 5" H_2O. Intake restriction was steady at 10" H_20 vacuum throughout the test.

Time	Exh Gas	Exh Coolant	Lid Max	Manifold Max	Backpressure	Intake Restriction
Minutes	°F	°F	°F	°F	in H2O	in H2O
0	95.9	123	155	220	10	10
15	148.9	200.5	170	234	8	10
30	149.4	202.1	179	265	7	10
45	148.8	204.6	189	266	5	10
60	149.7	204.4	196	274	6	10
62	153.3	212	200	287	5	10
70	156.5	222.8	205	296	5	10

Table 6 - Load Test Data 18 April 2018

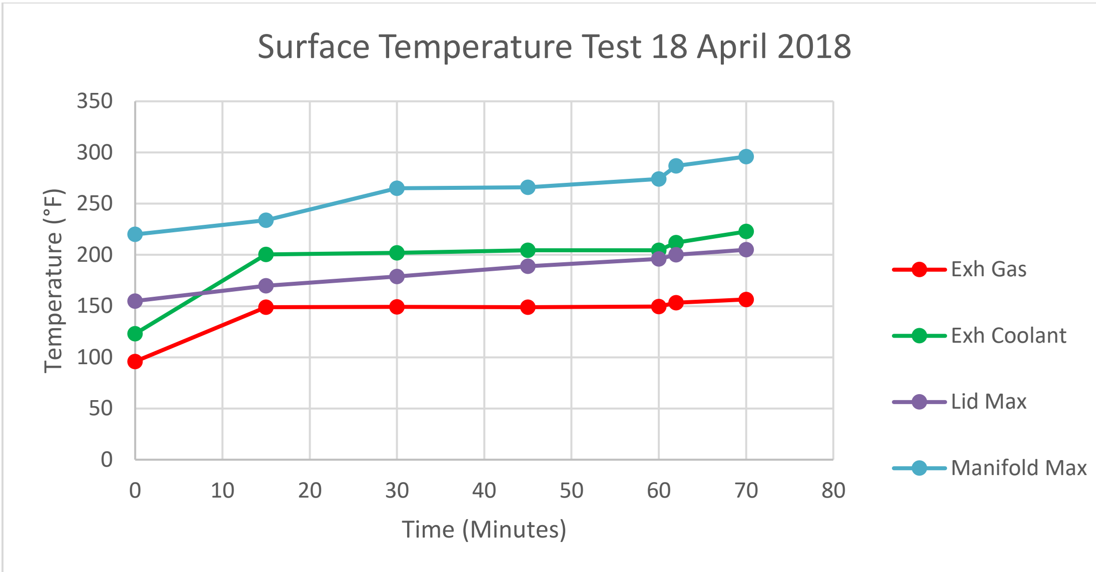


Figure 21 - Test Data 18 April 2018

After the test, data was reviewed against previous test data, and improvement was minimal. Upon inspection of the machine however, it was discovered that the engine coolant level was low, and it was suspected that an air bubble had remained in the system after the flow improvement modification. As low coolant would have significantly impacted test results, the coolant was refilled, and another test was performed on 20 April 2018 starting at 11:20 am with an ambient temperature of 33 °F. This test was performed with the engine operating at 3000 rpm, producing 16 gpm at 1150 psi, which was approximately 10.75 hp. Table 7 shows the data observed during this test, which was collected at ten-minute intervals. As the fluid thinned during the test, the flowmeter read 18 gpm, and at twenty minutes, the pressure was reduced to 1100 psi (which calculates 11.5 hp) to prevent engine stall. At seventy minutes into the test, the load pressure was increased to 1250 psi (approximately 13 hp).

Time	Exh Gas	Exh Coolant	Eng Oil	Lid Max	Manifold Max	Backpressure
Minutes	°F	°F	°F	°F	°F	in H2O
0	83.1	94.9		76	156	10
10	144.9	183.7	130	150	251	10
20	147.9	186.5	140	177	253	8
30	149.6	192	143	188	262	7
40	149.9	193.2	150	192	260	6
50	149.6	192.4	150	192	266	5
60	142.4	190.3	152	189	263	8
70	150.4	192.3	155	192	265	7
80	153.9	203	159	196	282	6
90	153.4	202.7	160	205	280	6
100	152.5	205.2	161	220	283	5
110	152.3	206.5	163	221	289	4

Table 7 – Load Test Data 20 April 2018

The exhaust gas temperature recorded during this test was nearly identical to previous tests, the temperature settled around 150-155 °F. However, during this test, the exhaust coolant exit temperature settled around 193 °F, and the recorded maximum was 206.5 °F after increasing the load. Engine oil temperature was recorded for this test and the temperature was nearly 155 -160 °F during the test. The maximum surface temperatures on the lid and the manifold were 221 °F and 289 °F respectively. These temperatures fell in range to meet MSHA approval requirements. Again, the backpressure levels indicated the consumption of mixing chamber water during the test. At the fifty-minute mark, four gallons of water were added to the mixing chamber to prevent low water shutdown. It was noteworthy that most of the temperatures decreased a few degrees when the water was added. Figure 22 shows a line graph of the temperature data recorded during this test, the data again indicated stable temperatures after a short warm up cycle.

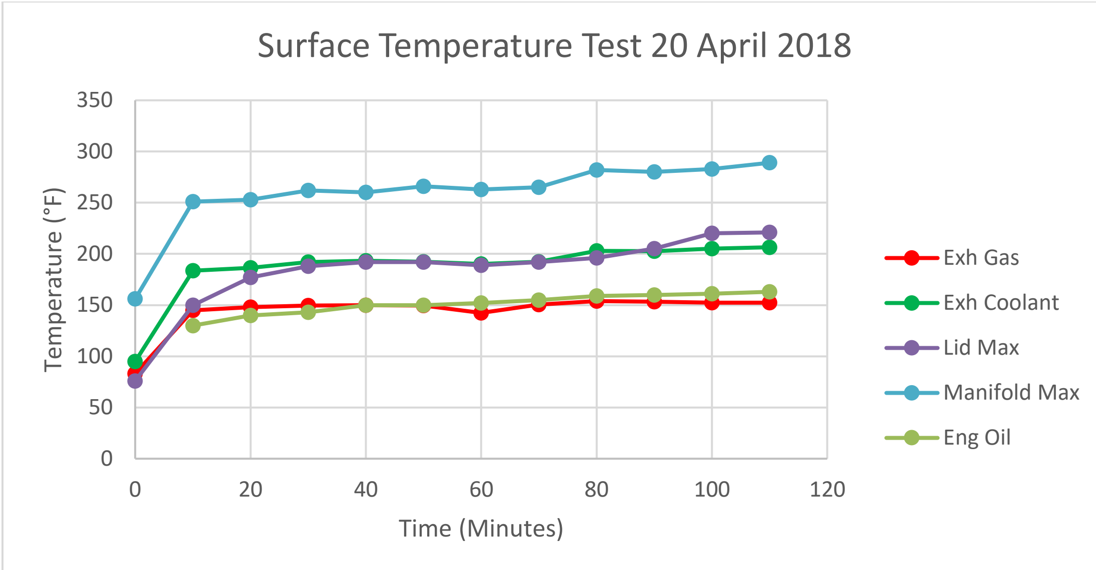


Figure 22 - Test Data 20 April 2018

The test results of 20 April 2018 indicated that the system design concept was capable of meeting MSHA approval requirements with modifications such as an increase in the volume of water to achieve eight-hour run time. At the time, and based on the results of this testing, the contractor and CDC NIOSH agreed to move forward with final design of a revised mixing chamber style exhaust system. Once detail drawings were developed, they would then be reviewed with MSHA prior to manufacture.

In the interest of further investigation into the efficiency of the cooling system, load tests were again performed on the prototype machine to determine the increase in temperature across the exhaust coolant system. Modification was made to the coolant pipe between the engine thermostat housing and the exhaust system coolant inlet port to allow for installation of a thermocouple. An initial test of the system was conducted on 4 June 2018. Table 8 shows data collected during this test. The engine was set at 3000 rpm, the hydraulic load was 18 gpm at 1100 psi, ambient temperature was 60 °F.

Time	Coolant In	Exh Coolant	Lid Max	Manifold Max	Backpressure
	°F	°F	°F	°F	in H2O
3:15 PM	180	186	105	220	10
3:25 PM	207	213	162	228	6
	Stop		Radiator Cap Leaking		
3:35 PM	178	183	170	227	6
3:45 PM	213	219	187	234	5
	Stop		Radiator Cap Leaking		
3:50 PM	164	169	166	202	5
3:55 PM	205	212	182	233	5

Table 8 - 4 June 2018 Coolant Temperature Test Data

The temperature increased quickly in the first ten minutes and the test was stopped when a leak was discovered at the radiator cap, attempts to get the cap to seal were unsuccessful, as the table shows the test was stopped again after approximately ten minutes, restarted, and then terminated after a five-minute runtime. Data gathered during this test shows an approximate increase of 6 °F to the coolant across the exhaust system.

Figure 23 shows a graphical representation of the test data. While limited data were gathered, a notable observation was that the rate of coolant temperature increase was greater during the second and third test attempts after the engine had warmed. After the test was stopped, the machine was allowed to cool to check for air that may have been in the system after the aforementioned thermocouple modification.

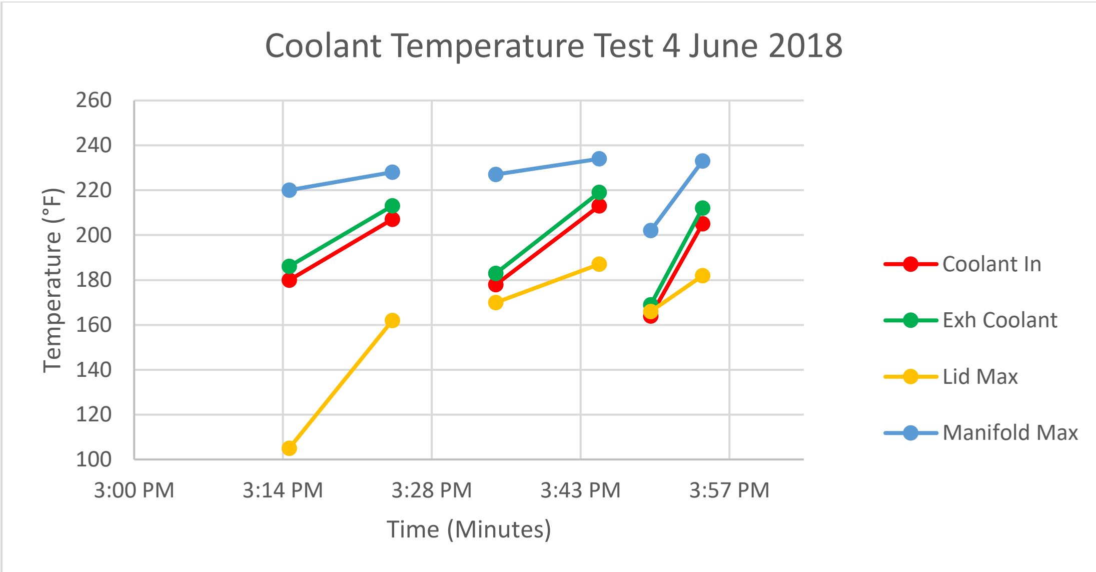


Figure 23 - Coolant Temperature Test Data 4 June 2018

On 11 June 2018 at 11:15 am, another test attempt was performed. During this test, a thermocouple was also placed in the raw exhaust port to measure exhaust gas temperature near the exhaust manifold. Table 9 shows data collected during this test. The engine was placed at 3000 rpm with a hydraulic load of 18 gpm at 1100 psi, ambient temperature was approximately 60 °F. After fifteen minutes the test was stopped and an attempt was made to remove air from the cooling system and add coolant, the test resumed at 12:35 pm and continued until 1:00 pm.

The coolant temperature increased above 212 °F during this test, but the same increase of approximately 6 °F was observed. The manifold exhaust gas temperature was approximately 510 °F during the test. The surface temperatures of the lid and manifold were measured as done in previous tests, however, due to the brief test periods, the temperatures were well below those observed in previous tests.

Time	Coolant in	Exh Coolant	Lid Max	Manifold Max	Engine Oil	Hot Exh Temp	Backpressure
	°F	°F	°F	°F	°F	°F	in H2O
11:15 AM	144	164	107	220	130	512	10
11:25 AM	208	214	166	228	155	507	8
11:30 AM	213	218	187	230	165	505	7
	Stop		Add coolant				
12:35 PM	125	140	111	207	130	450	5
12:40 PM	184	190	131	221	130	508	6
12:50 PM	216	221	194	227	160	511	5
1:00 PM	224	230	213	243	180	514	5

Table 9 - Coolant Temperature Test 12 June 2018

Figure 24 shows a graphical chart of the test data. After the test, the engine was allowed to cool, and a manifold exhaust gas temperature of 243 °F was observed, which was below the recommended operating temperature for the exhaust treatment components, and thus reinforced that the engine should not be excessively operated at idle to ensure proper operation of these components.

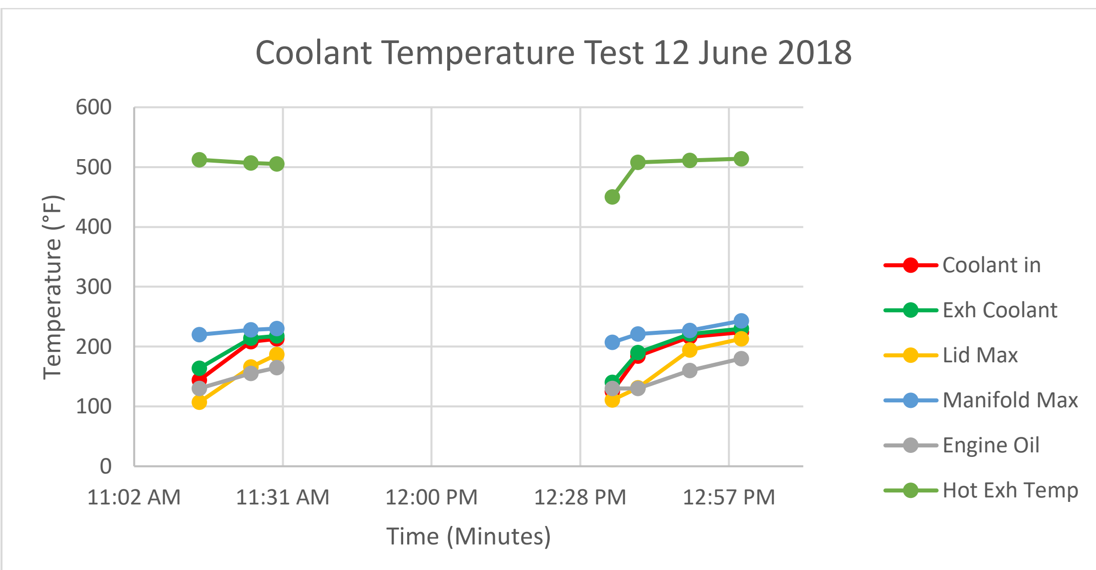


Figure 24 - Coolant Temperature Test Graph 12 June 2018

Data from these tests suggested that the heat input to the engine coolant from the exhaust system was not the most significant contributor to the overall cooling load requirement. The cause of the higher engine coolant temperatures observed during this test cycle was inconclusive. Possible contributors included air entrapment, increased ambient temperature, or cooling flow restriction. Review of these test data suggested that reversing the coolant flow through the system (passing coolant through the exhaust system before going through the engine), could be implemented as a means of keeping the coolant temperatures within required temperature ranges. Upon review of the data collected to this point, the redesign of the exhaust system began.

The initial exhaust system redesign involved addition of scrubber volume and improvement of water jacket cooling that was necessary to meet the requirements for permissible approval. Due to the volume increase, the thickness of the scrubber tank walls was increased, which, while it added weight to the machine, was necessary to ensure the structural integrity of the tank. Exhaust system water jacket thickness and porting size was increased to promote coolant flow, in order to reduce the coolant temperature in the water jacket. The contractor was also advised that MSHA may require the addition of a coolant expansion tank to the pressurized system.

The redesigned exhaust mixing chamber, shown in Figure 25, held approximately eighteen usable gallons of water. Designers opted for a single tank design instead of attempting to incorporate a makeup water reservoir (a design in which water is stored in a separate tank and added to the mixing chamber as needed). To increase water volume the height of the tank around the filter chamber water jacket was raised, and the tank was widened. Design of the exhaust flow directed it from the engine manifold through the oxidation catalyst and dpm filter, which was housed inside of a chamber jacketed with engine coolant, before passing through a tube that routed exhaust to the bottom of the water mixing chamber. The tube also passed near the top of the mixing chamber to form a barrier, similar to a trap, such that the water level could be raised around the filter chamber without allowing water to infiltrate. Exhaust gas mixed with water at the bottom of the mixing chamber, and then rose into a duct that would direct it to the outlet where it would be dispersed by the cooling fan. Baffles were designed to reduce water loss due to splashing. A float valve bolted to a flange on the side of the box, a rod and float ball would be used as a low water level shutdown control. The side location was used to make the valve much more accessible than it was on the original prototype.

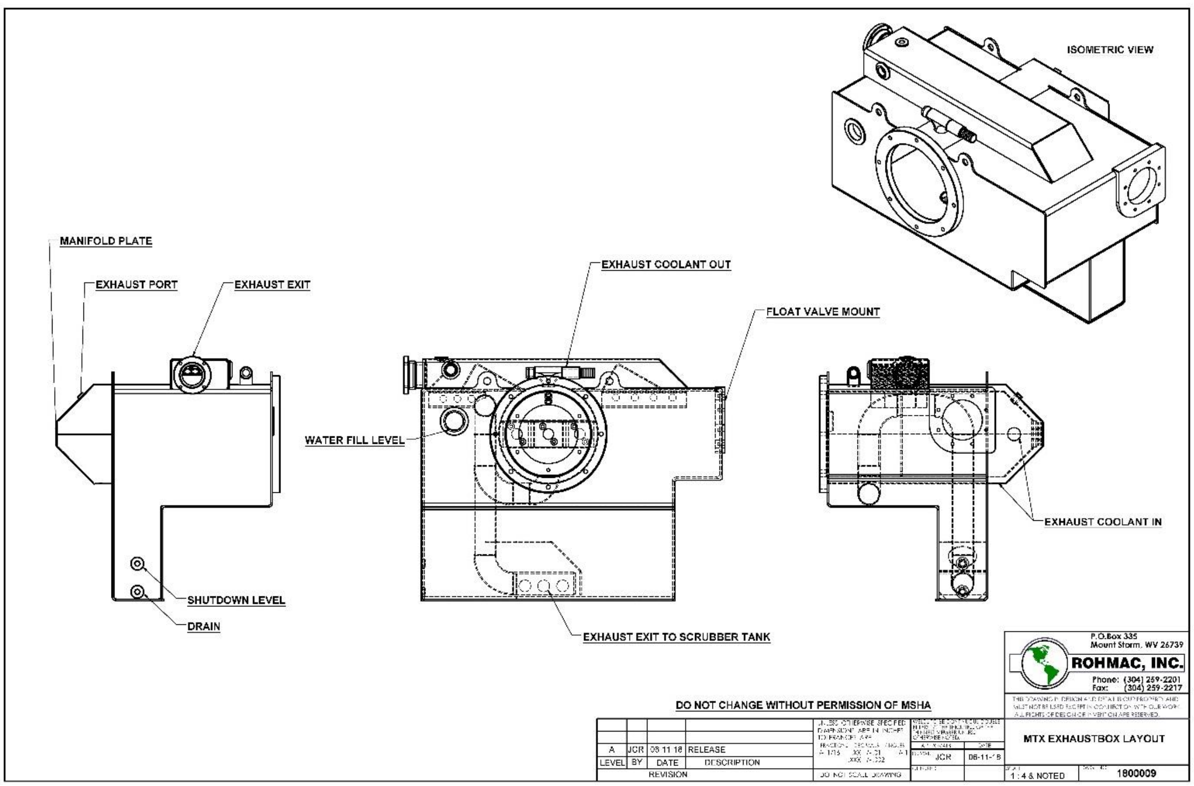


Figure 25 – Initial Redesigned Exhaust System Layout

Figure 26 shows a comparison drawing of the original prototype next to the redesigned exhaust system. The volume of the coolant jacket around the filter chamber was increased ½ in. to promote flow and cooling. The height of the exhaust chamber was increased approximately 5 in. The chamber was widened approximately 1.3 in., and two additional bolts were installed in the DPM filter access cover to correct leakage that was observed on the original prototype. The side of the chamber was extended approximately 4 in. to finish increasing the volume. As mentioned earlier, an exhaust duct was added on top of the exhaust in order to equalize pressure and reduce splash loss of water by giving additional volume for exhaust gasses to expand and escape. The duct was baffled with deflectors to redirect water into the tank while allowing gases to escape.

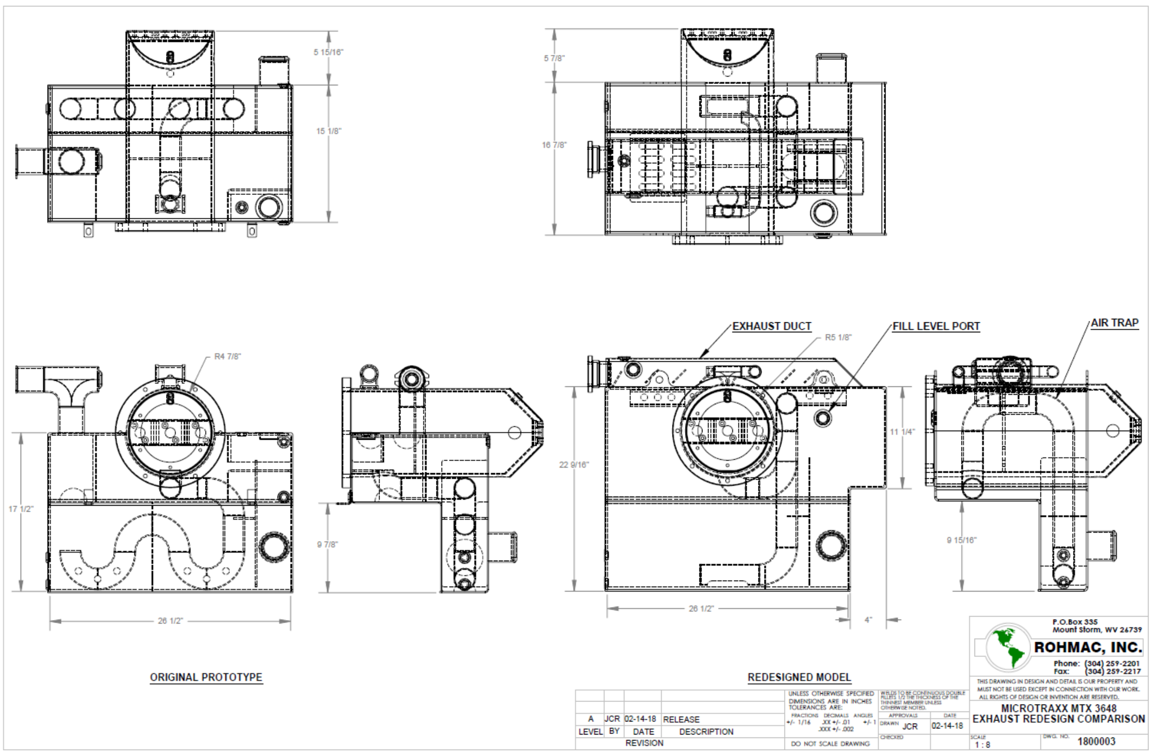


Figure 26 - Redesigned Exhaust Box Comparison Drawing

The redesigned exhaust system caused other necessary alterations to the machine layout. To make room for the volume of the exhaust system, the electrical enclosure was moved to the space vacated by the air supply tank. The hydraulic control valves were then placed in the area where the electrical enclosure previously occupied, which was expected to improve hydraulic serviceability and make room for the overhung load adapter used for the alternator. Figure 27 shows top and side views of a revised general layout of the machine components, based on the redesigned wet exhaust system. While the increase in water volume did impact machine design, the overall increase in space was kept to a minimum. The hydraulic accumulator was located to the right of the exhaust system and the hydraulic control valves were located above the accumulator.

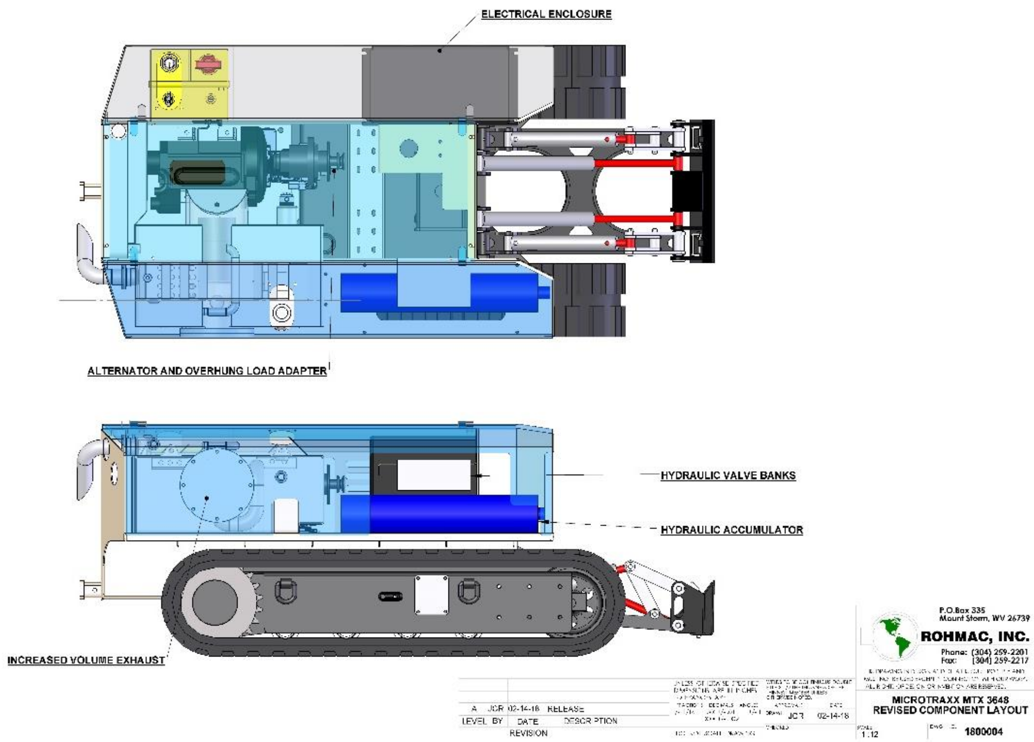


Figure 27 - Revised Machine Layout

EXHAUST DESIGN EVALUATION

A set of preliminary drawings of the redesigned exhaust system were reviewed with MSHA A&CC representatives. Concerns were expressed with the expected performance of the design relative to the gradeability of the machine, and further with the on-board mixing tank capacity being sufficient. In designs where mixing tanks are used as the required spark / flame arrestor, contact of water with the engine exhaust must be maintained and no pathway can exist for exhaust to bypass the water before exiting the tank. This concern was most significant in a low water situation, if the machine was operated on a sufficient grade, where the exhaust mixing point would no longer be submerged by water. It was explained that the minimum operating water condition would then be the water level at which the machine could be operated on the maximum expected grade while maintaining submersion of the exhaust mixing point. It was anticipated that this would add to the necessary on-board water volume needed to meet the eight-hour runtime requirement, and thus increase the size of the exhaust system. It was mentioned that designers may wish to consider using a "Dry" exhaust system, in which heat transfers to the coolant and no mixing with exhaust occurs. This design required a flame arrestor at the exhaust exit.

The concerns expressed on the exhaust design were discussed with CDC NIOSH and it was determined that they merited further investigation as the mine rescue machine was expected to traverse uneven terrain that could place the exhaust on extreme grades. The contractor requested permission to modify the existing exhaust system to perform a test with it acting as a dry system, and CDC NIOSH agreed to permit the modification and test. In order to modify the exhaust system, the piping at the mixing point was removed, and 2-inch diameter pipe was added, which routed the exhaust directly to the exit point, through the cooling water without mixing. After this modification was completed and the system was reinstalled, and a load test was conducted to evaluate the heat transfer.

The load test was conducted on 6 July 2018, starting at approximately 12:30 pm. The engine speed was set at 3000 rpm, the hydraulic load was 18 gpm at 1100 psi, ambient temperature was 64 °F, and the exhaust water tank was filled to capacity for the test. The test was stopped after forty minutes due to engine coolant temperatures approaching the maximum recommended by the engine manufacturer. Table 10 shows data collected in ten-minute increments during this test, and the data are graphed in Figure 28.

Time	Exhaust in	Exh Out	Coolant In	Coolant Out	Lid Max	Manifold Max	Backpressure
	°F	°F	°F	°F	°F	°F	in H2O
12:30 PM	635	180	135	154	115	207	1
12:40 PM	682	389	208	214	163	248	1
12:50 PM	688	147	223	228	214	271	1
1:00 PM	691	449	229	235	233	274	1
1:10 PM	700	479	235	240	240	286	1

Table 10 – 6 July 2018 Dry Exhaust Temperature Test Data

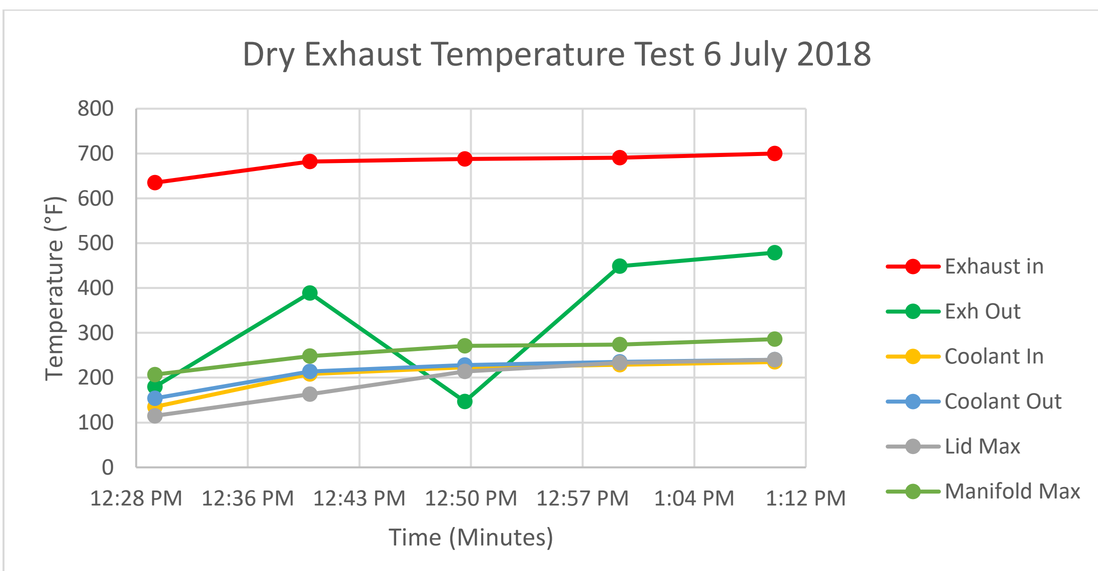


Figure 28 – Dry Exhaust Temperature Test Data 6 July 2018

Test data indicated a steady rise in the temperatures except for the exhaust outlet temperature. As the cooling water in the exhaust tank heated, it expanded past the exhaust point of the tank, collected with the exhaust flow and thus began mixing with the exhaust gas and caused a significant drop in temperature. Once the water was no longer mixing with the gas, it stopped interfering with the exhaust gas temperature measurement. The exhaust gas reached a temperature of 700 °F, with the corresponding cooled temperature of 479 °F. After the test, water was refilled, and an estimated 2.5 gallons of water was used. Most of this loss was attributed to the aforementioned expansion and mixing, and a small leak that was observed during the test. Of note was the backpressure, which was stable at only 1” $H_2 0$, as opposed to approximately 10” $H_2 0$ observed with the mixing design.

A simple estimation of heat removal by using specific heat of air (.245 Btu/lbmR) and temperature change in the exhaust gives roughly 54 Btu/lbm. To effectively reduce the exhaust temperature to meet MSHA requirements, the outlet temperature should drop to 250 °F, which would be approximately 110 Btu/lbm, or approximately double the heat reduction seen during the test. The pipe installed during the modification was simply to test the concept and was not optimized for heat exchange. Exhaust heat exchangers are commercially available that use the engine coolant to reduce exhaust gas temperatures. Using this style of exhaust temperature reduction as compared to the mixing style would have the following comparisons:

- The mixing chamber style was a simpler fundamental design than the dry heat exchanger system and did not introduce additional heat into the engine coolant system, did not require a separate flame arrestor.
- The dry system was not affected by gradeability of the machine, did not use consumable water, meaning run time would not be limited and further eliminated the float switch used for low water shutdown, thus simplifying the

safety circuit. It also would not need to have a tank drained and refilled each shift, nor would there be a danger of water freezing when parked or stored.

- The dry system would operate at a lower backpressure than the mixing system, and while the effect may be minimal, backpressure acts as a load on the engine, so more power would be available and fuel burn would be reduced at the lower pressure
- The mixing system produced a very stable and dependable exhaust gas temperature reduction, and as measured through testing, averaged 156 °F. The required exhaust gas temperature shutdown for this system was 185 °F. The dry system allowed for the exhaust gas shutdown to be increased to 302 °F, requiring less heat to be removed from the exhaust gas.

Giving consideration to these comparisons showed favorable characteristics for each system. Another, more critical, key to the design was the size of the system, whereas a more compact device was favorable. With the likely increase in size of the mixing system expected to accommodate gradeability, the dry system was likely to be more compact and ultimately weigh less, which were highly desirable features. Although it contributed to additional time requirements, designers and CDC NIOSH determined that it was in the best interest of the project to design a dry system for exhaust cooling.

DRY EXHAUST SYSTEM DEVELPOMENT

The dry exhaust system design removes heat from the exhaust without mixing the exhaust and coolant together. Stainless steel tubing bends were procured to fabricate a cooler consisting of exhaust piping inside of an engine coolant reservoir, which also acted as a pressure reservoir. The reservoir added approximately ten gallons of coolant to the engine cooling system. Coolant from the radiator entered the chamber near the exhaust manifold, then passed through the reservoir, and out of a lower port connected to the water pump inlet, the engine's thermostat port then connected directly to the radiator. This was a "reverse flow" design, as described earlier, and was used to lower the temperature of the exhaust water jacket coolant. The exhaust flow of the initial dry system prototype went from the manifold through the catalyst and particulate filter, then split into two streams, that went to each side of the filter chamber, and passed through u-bends before recombining at a collector, below the filter chamber. The exhaust then went through additional piping before entering an expansion chamber and finally exiting the device. Figure 29 shows a drawing of the initial design.

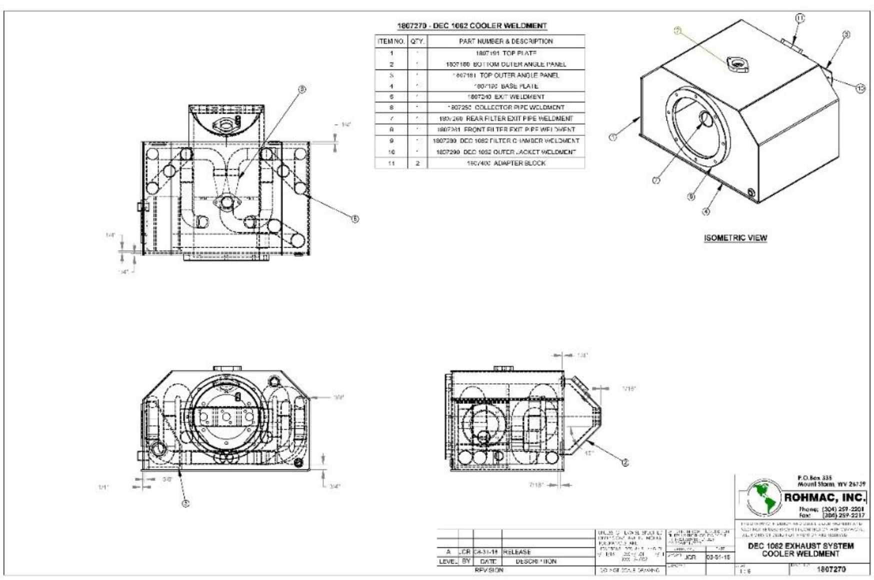


Figure 29 - Dry Exhaust System Prototype Design

The new system design was more compact than the previously proposed wet exhaust system. Since there was no mixing with water in this system, a crimped ribbon style flame arrestor was added to the exhaust exit. The flame arrestors for the exhaust and intake were sourced from the same manufacturer, and are shown in Figure 30.

Figure 30 - Intake and Exhaust Flame Arrestors

Figure 31 shows the initial dry exhaust system prototype during fabrication. The picture is looking into the end of the exhaust filter chamber, which would orient to the outside of the machine, in the same fashion as the mixing chamber. Visible in the picture are the lid mounting flange, the exhaust manifold, the inner wall of the filter chamber, and the external sides of the coolant reservoir.

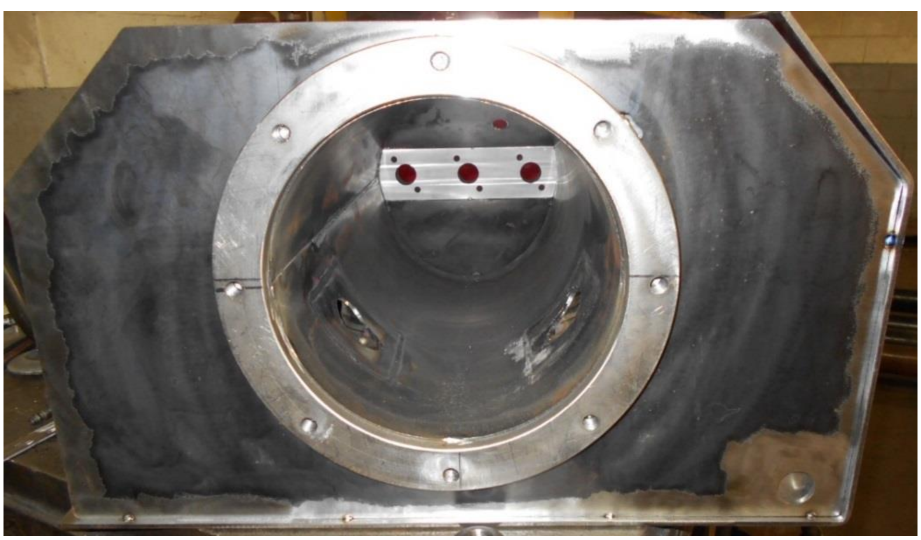


Figure 31 - Dry Exhaust System Fabrication

Figure 32 shows exhaust piping during fabrication. This piping is surrounded by coolant when in operation. In this design, the exhaust exited the filter chamber through two separate 1.75-inch pipes, one of which is visible in the photograph. The pipes recombined into a single 2-inch pipe and then transferred to the exhaust expansion chamber, shown in the lower left of the figure. A flange ring was welded to the expansion chamber and the flame arrestor bolted to this flange. The lower port in the expansion chamber was for the exhaust gas temperature shutdown control. The reservoir side plate also welded to the exit flange, and the lower port fitting, to form a coolant jacket around the expansion chamber.

Figure 32 - Exhaust Piping Fabrication

Figure 33 shows the completed dry exhaust system prototype weldment. The access lid bolt ring is visible in the right center of the photograph, while the mounting flange for the DPM filter is visible inside the inner chamber next to one of the exhaust ports. On the left side, the flame arrestor mount ring and the port for the exhaust temperature sensor are shown, the plugged port visible in the lower right was a coolant drain port. As pictured, the device was undergoing a leak test evaluation. The assembly passed a low air pressure leak test, after this test, the housing was filled with a water antifreeze mixture, and was monitored for any leak or loss of coolant level.

Figure 33 - Dry Exhaust System Weldment

Figure 34 - Exhaust System Manifold Side

Figure 34 shows the engine side of the exhaust system. The exhaust manifold ports and engine bolt pattern are shown in the center. Above the manifold plate is the raw exhaust gas / backpressure sample port, and the water inlet port, which was covered for leak testing. After testing, the cover plate was replaced with a bolt on water neck fitting. The port on the lower right was connected to the engine water pump inlet, the port on the upper left was for a temperature sensor. On the top of the assembly was the fill port; the test cover shown was replaced with a bolt on coolant filler neck with a pressure cap.

Figure 35 shows a comparison photograph of the dry exhaust system prototype next to the original wet exhaust design. The smaller footprint of the dry exhaust system was evident.

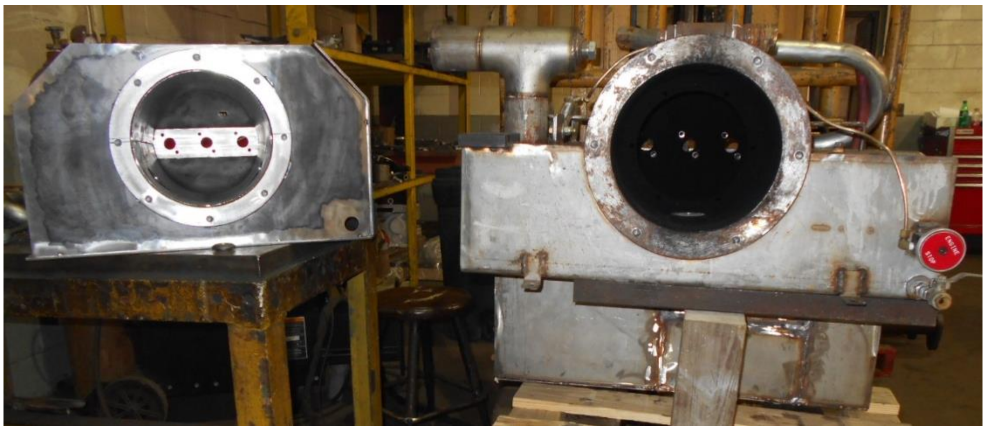


Figure 35 - Comparison of Exhaust Systems

Figure 36 shows the exhaust system installed on the machine for an initial start test. The cooling system, with the exhaust system installed, held approximately sixteen gallons of coolant. Visible in the figure are the two pressure caps, one on the radiator and one on the exhaust system, that allowed the machine to be filled from either location and prevented air bubbles from being trapped. The vents were teed to a common overflow reservoir, visible in the upper left part of the figure next to the radiator. In the lower left, the exhaust flame arrestor can be viewed. Figure 37 shows a picture of the exhaust exit pipe installed on the flame arrestor. The exit pipe housed the exhaust gas temperature shutdown sensor, and directed the exhaust toward the radiator to be diluted by airflow from the cooling fan.

Figure 36 – Exhaust System on Machine for Initial Start Test

Figure 37 - Exhaust Outlet and Temperature Sensor

During initial testing, it was determined that the coolant system required a larger coolant expansion bottle than had been installed, as the existing bottle overflowed when the engine was at temperature, and was empty after the system cooled back down. Figure 38 shows the installation of a larger expansion bottle.

Figure 38 – Coolant Expansion Bottle

After preliminary startup checks were complete and the machine was operational, load testing was performed to evaluate the dry exhaust gas treatment system and surface temperature control. Initial load testing was performed by using the PTO circuit to apply load to the engine, as done in previous tests. A significant mechanical change to the machine, since the last test was performed, was that a displacement limiter had been installed on the hydraulic pump. The pump output has been reduced to approximately 12 GPM from the 18 GPM that was previously produced. The normal pump displacement capacity exceeded the available power curve of the engine when pressure increased (as described from earlier load testing), so to prevent the engine from stalling, the displacement limiter was used. The first tests involved inducing load on the engine until the engine speed fell to approximately 2500 rpm from the high idle point. The first test was performed on 11 March 2019 starting at 9:55 am. The ambient temperature was 33 °F and the hydraulic load was 12 GPM at 2000 psi. Intake Restriction and Engine

Backpressure started at 10” H_20. Table 11 shows data recorded at five-minute intervals during this test. The exhaust gas, exhaust coolant, and engine coolant temperatures were measured with J-type thermocouples, and read from a digital handheld device. The exhaust gas thermocouple was located in the exhaust expansion chamber, to the lower left of the exhaust exit from the exhaust treatment system. The exhaust coolant thermocouple was located on a coolant chamber port to where the high temperature coolant shutdown device was installed, and the engine coolant thermocouple was located at the thermostat housing on the engine. The lid maximum and manifold maximum temperatures were recorded with a non-contact IR temperature device, and the temperature listed was the highest observed from scanning the external area of the dpm filter lid and the exhaust manifold plate. Backpressure was recorded and read with a dial pressure gage. Figure 39 shows a chart of the temperature data collected during this test.

Time	Exh Gas	Exh Coolant	Eng Coolant	Lid Max	Manifold Max	Backpressure
Minutes	°F	°F	°F	°F	°F	in H2O
0	105	119	140	60	250	10
5	115	138	142	77	244	10
10	134	167	145	93	257	20
15	151	181	148	120	249	25
20	165	165	155	125	235	45
25	173	164	156	134	231	95
27	175	165				100

Table 11 - Load Test Data 11 March 2019

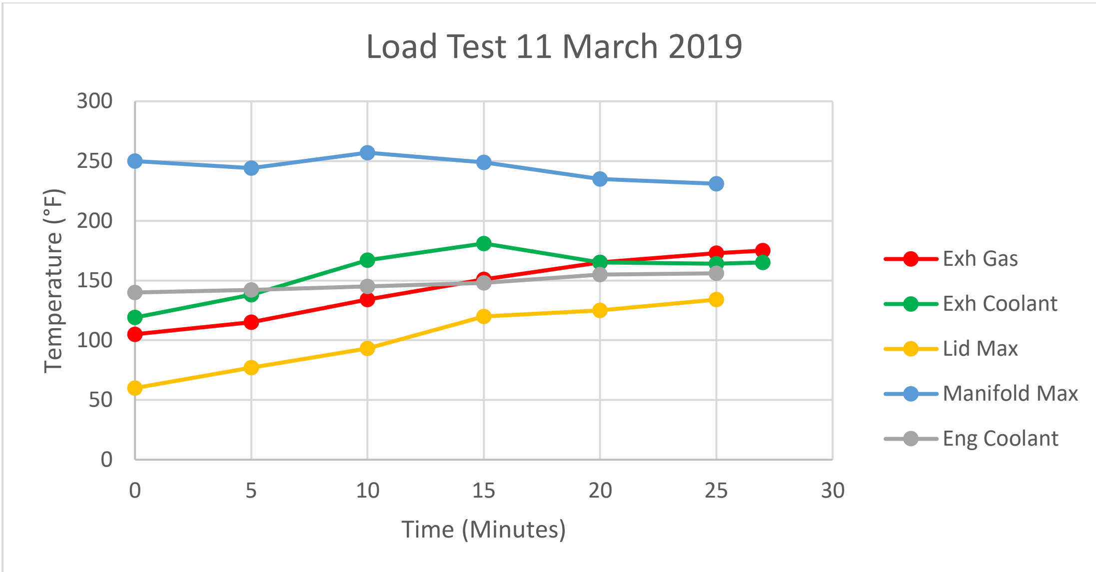


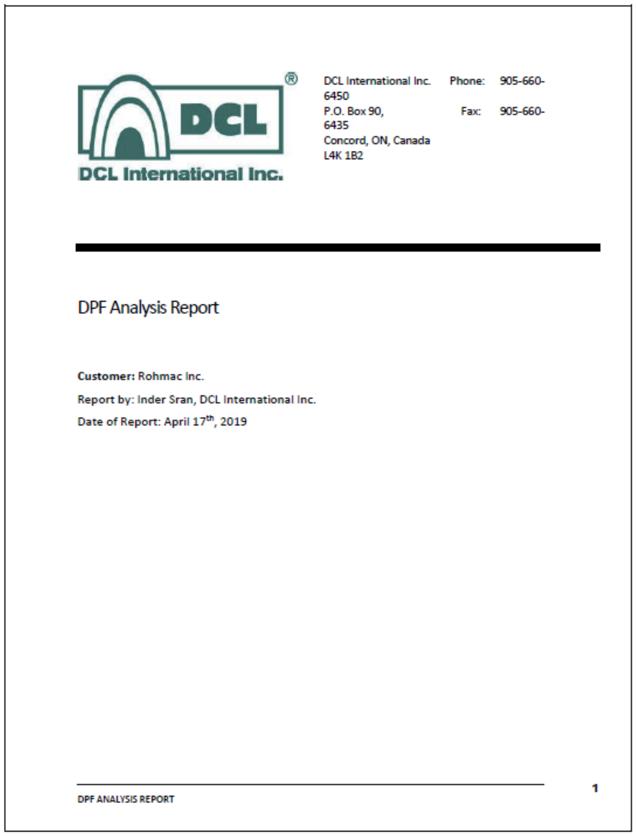
Figure 39 – Load Test Temperature Data 11 March 2019

During the test, the treated exhaust gas rose to a temperature of 175 °F, the exhaust system coolant leveled out at approximately 165 °F, the engine coolant temperature reached 155 °F, and the maximum temperatures observed on the lid and manifold were 134 °F and 257 °F, respectively. While these temperatures were well within the requirements of MSHA testing, the test was ended prior to the sixty-minute mark specified in MSHA guidelines. The test was conducted for approximately twenty-seven minutes, during which time the backpressure rose rapidly. At that time, the load was removed from the engine to evaluate the issue. At idle, the backpressure fell, and another attempt was made to load the engine. After a few minutes, visible smoke was observed in the exhaust and the test was terminated to assess the problem.

Whereas visible smoke was observed, a problem with the dpm filter was suspected, and the filter chamber lid was removed to inspect the condition of the filter. Figure 40 shows the DPM filter after the load test. The black soot traces on the face of the filter were indicative of a filter failure. A coating of soot was also visible on the bolt ring and other surfaces in the picture, also evidenced by the “clean” areas where two bolts were removed near the six and eight o’clock positions. The filter was removed from the assembly, and, after discussions with the filter manufacturer, sent out for evaluation. As the filter and catalyst assembly were fabricated in a single housing arrangement, removing the filter involved cutting the filter housing away from the mount ring and the oxidation catalyst housing. The oxidation catalyst was later re-welded to the mounting ring so that it could be re-installed for testing the system with catalytic converter only.

Figure 40 – DPM Filter post-test 11 March 2019

Results from the filter manufacturer’s evaluation of the failed diesel particulate filter indicated that the filter failed due to excessive soot loading, and an uncontrolled regeneration cycle that exceeded the maximum temperature capability of the ceramic filter material. The report stated that a possible cause of the excessive soot was an injector problem. Later discussions with the engine representatives and additional testing of the machine revealed that the engine was likely operated in an overloaded condition, which caused over-fueling and thus excessive soot. The report is shown in the following figures:



DCL International Inc.

DCL International Inc. Phone: 905-660-6450
P.O. Box 90, Fax: 905-660-6435
Concord, ON, Canada
L4K 1B2

DPF Analysis Report

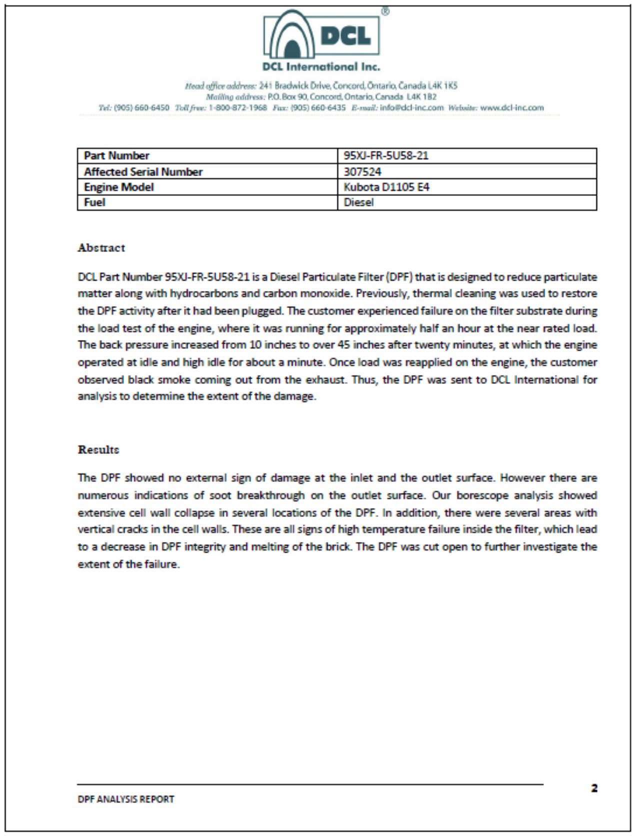
Customer: Rohmac Inc.

Report by: Inder Sran, DCL International Inc.

Date of Report: April 17th, 2019

DPF ANALYSIS REPORT 1

Figure 41 - Filter Failure Report page 1



DCL International Inc.

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Part Number	95XJ-FR-5U58-21
Affected Serial Number	307524
Engine Model	Kubota D1105 E4
Fuel	Diesel

Abstract

DCL Part Number 95XJ-FR-5U58-21 is a Diesel Particulate Filter (DPF) that is designed to reduce particulate matter along with hydrocarbons and carbon monoxide. Previously, thermal cleaning was used to restore the DPF activity after it had been plugged. The customer experienced failure on the filter substrate during the load test of the engine, where it was running for approximately half an hour at the near rated load. The back pressure increased from 10 inches to over 45 inches after twenty minutes, at which the engine operated at idle and high idle for about a minute. Once load was reapplied on the engine, the customer observed black smoke coming out from the exhaust. Thus, the DPF was sent to DCL International for analysis to determine the extent of the damage.

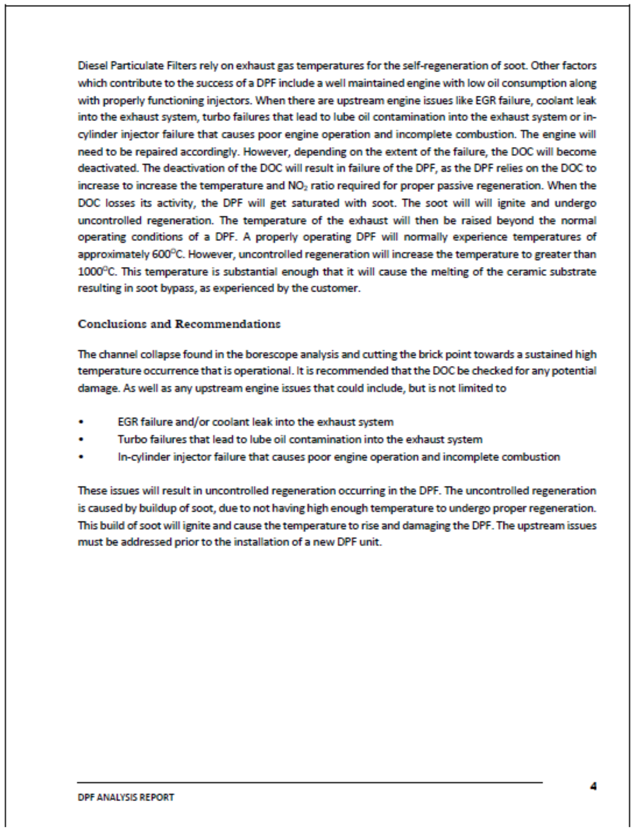
Results

The DPF showed no external sign of damage at the inlet and the outlet surface. However there are numerous indications of soot breakthrough on the outlet surface. Our borescope analysis showed extensive cell wall collapse in several locations of the DPF. In addition, there were several areas with vertical cracks in the cell walls. These are all signs of high temperature failure inside the filter, which lead to a decrease in DPF integrity and melting of the brick. The DPF was cut open to further investigate the extent of the failure.

DPF ANALYSIS REPORT 2

Figure 42 - Filter Failure Report page 2

Figure 43 - Filter Failure Report page 3



Diesel Particulate Filters rely on exhaust gas temperatures for the self-regeneration of soot. Other factors which contribute to the success of a DPF include a well maintained engine with low oil consumption along with properly functioning injectors. When there are upstream engine issues like EGR failure, coolant leak into the exhaust system, turbo failures that lead to lube oil contamination into the exhaust system or in-cylinder injector failure that causes poor engine operation and incomplete combustion. The engine will need to be repaired accordingly. However, depending on the extent of the failure, the DOC will become deactivated. The deactivation of the DOC will result in failure of the DPF, as the DPF relies on the DOC to increase to increase the temperature and NO_2 ratio required for proper passive regeneration. When the DOC losses its activity, the DPF will get saturated with soot. The soot will will ignite and undergo uncontrolled regeneration. The temperature of the exhaust will then be raised beyond the normal operating conditions of a DPF. A properly operating DPF will normally experience temperatures of approximately 600°C. However, uncontrolled regeneration will increase the temperature to greater than 1000°C. This temperature is substantial enough that it will cause the melting of the ceramic substrate resulting in soot bypass, as experienced by the customer.

Conclusions and Recommendations

The channel collapse found in the borescope analysis and cutting the brick point towards a sustained high temperature occurrence that is operational. It is recommended that the DOC be checked for any potential damage. As well as any upstream engine issues that could include, but is not limited to

- EGR failure and/or coolant leak into the exhaust system
- Turbo failures that lead to lube oil contamination into the exhaust system
- In-cylinder injector failure that causes poor engine operation and incomplete combustion

These issues will result in uncontrolled regeneration occurring in the DPF. The uncontrolled regeneration is caused by buildup of soot, due to not having high enough temperature to undergo proper regeneration. This build of soot will ignite and cause the temperature to rise and damaging the DPF. The upstream issues must be addressed prior to the installation of a new DPF unit.

DPF ANALYSIS REPORT 4

Figure 44 - Filter Failure Report page 4

In order to perform additional load testing on the engine and exhaust without the dpm filter/doc assembly installed, a baffle plate was fabricated in an attempt to hold a small amount of backpressure against the exhaust, and allow mixing to promote heat exchange to the coolant from the exhaust stream. On 12 March 2019, a load test was performed using the same load conditions as the previous test. The test started at 3:10 pm, the engine speed was set to 2500 rpm, the hydraulic load was 11 GPM at 2200 psi, the intake restriction was 10” H_20 and the backpressure read 0” H_20, the ambient temperature was 39 °F. Table 12 shows the data collected during this test and a chart of the temperature data is shown in Figure 45. The cooled exhaust gas peaked at 266 °F at the end of the sixty-minute test, coolant temperatures were stable at 163 °F in the exhaust system, and 157 °F at the engine thermostat housing. The maximum observed temperatures of the dpm filter chamber lid and the exhaust manifold were 146 °F and 261 °F,respectively. It was believed that the temperature peak was reached before the engine thermostat opened and allowed coolant to flow. During the test, very heavy smoke was visible in the exhaust.

Time	Exh Gas	Exh Coolant	Eng Coolant	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F
0	118	120	142	75	235
5	151	137	144	81	261
10	176	160	146	118	255
15	195	175	147	135	256
20	216	159	154	137	244
25	222	161	154	137	245
30	233	161	155	137	243
35	248	162	153	143	245
40	253	163	156	144	244
45	257	163	157	145	245
50	262	163	157	144	244
.55	263	163	157	146	244
60	266	163	157	141	246

Table 12 - Load Test Data 12 March 2019

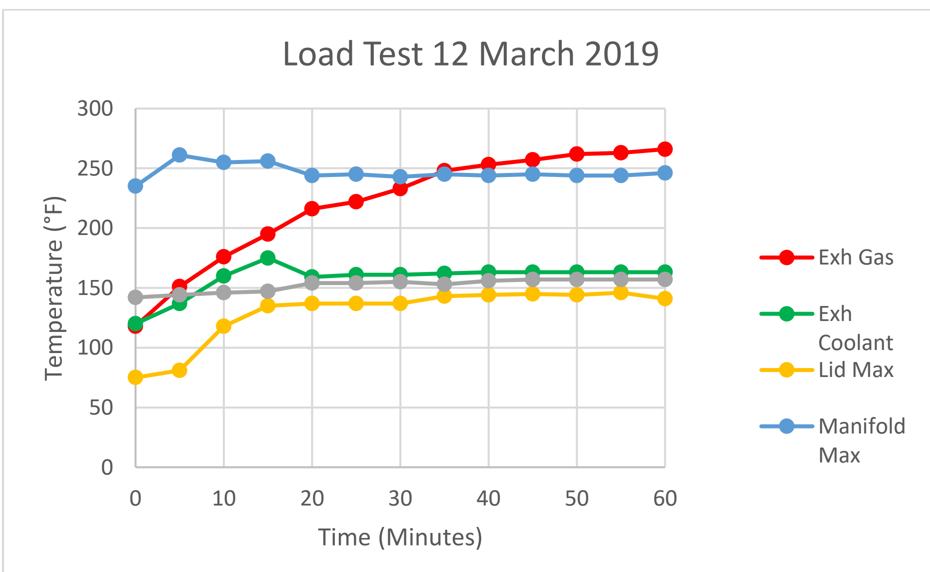


Figure 45 – Load Test Temperature Data 12 March 2019

At the end of this test, a thermocouple was placed in the exhaust exit pipe, and a temperature of 320 °F was observed. This raised concern about the accuracy of the cooled exhaust gas temperature data, that was measured at the port on the lower left-hand side of the exhaust expansion chamber. Upon discussion with representatives of CDC NIOSH, and subsequently MSHA A&CC, it was determined that another test should be performed with a thermocouple in the exhaust exit pipe, which was where the temperature would be measured during approval tests. The exhaust temperature shutdown device was removed from the exit pipe, and a J-type thermocouple was installed in its place. On 15 March 2019, the test was started at 12:40 pm. The load was set to 12 GPM and 2000 psi. The ambient temperature was 55 °F. Intake restriction measured 10” H_20 and backpressure was 0” H_20. Incidental damage to the tachometer cable made the tachometer unusable for engine speed measurement. Table 13 shows the data collected at five-minute intervals during the thirty-five-minute test and Figure 46 shows the chart of temperature data.

Time	Exh Gas	Exh Coolant	Eng Coolant	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F
0	185	98	145	71	220
5	264	120	147	83	244
10	316	148	149	101	249
15	360	162	154	122	236
20	382	164	162	132	238
25	402	172	167	142	242
30	418	174	170	144	244
35	434	175	170	146	246

Table 13 - Load Test Data 15 March 2019 12:40 pm

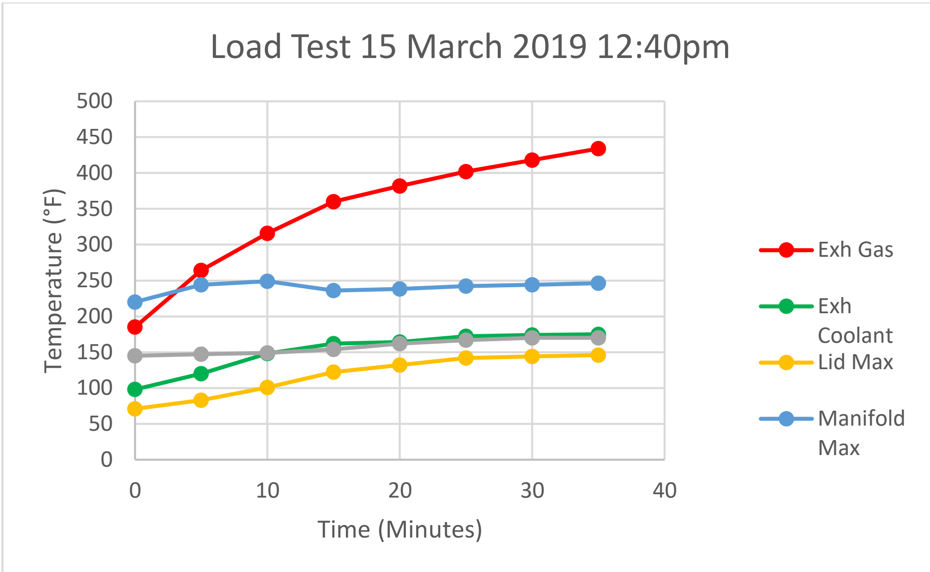


Figure 46 - Load Test Temperature Data 15 March 2019 12:40 pm

During the test, the exhaust gas temperature rose quickly over the 302 °F limit set by MSHA for permissible diesel equipment, and reached 434 °F before the test was stopped. The measuring point change returned a significantly different treated exhaust gas temperature. It was believed that the original thermocouple location was either not sufficiently in the exhaust stream for an accurate reading, or that the exhaust flow had formed a low temperature pocket at that location while hot exhaust gas escaped the chamber. Other temperatures were consistent with previous testing, but heavy smoke was again visible in the exhaust. It was believed that the engine may have been in an overloaded condition. Prior to the installation of the hydraulic pump displacement limiter, load was applied to a certain point above which the engine would stall. Review of the load applied during previous tests, by equating hydraulic load to horsepower, revealed that the 12 GPM and 2000 psi load was higher than previous levels. To match prior tests, a pressure of 1650 psi at 12 GPM would be equivalent. It was decided to attempt another test at the lower load setting.

The next test was performed on 15 March 2019 starting at 3:15 pm. The load was set to 12 GPM and 1700 psi. Ambient temperature was 65 °F, intake restriction measured 10" H_20 and backpressure read 0" H_20. In addition to recording temperature data, a gaseous measuring device was placed in the raw exhaust port to gather temperature and gaseous data near the exhaust manifold. Gas data was recorded for percentages of Oxygen and Carbon Dioxide, Carbon Monoxide in ppm, and temperature of the gas. These data are shown beside the temperature data in Table 14. Temperature Data are charted in Figure 47. Again, the treated exhaust gas temperature quickly rose above the 302 °F limit. Comparison of the manifold exhaust temperature with the exit temperature indicated that the system was reducing the exhaust temperature approximately 450 – 500 °F. At 1700 psi, there was no visible smoke in the exhaust, and the gaseous Oxygen and CO2 levels were approximately 10.5 and 7.5% respectively. At twenty minutes into the test, the load was increased to 1800 psi, at which point light smoke was visible, exhaust temperatures increased, and Carbon Monoxide levels spiked, indicating over-fueling or overload. After fifteen minutes in this loaded condition, temperatures stabilized, and the load was reduced to 1750 psi, which produced gaseous data more indicative of a properly loaded and fueled condition.

Time	Exh Gas	Exh Coolant	Eng Coolant	Lid Max	Manifold Max	T Gas	O2	CO2	CO
Minutes	°F	°F	°F	°F	°F	°F	%	%	ppm
0	170	125	133	92	221	865	11.1	7.2	720
5	379	147	150	102	248	860	10.8	7.5	600
10	382	158	151	115	242				
15	408	159	155	122	237				
20	405	162	158	127	232	870	10.5	7.7	650
25	402	163	160	130	236	870	10.3	7.8	670
					Load 1800 psi				
30	414	166	163	132	237	915	9.7	8.3	High
35	424	168	164	134	240				
40	427	168	165	135	242	920	9.5	8.4	1850
45	425	169	166	137	239	915	9.4	8.5	1350
					Load 1750 psi				
50	418	169	165	136	239	870	9.5	8.4	770
55	412	167	164	140	243	860	9.5	8.4	600

Table 14 - Load Test Data 15 March 2019 3:15 pm

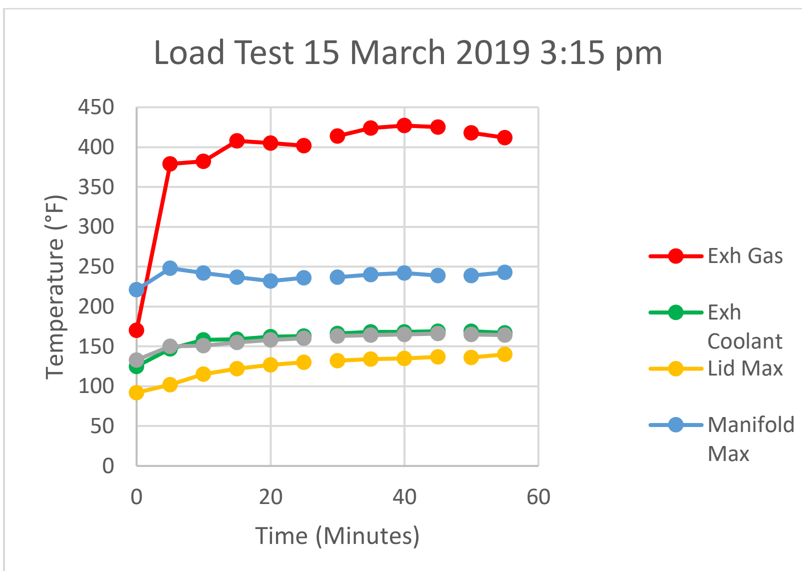


Figure 47 - Load Test Temperature Data 15 March 2019 3:15 pm

Review of the test data led investigators to believe that the exhaust was allowed to exit the system without sufficient opportunity for heat transfer due to the low backpressure. The baffle plate that had been installed in place of the dpm filter assembly was not effective in causing heat transfer and mixing in the exhaust. Figure 48 shows the baffle plate after the load tests, the soot buildup from operating in the over fueled condition is visible. It was believed that the heavy soot coating in the exhaust system was affecting some level of heat transfer.

Figure 48 - Exhaust Baffle Plate Post-Test

After this test, methods of increasing exhaust mixing and contact with the cooling system surfaces were reviewed. A deflector tube was designed and built that installed over the dpm/doc assembly and directed exhaust gas along the outer wall of the filter chamber before allowing it to exit through the catalyst and dpm filter. This device was installed along with the modified oxidation catalyst assembly, and another load test was performed at the 12 GPM and 1750 psi load level on 21 March 2019. A J-type thermocouple was installed in an exhaust system port near the manifold to record the hot exhaust gas temperature. The test started at 10:25 am and the ambient temperature was 40 °F, the test lasted for ninety-five minutes, and Table 15 shows the data that were recorded at five-minute intervals.

Time	Hot Exh Gas	Cool Exh Gas	Exh Coolant	Eng Coolant	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F	°F
0	754	116	86	140		
5	942	215	113	143		
10	920	236	144	137		
15	894	249	156	146	108	252
20	905	263	169	147	116	254
25	908	275	173	148	123	251
30	910	280	170	150	137	245
35	904	283	166	149	128	246
40	907	285	165	150	131	245
45	904	287	165	150	129	245
50	897	290	164	150	131	240
55	900	290	164	150	130	244
60	912	295	161	149	131	241
65	902	295	164	150	133	242
70	918	300	161	150	130	245
75	899	298	162	150	132	241
80	912	301	161	149	133	242
85	894	300	163	149	134	242
90	915	304	161	149	131	243
95	910	306	164	149	131	244

Table 15 - Load Test Data 21 March 2019

The hot exhaust temperature was typically 900 – 915 °F, and the cooled exhaust did not exceed 302 °F until the ninety-minute mark. Other temperatures again reflected the results of previous tests. The typical temperature reduction was around 600 °F, which was a significant improvement from the previous tests. This test indicated that the cooling capacity of the system was capable of increased performance, and that minor changes to improve mixing and contact of the exhaust gas with the cooling surfaces would likely result in the exhaust system cooling performance meeting the standard for permissible approval. Figure 49 shows the chart of the temperature data collected during the test, while Figure 50 shows a chart of the hot and cooled exhaust gas temperatures along with the temperature reduction. During the test, a small coolant leak was observed on the radiator, which may have slightly affected cooling performance, but was not significant enough to warrant removal for repair.

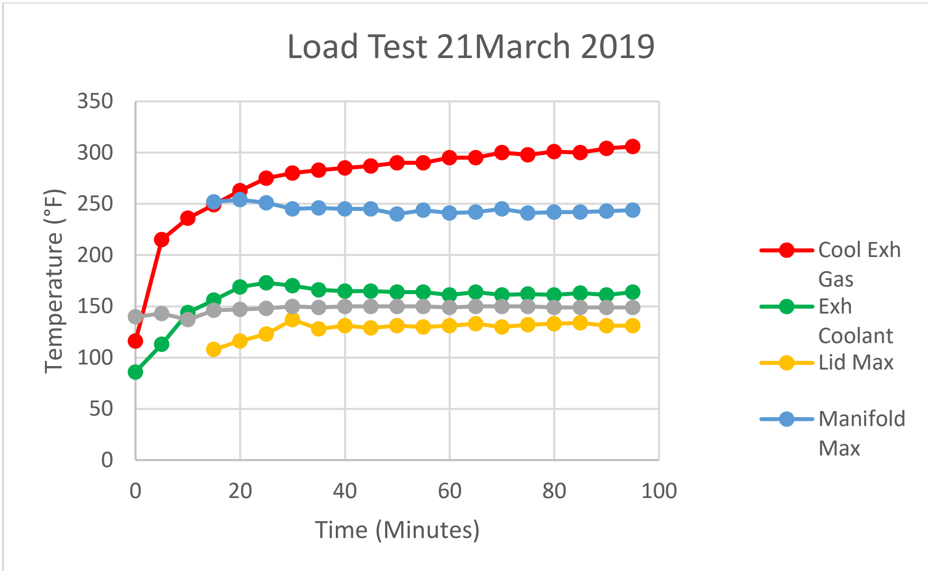


Figure 49 - Load Test Temperature Data 21 March 2019

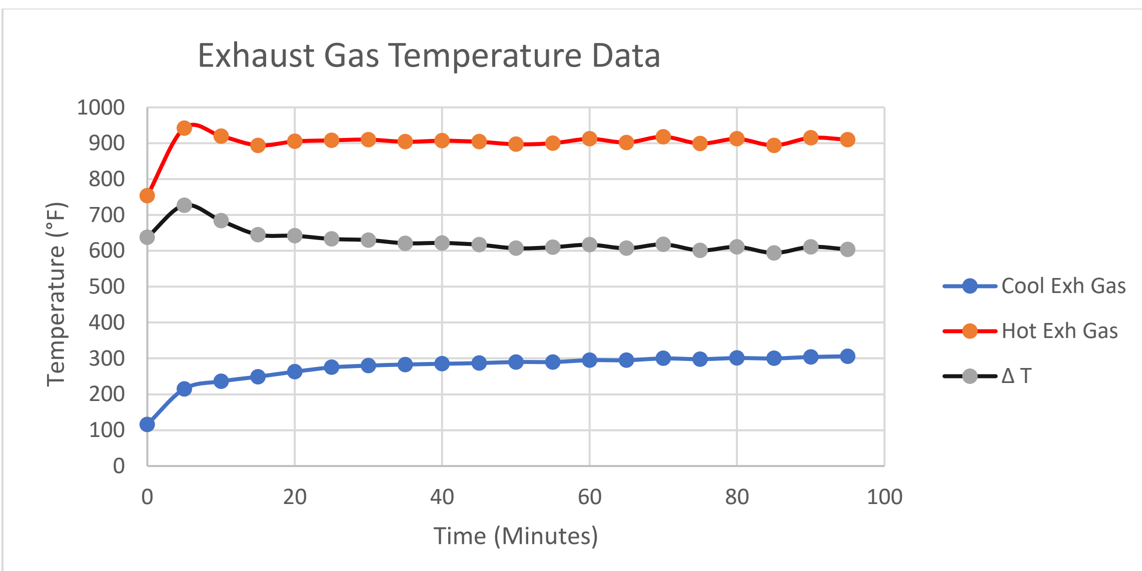


Figure 50 - Exhaust Gas Temperature Reduction 21 March 2019

After the load test on 21 March 2019, the tachometer cable was replaced, and an additional exhaust baffle was built and installed between the flame arrestor and exhaust exit chamber. Load tests were then conducted to evaluate the performance of the system.

The first test was performed on 27 March 2019 starting at 3:12 pm. The engine was operated at 2600 rpm with the load set at 12 gpm and 1750 psi. The ambient temperature was 50 °F, intake restriction was 12" H_20. The exhaust system was notably dirty from the soot that had deposited during previous tests. Table 16 shows data recorded during this test, and the data is graphed in Figure 51. Temperatures observed for coolant, and manifold and lid surfaces, were similar to those noted in previous tests, the manifold exhaust temperature was approximately 860 °F, while the cooled exhaust gas temperature was approximately 245 °F. At the end of this test it was discovered that the flame arrestor temperature was higher than the lid over the filter chamber, therefore, future tests monitored the temperature at the flame arrestor exit and no longer checked the lid.

Time	Hot Exh Gas	Cool Exh Gas	Exh Coolant	Eng Coolant	Lid Max	Manifold Max
Minutes	°F	°F	°F	°F	°F	°F
0	891	165	100	140	65	220
5	869	175	113	144	72	243
10	919	199	136	145	88	258
15	887	220	154	147	103	250
20	882	232	167	148	113	249
25	873	237	170	149	125	246
30	871	242	166	150	127	238
35	863	242	161	151	130	242
40	861	244	155	151	127	237
45	860	243	160	151	129	242
50	860	245	159	150	127	241
55	853	243	161	150	136	239
60	859	246	159	150	133	236

Table 16 - Load Test Data 11 March 2019

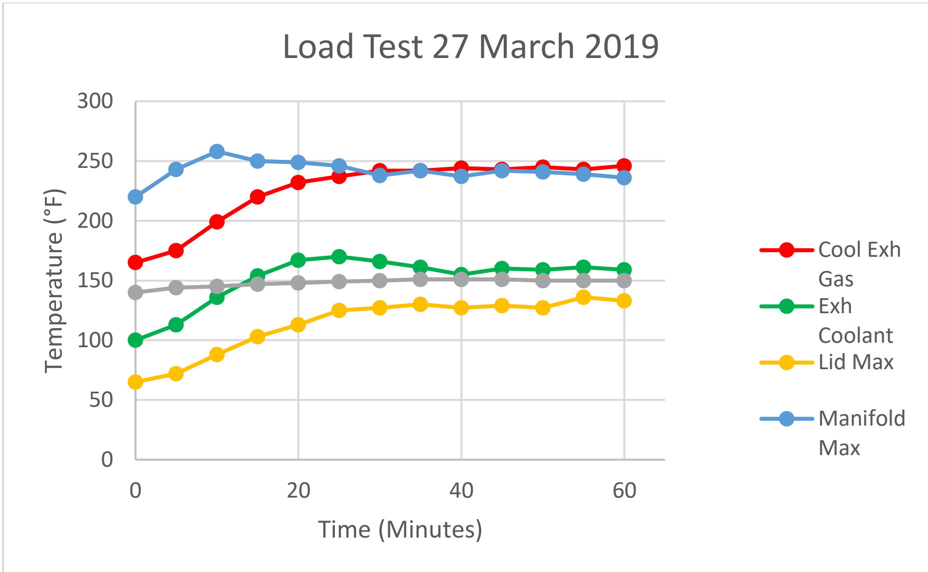


Figure 51 - Load Test Temperature Data 27 March 2019

Figure 52 shows a graphical representation of the exhaust gas temperatures observed during the test with a line showing the temperature reduction. The system achieved approximately 600 °F reduction in temperature.

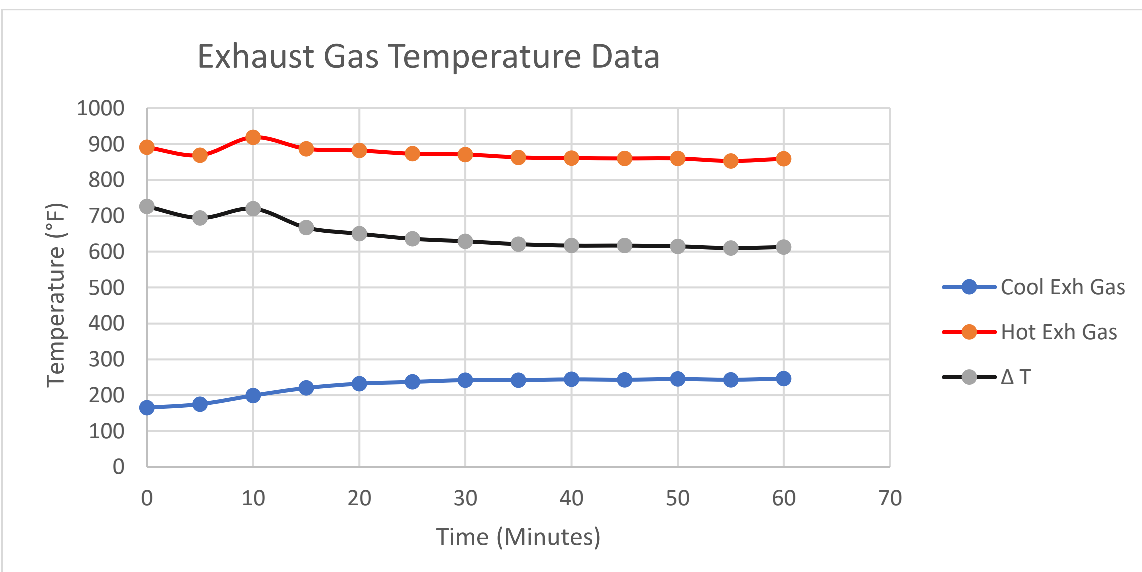


Figure 52 – Exhaust Gas Temperature Data 27 March 2019

Another load test was performed on 12 April 2019, Table 17 shows the data collected during this test, and a chart of the temperature data is shown in Figure 53. The test lasted for two hours, the engine was operated at 2800 rpm and the load was set to 12 gpm and 1750 psi. The ambient temperature was 67 °F and the humidity was approximately 67% with a barometer of 29.98 inches of mercury. Intake restriction was 13” H_20, and it was also noted that the pump pressure was 1900 psi. This was due to the standby pressure produced by the pump, that adds to working pressure seen on the PTO circuit load test gage.

Time	Hot Exh Gas	Cool Exh Gas	Exh Coolant	Eng Coolant	Flame Arr Max	Manifold Max
Minutes	°F	°F	°F	°F	°F	°F
0	910	124	115	140	105	205
5	982	235	133	149	129	247
10	949	254	154	151	174	243
15	920	265	161	156	184	235
20	923	272	166	163	196	237
25	918	277	170	166	215	238
30	924	281	170	168	218	240
35	925	281	172	168	218	243
40	924	284	172	169	219	244
45	908	286	173	169	220	244
50	915	286	173	169	221	243
55	914	286	174	169	222	244
60	913	288	173	170	221	242
65	927	290	174	170	222	243
70	925	293	172	170	224	239
75	917	291	174	170	227	240
80	923	295	172	170	226	236
85	924	295	174	170	226	232
90	922	297	174	171	227	240
95	925	293	175	170	227	239
100	923	299	174	171	228	240
105	932	299	173	171	230	251
110	928	300	175	171	232	243
115	929	303	174	172	232	249
120	925	301	175	171	232	244

Table 17 - Load Test Data 12 April 2019

Temperatures during this test were higher than the previous test, which may have been due to higher ambient temperature and increased engine speed. The throttle arm may not have been completely opened during the previous test as there seemed to be some play and friction to overcome near the full-open position. The manifold exhaust gas temperature was nearly 925 °F, while the cooled exhaust gas was approximately 285-295 °F through most of the test, the exhaust gas went above 302 °F after nearly two hours of full load operation. Coolant temperature was approximately 175 °F, while the manifold surface was nearly 245 °F, and the flame arrestor surface was nearly 230 °F.

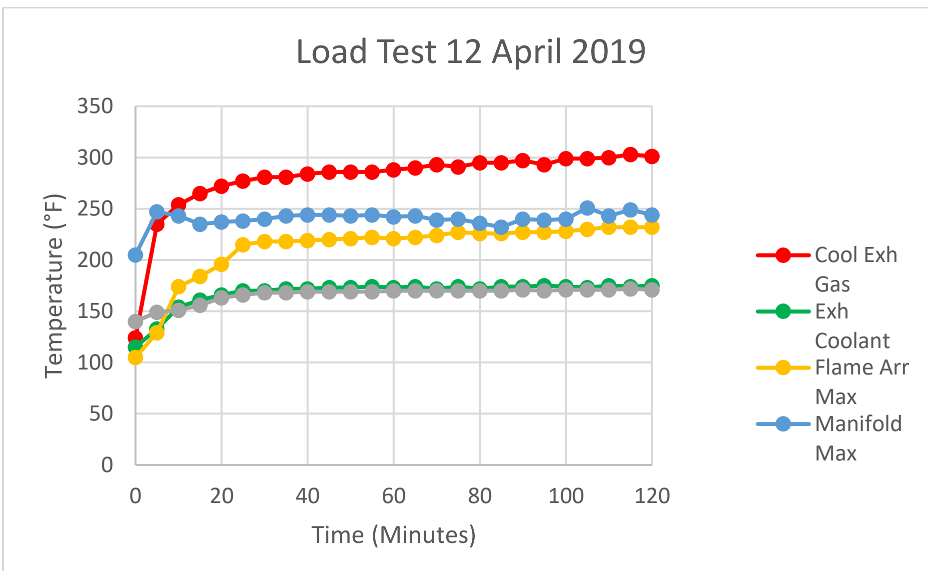


Figure 53 - Load Test Temperature Data 12 April 2019

Figure 54 shows a graph of the exhaust gas temperatures and the temperature reduction. The temperatures were steady after the initial warmup and the temperature reduction during the test was approximately 625 °F.

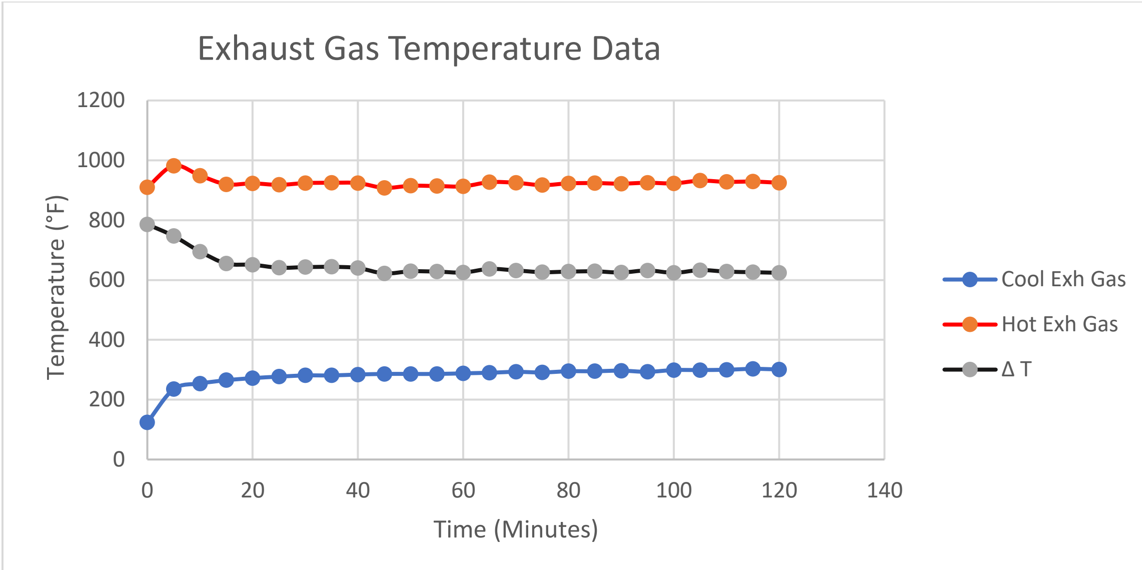


Figure 54 – Exhaust Gas Temperature Data 12 April 2019

Continuing development of the exhaust system, along with the delays experienced by component lead times throughout the project, were contributing factors to a six-month no-cost time extension request on 15 April 2019, that was enacted on 13 May 2019.

Another load test was performed on 23 April 2019. Ambient conditions during this test were approximately 74 °F with 33% humidity and a barometer of 29.92 inches of mercury. The engine speed was set to 2900 rpm, and the load was set to 12 gpm and 1750 psi, again 1900-1950 psi was observed on a pump pressure gage. Intake restriction measured 14” H_20, and the test started at 4:05 pm and was conducted for ninety minutes. Temperature data is shown in Table 18 and graphed in Figure 55.

Temperatures during this test were again higher than the previous test, with engine speed and increased ambient temperature being likely contributors. The manifold temperature was nearly 940 °F and the cooled exhaust gas nearly 290 °F during the test. Coolant temperature was approximately 180 °F with the manifold surface temp nearly 250 °F and the flame arrestor surface nearly 230 °F.

Time	Hot Exh Gas	Cool Exh Gas	Exh Coolant	Eng Coolant	Flame Arr Max	Manifold Max
Minutes	°F	°F	°F	°F	°F	°F
0	740	134	147	150	132	225
5	972	240	159	155	175	228
10	950	256	163	164	193	238
15	942	266	174	171	202	242
20	945	273	176	175	211	243
25	943	279	182	178	219	252
30	945	281	181	179	222	256
35	940	283	183	180	220	252
40	948	286	184	180	229	255
45	942	287	185	181	226	256
50	942	287	183	181	230	256
55	941	289	184	180	231	256
60	938	291	184	180	236	250
65	939	292	184	180	231	250
70	939	292	184	180	232	251
75	937	292	184	179	231	247
80	940	294	182	179	234	247
85	938	292	182	178	236	248
90	943	294	181	178	233	245

Table 18 - Load Test Data 23 April 2019

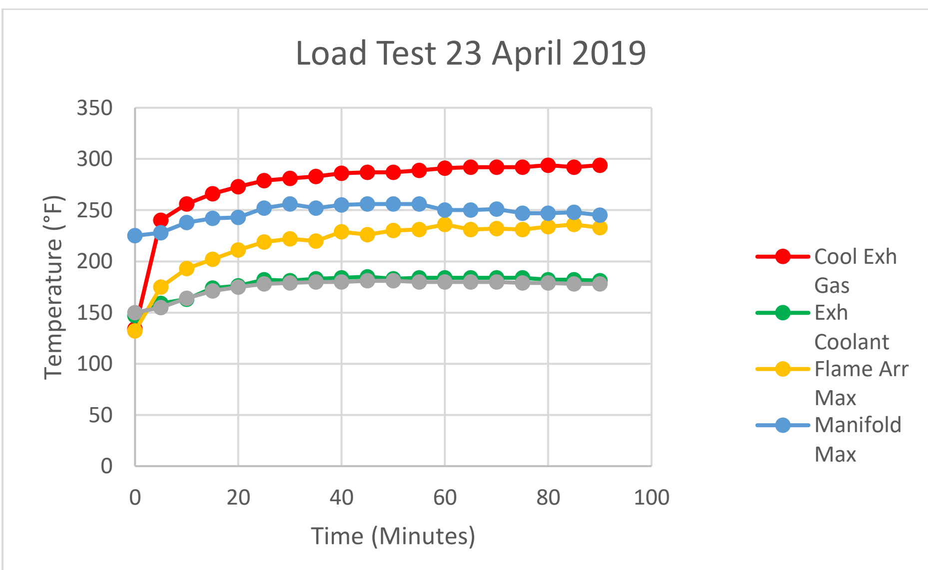


Figure 55 - Load Test Temperature Data 23 April 2019

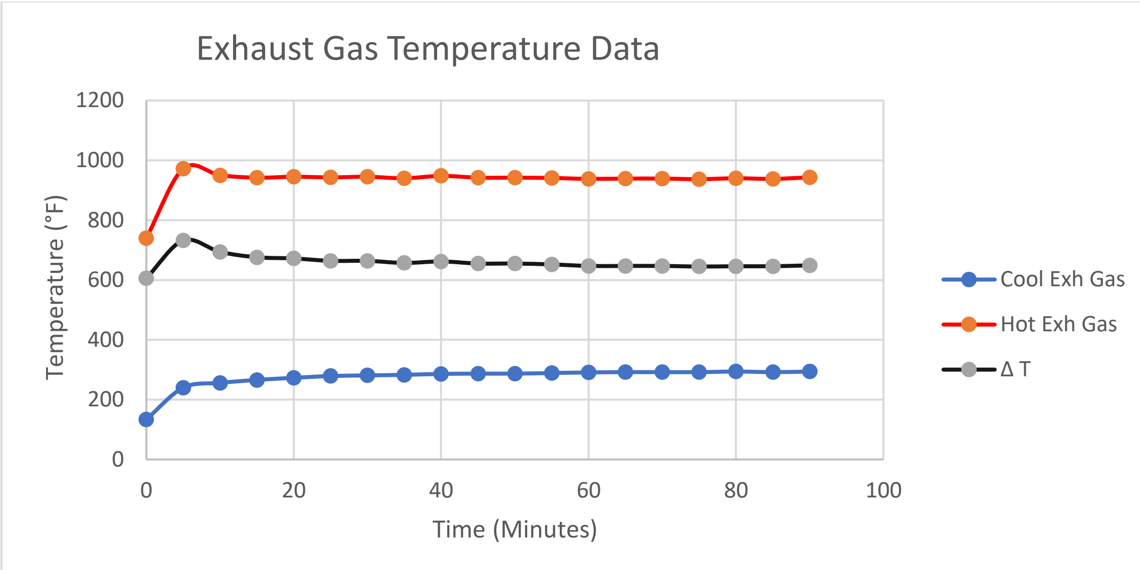


Figure 56 – Exhaust Gas Temperature Data 23 April 2019

Figure 56 shows a graph of the exhaust gas temperature data and temperature reduction during the test, the temperature reduction was nearly 650 °F. Results of these tests indicated that adding the exhaust baffle improved the heat transfer of the exhaust cooling system significantly.

After this test, data was shared with representatives of CDC NIOSH and MSHA A&CC, and some basic system design information was discussed. It was decided that additional revision to the exhaust system would help improve the performance toward meeting the temperature and pressure testing requirements for permissible approval (unit gets hydrostatically tested to 150 psi, cannot exhibit permanent deformation). Six split ring baffle plates were installed in the prototype filter chamber with the split openings alternating from top to bottom and evenly spaced, to create exhaust pathways that improved contact with the cooling jacket, and functioned as a strengthening device for the thin chamber wall. Installing the rings in the existing weldment was a difficult task, and the wall of the filter chamber was compromised and required repair. On 29 May 2019, a load test was performed on the system with the new baffles installed. The test started at 12:00 pm, the engine was operated at 3000 rpm with the load set at 12 gpm and 1700 psi. The ambient temperature was 75 °F, relative humidity was 71%, barometer was 29.88 inches of Mercury, intake restriction was 10” H_20, exhaust backpressure was 20” H_20. Table 19 shows data recorded during this test.

Time	Hot Exh Gas	Cool Exh Gas	Exh Coolant	Eng Coolant	Flame Arr Max	Manifold Max
Minutes	°F	°F	°F	°F	°F	°F
0	890	120	125	160	100	150
5	949	139	140	165	122	217
10	988	192	161	170	150	212
15	1003	216	170	180	177	214
20	1013	235	182	188	189	223
25	1025	246	189	193	197	229
30	1041	254	192	199	207	224
35	1039	258	196	201	208	238
40	1039	263	196	202	213	239
45	1043	267	197	203	213	242
50	1043	269	199	202	217	245
55	1051	272	198	202	218	243
60	1052	276	197	202	222	245
65	1055	283	195	202	222	243
70	1063	285	197	202	224	245
75	1057	288	197	201	223	240
80	1067	290	197	201	229	241
85	1060	296	198	202	223	244
90	1071	298	197	202	235	243
95	1072	303	198	202	231	243

Table 19 - Load Test Data 29 May 2019

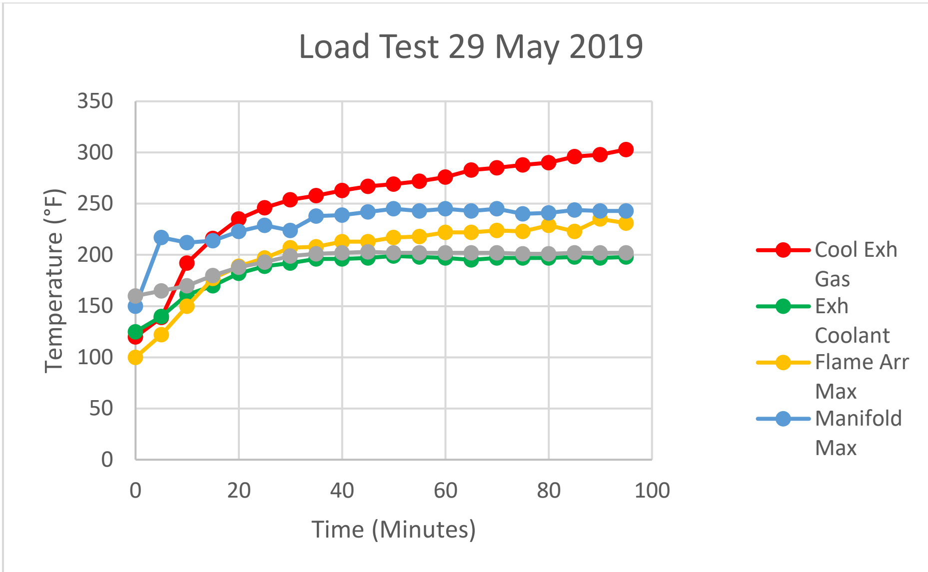


Figure 57 - Load Test Temperature Data 29 May 2019

Figure 57 shows a graph of the data collected during the May 29 load test. Engine manifold exhaust temperatures observed during the test were approximately 1050 °F, which was significantly higher than temperatures observed in previous tests. The cooled exhaust gas was approximately 280 °F after one hour, and went over 302 °F after one and a half hours. Surface temperatures were similar to those observed in previous tests, but coolant temperature was approximately 10 °F higher than seen in previous tests, which may have been due to additional heat rejection from the exhaust to the coolant, or a small coolant leak.

Figure 58 shows a graphical representation of the exhaust gas temperatures observed during the test with a line showing the temperature reduction. The system achieved approximately 775 °F reduction in temperature. This was a significant increase in temperature reduction as compared to previous tests.

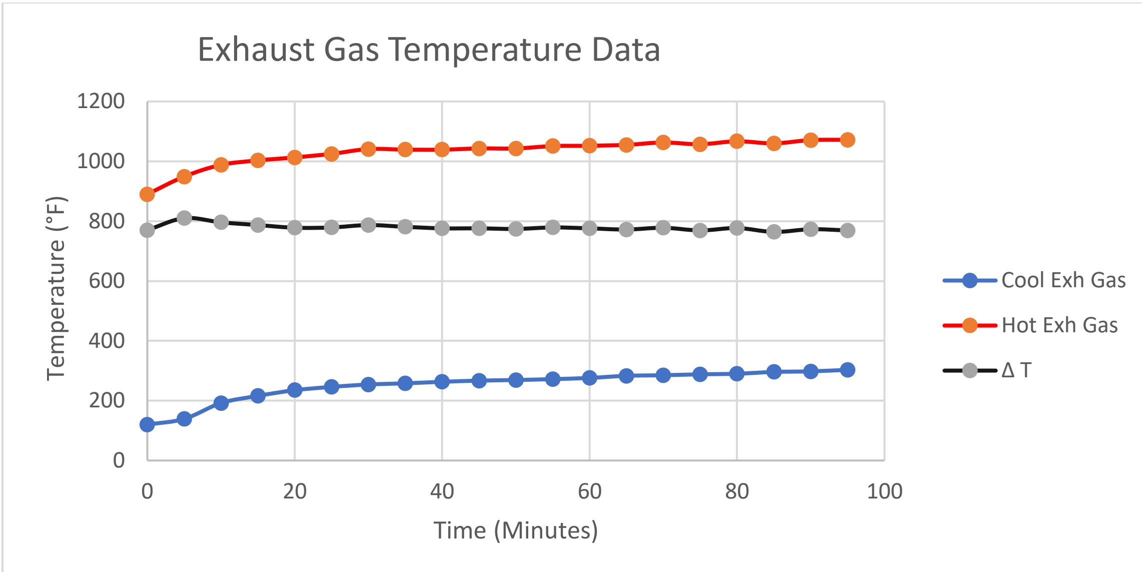


Figure 58 – Exhaust Gas Temperature Data 29 May 2019

On 29 July 2019 at 2:55 pm, a second load test was performed to gather temperature data on the exhaust system. The approximate atmospheric conditions during the test were ambient temperature of 80 °F, relative humidity 57%, and a barometric pressure of 30.15 inches of Mercury. The engine was set to 2900 rpm, load was set to 1750 psi and 12 gpm, engine intake restriction read 10" H_20 and exhaust backpressure read 20" H_20.

During the seventy-five-minute test, hot exhaust gas temperature ranged from 995 °F to 1030 °F and the cooled exhaust gas temperature leveled out at nearly 267 °F after about an hour of operation. Engine coolant temperature was approximately 190 °F, and the surface temperatures of the manifold and the flame arrestor were most nearly 240 °F and 225 °F respectively. Table 20 shows temperature data collected during the test. The data are charted in Figure 59.

Time	Hot Exh Gas	Cool Exh Gas	Exh Coolant	Eng Coolant	Flame Arr Max	Manifold Max
Minutes	°F	°F	°F	°F	°F	°F
0	1030	123	134	163	118	235
5	1030	190	160	169	148	234
10	1003	212	168	175	173	231
15	1010	232	181	185	195	235
20	1003	241	183	188	198	241
25	1010	247	187	192	209	242
30	1014	251	187	195	211	241
35	1005	253	188	195	216	235
40	997	255	189	195	217	239
45	995	258	185	195	220	237
50	1001	260	186	195	220	235
55	1006	261	189	195	223	236
60	1008	265	189	195	224	237
65	1000	267	189	195	223	243
70	1005	267	190	195	226	241
75	1007	268	189	195	225	241

Table 20 - Load Test 29 July 2019

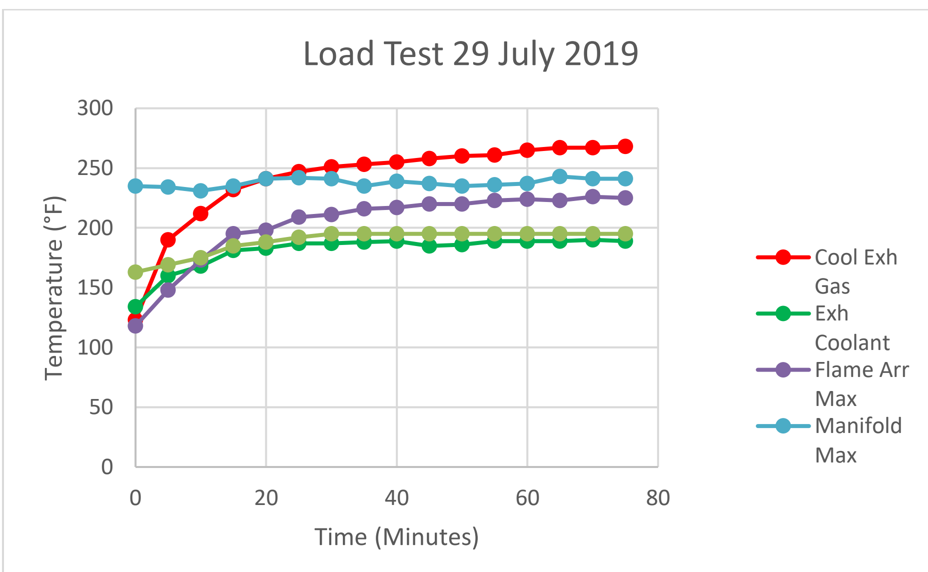


Figure 59 - Load Test Data 29 July 2019

Figure 60 shows the hot and cooled exhaust gas temperatures along with the temperature reduction. The data show a brief period of reaching temperature, then a relatively steady state operation. The reduction in exhaust gas temperature was nearly 740 °F during the test.

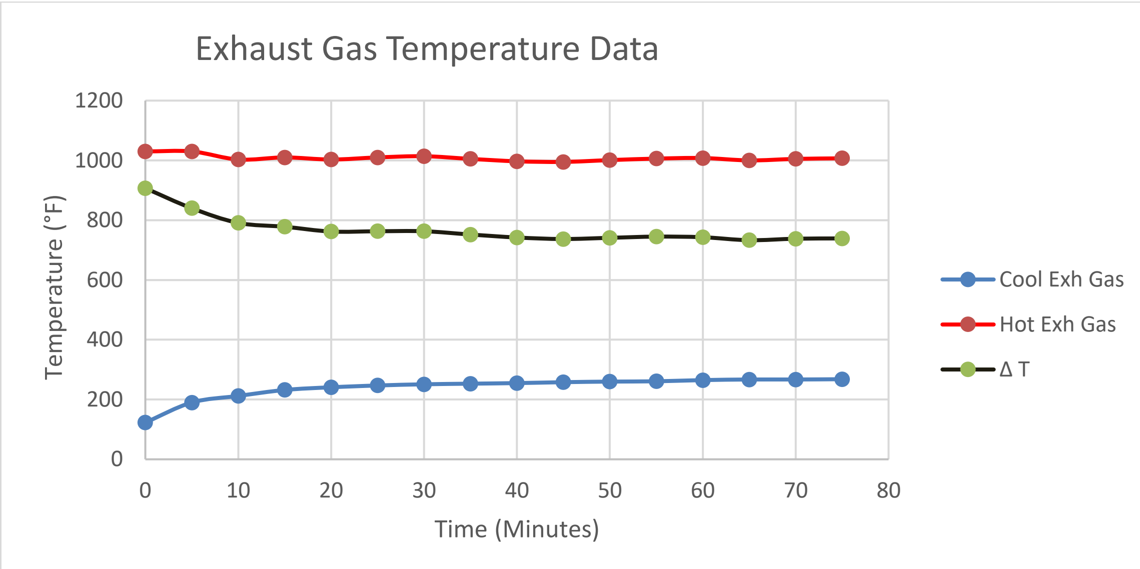


Figure 60 - 29 July Exhaust Gas Temperature Reduction

A comparison of the data from the tests performed on 29 July and 29 May was charted, and is shown in Figure 61. The test data show very repeatable results. A third order polynomial trendline was fitted to the cooled exhaust gas data for comparison purposes, the trendline for the 29 July test is shown in the lower left of the chart, with the 20 May trendline above and to the right side.

Based upon the results of prototype testing, and discussion with representatives of CDC NIOSH and MSHA A&CC, the dry exhaust system design was altered to improve performance. A complete set of drawings of the new system were sent to MSHA for a preliminary review, and with the results of test data, comments were generally positive that the design would pass the required tests. Figure 62 shows the assembly drawing of the redesigned exhaust system.

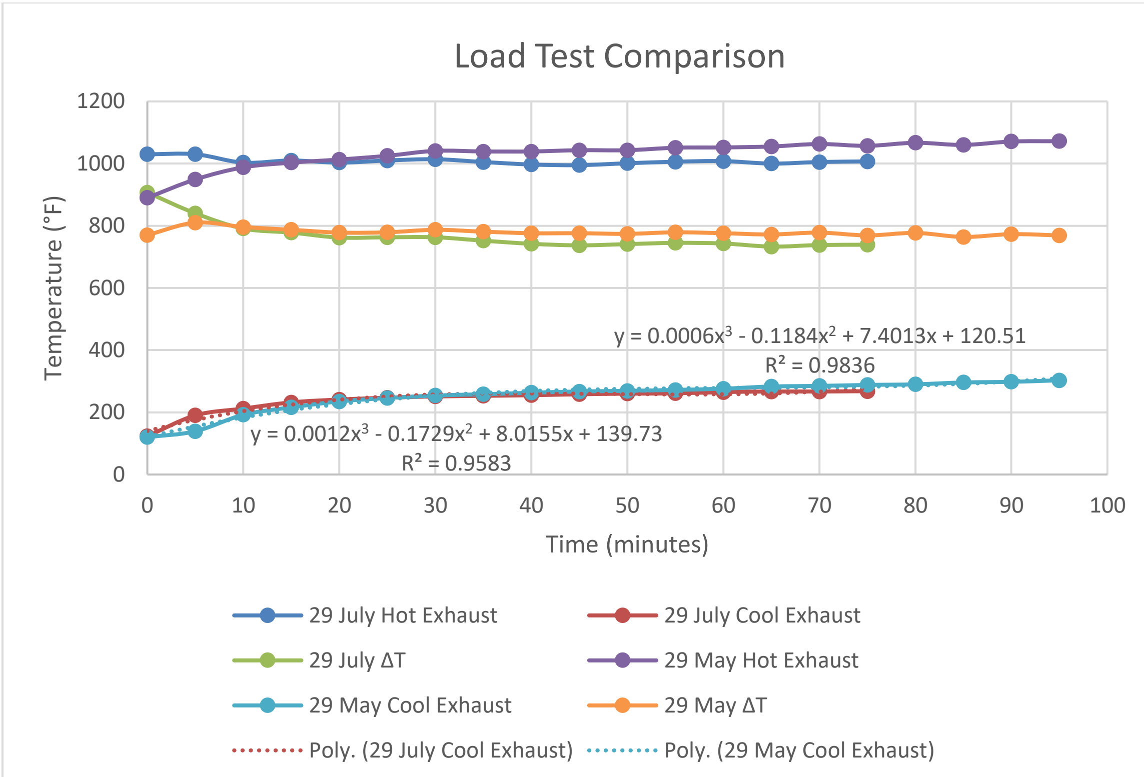


Figure 61 - Exhaust Temperature Test Comparison

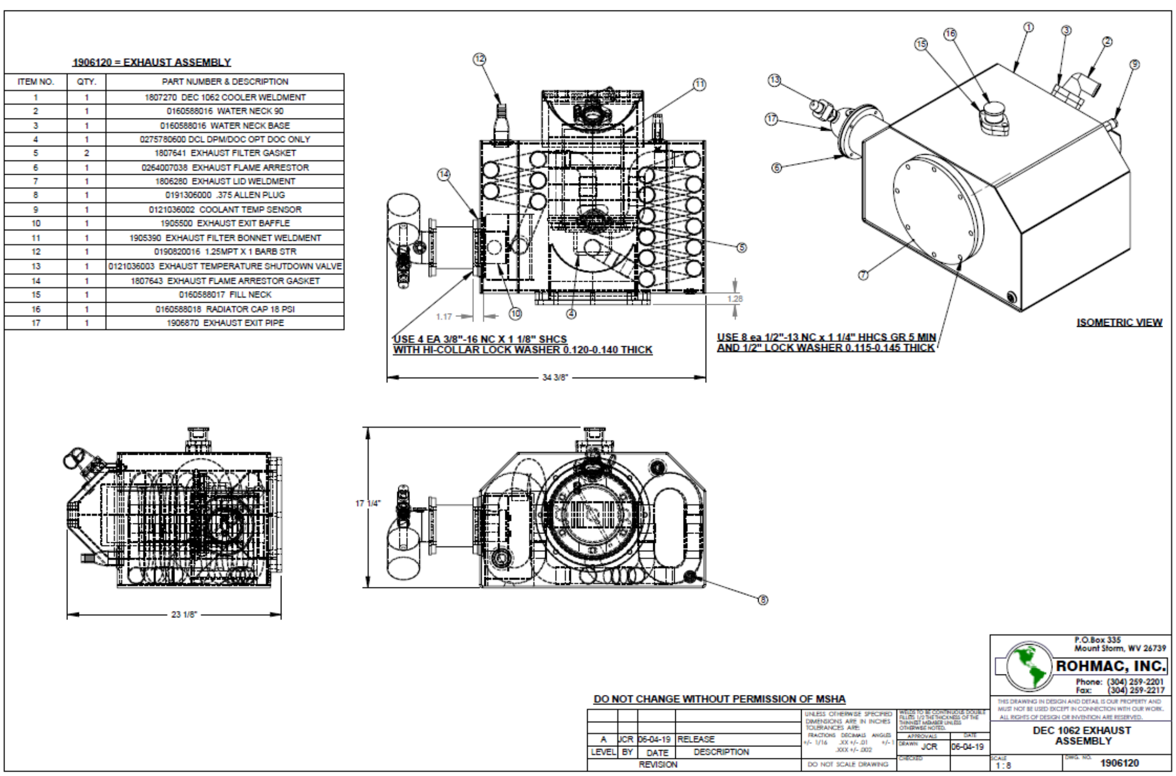


Figure 62 - Exhaust System Assembly Drawing

The exhaust system design was altered to incorporate additional exhaust cooling surface area. The filter chamber had five baffle plates installed along the filter chamber wall that fit closely to the filter bonnet, and were equally spaced between the manifold and the filter mount plate. In addition to directing exhaust in such a fashion as to improve mixing and contact with the outer cooling jacket, and adding structure to the chamber wall, the baffle plates could also act as cooling fins to conduct heat to the water jacket. Once the exhaust passed through the fins and into the filter bonnet, it traveled back, between the walls of the filter and the bonnet, toward the manifold where it entered the oxidation catalyst and filter assembly. From the filter exit, the exhaust piping was changed to a single pathway instead of the dual pipe design. This change was made to increase the length of piping traveled by the exhaust through the cooling chamber, to add area for heat exchange, and to improve the fabrication process. The single exit at the bottom of the filter chamber improved the fabricator's ability to cope the exhaust pipe and ensure a sound weld. The revised coil design of the exhaust tube routing was easier for the fabricator to layout, and nearly doubled the length of tubing for heat transfer as compared to the initial prototype. The exhaust tubing routed the exhaust to the expansion / exit chamber. A baffle plate was also added to the exit chamber to direct exhaust gases, and the previously tested exit baffle was also included in the design. The outer dimensions of the exhaust system were kept the same as the initial prototype.

Drawings of the redesigned exhaust system were shared with MSHA A&CC representatives for a preliminary review. After discussion of the drawings, the new device was fabricated. Complete drawings of the system are shown later in the report

Figure 63 shows the exhaust cooler fabrication during a leak test. The filter chamber is visible in the center of the figure and the cooler tubing is shown on each side of the chamber. Also visible is the tubing connection at the top of the exhaust exit chamber.

Figure 63 - Exhaust Cooler Fabrication

Figure 64 shows a picture of the device from the exhaust exit chamber side. The bolt-on cover used for the leak test was installed, and the exhaust manifold was visible on the left side of the picture. At the top center of the picture, the exhaust chamber lid and the exhaust filter bonnet are visible on the table.

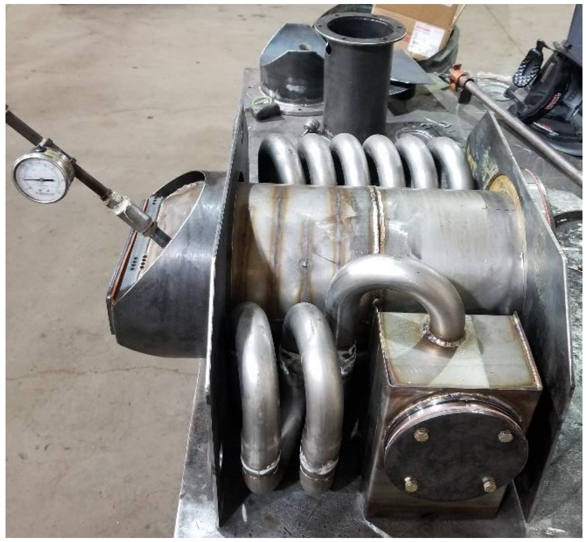


Figure 64 - Exhaust Exit Chamber Side of Cooler

MACHINE DESIGN REVISIONS

The prototype mine rescue machine was a very compact design. This made design revision difficult, because alteration to one design feature usually required modifications to other parts of the machine, to accommodate the change. While the hydraulic and exhaust system modifications and testing represented the most significant and time-consuming work performed, several other significant changes were made.

As part of the project goal for implementing space saving measures, and to make room for the MSHA approved alternator, the intake system was redesigned. The new intake flame arrestor was much more compact than the arrestor used on the original prototype, and permitted the arrangement shown in Figure 65 to be used. The arrestor was a crimped ribbon style device, and could be tested (as required by MSHA) using a standard pin gage that miners were familiar with. An additional space reduction was realized by machining a direct mount plate for the intake shutdown device and removing an intake tube; the shutdown device was also visible in the figure. Below the intake, the hydraulic throttle control was shown on a redesigned engine mount. The model also displayed the dry exhaust treatment assembly.

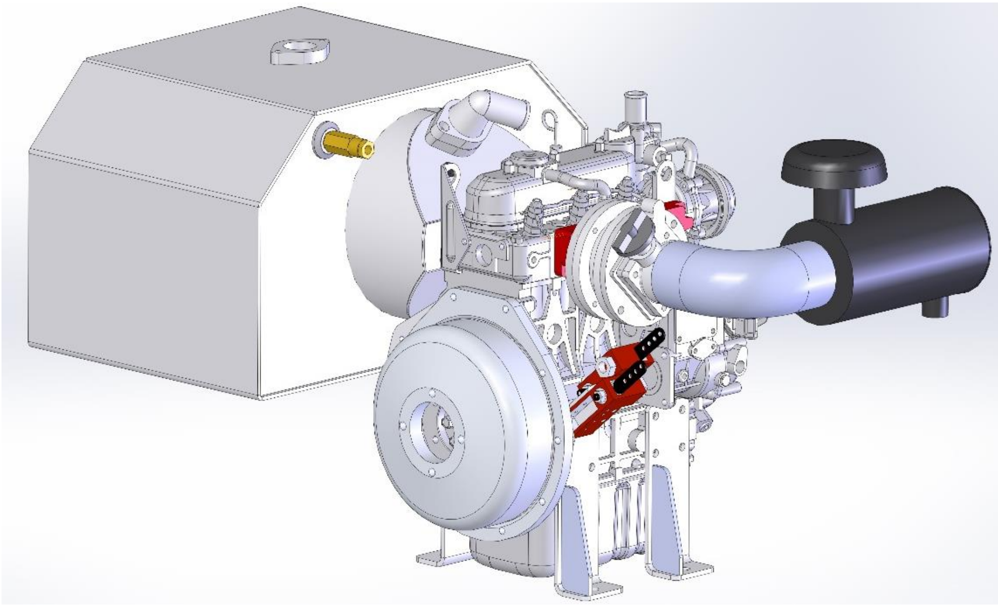


Figure 65 - Engine Assembly Model

Figure 66 and Figure 67 show the intake manifold during fabrication. The engine side was machined to match the intake ports with a common plenum. Air entered the plenum through a short tube that welded to an adapter plate, which the flame arrestor bolted to. The redesigned intake manifold was simplified from the original prototype, utilizing fewer pieces and joints.

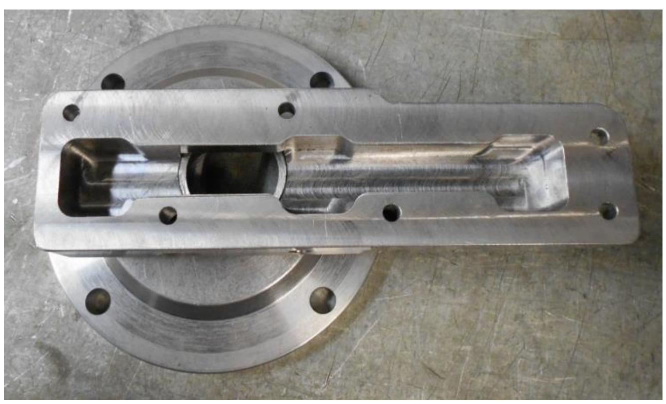


Figure 66 - Intake Manifold Engine Side

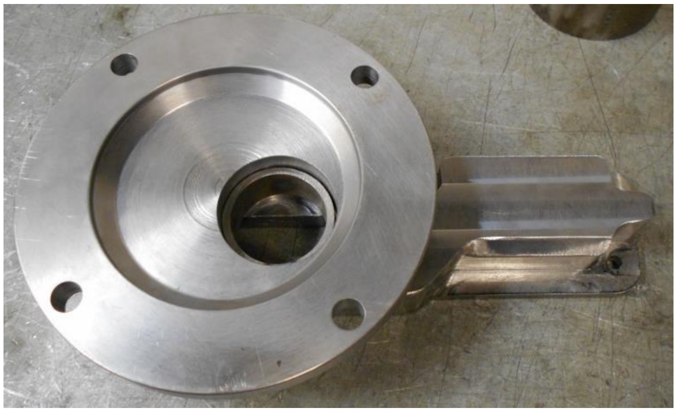


Figure 67 - Intake Manifold Flame Arrestor Side

Figure 68 shows the intake shutdown device and adapter plate on the intake flame arrestor. Initially, copper gaskets were used to seal the bolt flanges of the flame arrestors. Bolting the shutdown device directly to the adapter plate reduced the shutdown device to about half the original size by eliminating the outlet tubing adapter. Along with these changes, the air filter was also relocated. A 90-degree tube connected the air filter housing to the intake shutdown inlet. Access to the air filter was moved to the rear of the machine, instead of the front. To accommodate this change, the fuel tank was moved forward, and the engine control and gage panel was redesigned.

Figure 68 - Intake Shutdown Device

Figure 69 - Intake Manifold Installed on Engine

Figure 69 shows the intake as installed on the engine. The flame arrestor was visible with the intake shutoff valve mounted to the flame arrestor via an adapter plate. Figure 70 shows the reconfigured air filter location and service point on the back of the machine, also visible to the right of the filter was an updated fuel filter / water separator.

Figure 70 – Air Filter Installation

Figure 71 shows the redesigned gauge panel installation, which was near the manual start and override valve actuators. Engine monitoring gauges include the tachometer / hourmeter, engine oil pressure and temperature, engine coolant and exhaust gas temperatures, and intake restriction and exhaust backpressure. Hydraulic pressure gauges were included for the accumulator, safety shutdown system, and pump system pressures. The yellow fuel tank was visible to the left of the panel.

Figure 71 – Gauge Panel

In order to meet MSHA requirements, the OEM engine cooling fan had to be replaced with an anti-static fan. The radiator, and mounting location and size of the fan were also modified to improve the cooling efficiency of the system. Figure 72 shows a picture of the new cooling fan, and additional fan details are shown in Appendix B.

Figure 72 - Cooling Fan

Figure 73 – Cooling Fan Shroud

Figure 73 shows the updated cooling fan mounting. The fan shroud was designed as a bolt together unit that could be removed without disconnecting the radiator or removing other components of the assembly. A fan lowering kit bracket manufactured by the engine OEM was modified to create the new fan mount. To align the fan belt drive, the water pump pulley was modified by cutting the belt sheave away, shortening the backspacing bell material and rewelding the sheave on. The radiator was replaced to alter the inlet and outlet port locations such that hosing to the engine and new exhaust system were simplified.

As mentioned, the size of the MSHA approved alternator required some consideration and design to locate it on the machine. To drive the alternator, a through shaft drive with an auxiliary PTO shaft on an overhung load adapter was used. Figure 74 shows the hydraulic pump with the devices installed.

Figure 74 - Hydraulic Pump with Auxiliary Drive

Figure 75 - Engine Assembly

Figure 75 shows the belt driven alternator and mounting bracket connected to the hydraulic pump, attached to the engine. Also visible was the oil filter; the original prototype used a remote filter mount primarily because of the size of the pneumatic starter. As the hydraulic starter was smaller, the oil filter was returned to the original location on the side of the engine. The modification to the bellhousing pump mount adapter mentioned earlier in the report was also visible in the picture. Figure 76 shows a guard for the alternator belt drive that was designed and installed.

Figure 76 - Alternator Belt Guard

The updated alternator was self-exciting, which simplified the electrical circuit since an excite wire from the battery to the alternator was not needed (which was causing some issues with dropout on the original prototype when switching to alternator power only). The alternator was tested and reliably provided the necessary power to operate the machine, even with no battery attached. This added a degree of service to the machine, that if it can be started manually, the alternator can pick up the electrical circuit and allow for operation even with a depleted battery.

Consultation discussions were held with the Electrical division of MSHA A&CC regarding the battery used on the machine for startup. Moving the battery outside of the explosion proof enclosure was discussed. As mentioned earlier, moving the battery outside of the enclosure would free up valuable space inside of the enclosure volume, and permit access to the battery for removal and/or charging without opening the enclosure. It was mentioned that the contractor should review 30 CFR parts 18, 7, and 75 in reference to batteries and battery enclosures. The battery would need to be housed in a protective enclosure. The standard specification for a battery box was that it be built of a minimum 1/8" thick steel or equivalent. Battery to cable connections were also required to be double secured per these regulations. The battery used on the prototype was a lithium-based battery. The battery would need to be lead acid based to be outside of the explosion proof enclosure. Designers procured an AGM lead battery to develop a new battery setup.

Development of the electrical system involved utilizing approved components wherever possible. Some focus was placed on the xp enclosure that housed the controls, and an effort was made to find an existing approved enclosure that fit on the machine, but none were found. Also, effective use of space was an important design consideration on this machine. Therefore, a revised proposal was designed where the explosion proof enclosure incorporated a battery box on the side. A removable cover was designed for battery access, and the control switches were moved from the lid to the enclosure wall to simplify wiring and improve maintenance access to the enclosure. The cable entry glands were also reconfigured for space saving and wiring simplification. Figure 77 shows a general layout drawing of the proposed electrical enclosure design. The battery box was shown on the right-hand side of the enclosure, the control switch locations were shown on the left-hand side of the enclosure, and the entrance gland locations were shown on top of the enclosure. The electrical enclosure was designed to fit in the same position as the electrical enclosure on the original prototype machine. It was later determined that this design was not feasible and another alternative must be used. Further development of the enclosure is discussed later in this report.

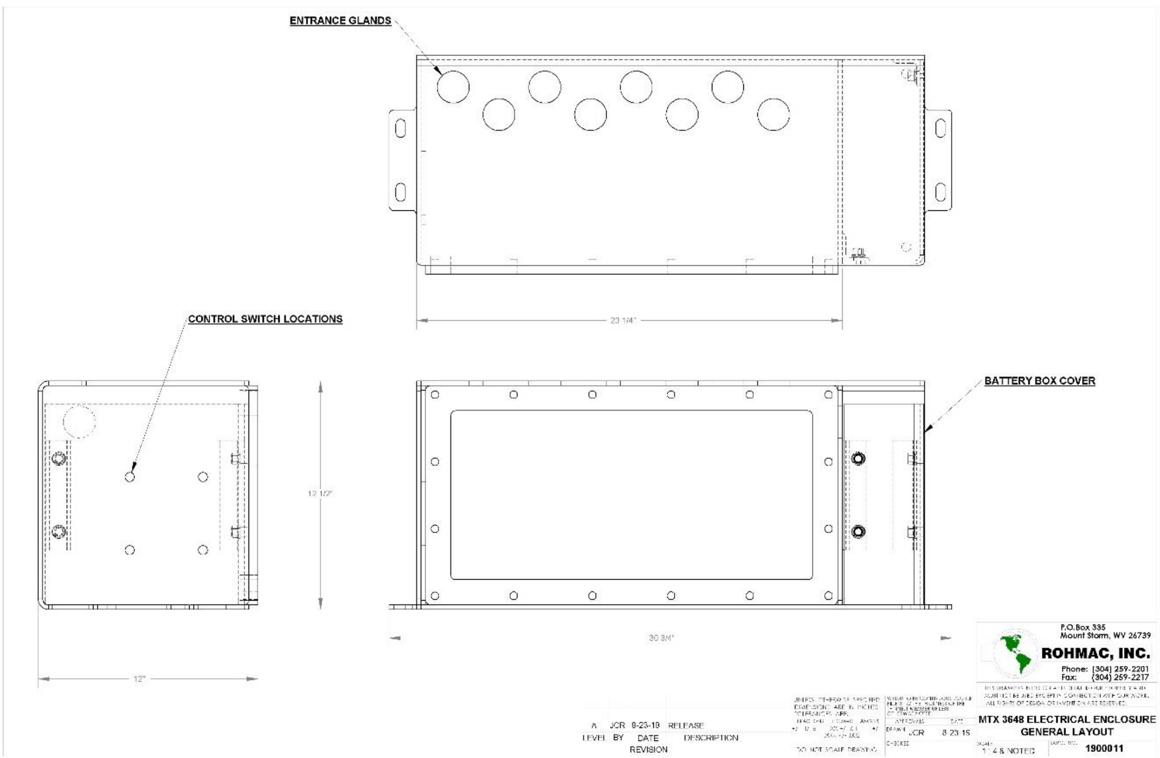


Figure 77 - Electrical Enclosure General Layout

As mentioned earlier, the Manufacturer of the prototype 2.4 GHz radio originally used on the machine, contacted the contractor after the start of this project and stated that they would not be able to produce the permissible radio needed for the machine (as originally intended) unless the radio operated in the 900 MHz frequency band. As this was a design criterion specifically requested by MSHA MEO representatives, the contractor began looking for an alternative.

The manufacturer of another permissible radio remote control system was contacted and the mine rescue machine application was discussed. This manufacturer's system was capable of operating the machine, and it's CAN bus protocol could interface with the PLC on the machine. The manufacturer had also developed wireless range extenders, wireless video componentry, and autonomous LHD controls, and while these products were not permissible, they did interface with the existing radio control products, which opened a possible pathway to developing the autonomous and long-range wireless ability of the mine rescue machine platform.

Unfortunately, the investigation into this alternative radio remote control system was later terminated when the contractor was informed by this manufacturer that they would no longer be able to provide their MSHA approved radio system to the US market. Again, the primary reason for pursuing this alternative was to attempt to find a permissible radio system that would operate outside of the 900 MHz frequency band to avoid any possible interference with the communication system utilized by MSHA MEO. However, there was not a suitable device found that met these criteria, so it became necessary to utilize an approved 900 MHz system built by the original prototype radio manufacturer to move the project forward.

The engineering drawing for the MSHA approved radio remote control system is shown in Figure 78. The system is similar to the prototype radio, with the main difference being the joystick operators. The top center of the figure shows the faceplate with the joysticks. The two left-hand joysticks controlled the tracks, the dual axis joysticks on the right-hand side controlled the loader and PTO / Aux functions.

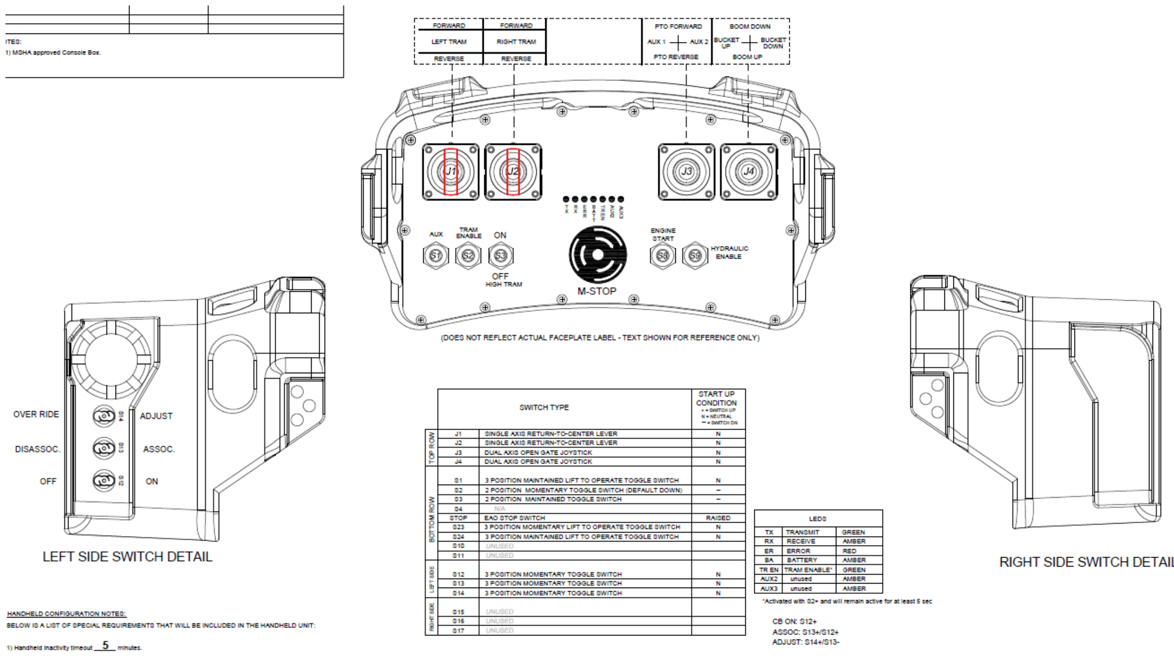


Figure 78 – Radio Remote Control Transmitter Layout

Figure 79 shows an isometric drawing view of the transmitter. The joysticks used on the new radio were the same smaller devices that were reviewed and accepted by mine rescue personnel during demonstrations of the prototype machine. Otherwise, the controller retains the same overall size and function as the original prototype.

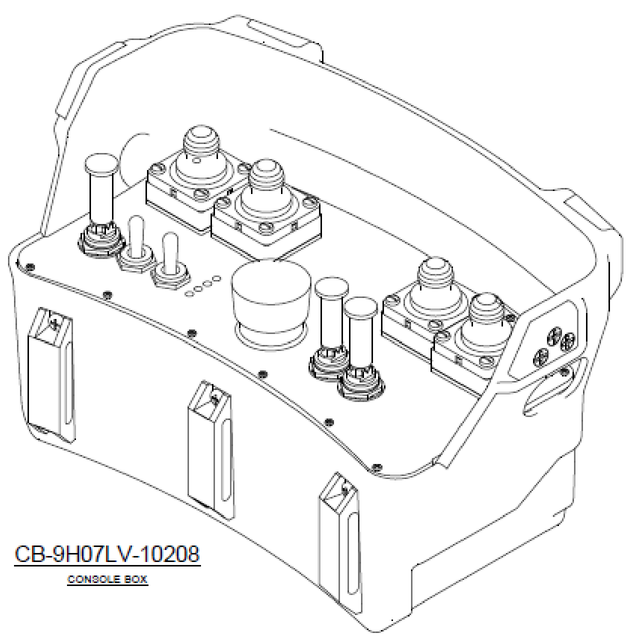


Figure 79 – Radio Remote Control Transmitter

The permissible radio remote control system was ordered in October 2018, Engineering drawings were approved for production in December of 2018, however, due to unforeseen delays, the radio system was not received until May 2019. This was one of several long component lead times that was experienced during the project, which was a contributing factor to the necessity for the extension of the project timeline.

Figure 80 shows the permissible radio control transmitter, and Figure 81 shows the MSHA approval tag on the transmitter. This radio transmitter used a shoulder harness that was anticipated to be more user friendly than the belt harness used on the original prototype version. The shoulder harness also had a break away design that added to safety, whereby if the transmitter were caught and pulled, the harness would break away from the operator, to prevent possible injury. The transmitter was powered by two C-Cell batteries, which provided up to 100 hours of operation.

Figure 80 - Permissible Radio Transmitter

Figure 81 - Radio Transmitter Approval Tag

Another radio manufacturer was later discovered, that offered a radio remote control system with an integrated video component. Upon discussion with the manufacturer, they indicated that they were pursuing MSHA approval for some of this equipment. A meeting was scheduled with this manufacturer on 5 February 2020 to discuss their system and see if it could integrate into the prototype machine, and the possibility of providing an improved system that enhanced one of the original project objectives. During the meeting, it was learned that the system was capable of operating up to 4 cameras and viewing the camera feed on a 4-inch screen on the transmitter. This system had been extensively used in fire-fighting robot applications, and the manufacturer had developed several systems for hazardous areas that require ATEX approval. It was also discussed that these representatives had met with MSHA A&CC representatives on 4 February 2020 to discuss the needs and procedures to develop and approve their system. It was further discussed about the integration of this system with the mine rescue support machine and the desired operating frequency range. Comments were generally positive and the radio manufacturer representatives indicated that they believed that MSHA approval of their equipment was possible and that it would be a good fit for this machine. A follow up phone call from the radio manufacturer was received on 19 February 2020, during this phone call it was indicated that the radio manufacturer was moving forward with pursuit of MSHA approval for their equipment. At the time, a no-cost time extension was requested to allow additional time to evaluate this new radio system, as well as allow time for this system to move closer to MSHA approval. Figure 82 shows a sample picture of the radio transmitter with a camera monitor screen. During a later meeting with representatives of this same manufacturer on 10 June 2022, a new prototype system was displayed with features that operators had requested, for instance, offering joystick control with a tablet interface. The representative also indicated that the manufacturer was still interested in pursuing MSHA approval, but that some other approval work for their systems was taking precedent. As of the date of this report, there has been no indication that the system has been approved for use by MSHA, but at such time that it may be approved in the future, it would merit consideration for use on the mine rescue machine, as it appears to offer several of the features that were requested by the mine rescue community.

Figure 82 - Stock Photo of Radio Transmitter

A new design was also developed to consolidate the location of the major components of the fire suppression system. They were mounted to a removable shelf which facilitated maintenance and access to the machine. Figure 83 shows the new fire suppression system assembly, located in the area previously used for the air tank.

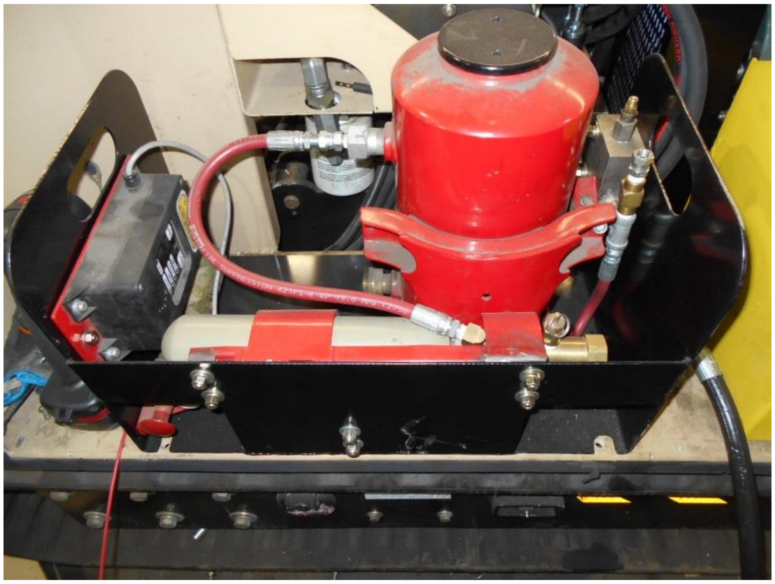


Figure 83 - Fire Suppression System Components

APPROVAL PROCESS CHANGES

On 23 Sept 2019, MSHA issued a letter indicating a policy change in the evaluation process for approval applications. In the past, approval applications submitted to MSHA would be reviewed, and any discrepancies found would result in a discrepancy letter to the applicant requesting revision or correction to the application, and if no corrections or revisions were received, the application would be canceled. This process could be ongoing through an approval process, and multiple discrepancy letters could be issued on an application as evaluators might find new additional, or previously unreported discrepancies in an application. MSHA deemed it necessary to change this process to improve the efficiency and effectiveness of the review process. The indicated policy change was to perform a complete application review and issue either an approval or disproval, with no discrepancy letters for correction requests. The letter of disproval was to contain a complete list of any discrepancy found, and the applicant could then resubmit the application to start the evaluation process again. This policy change increased the value of utilizing the consultation process prior to formally submitting an application for approval. It was therefore the prudent to utilize the consultation process with MSHA on the applications for this machine to avoid a discrepancy that would jeopardize the approval. The memo describing this change is shown in Figure 84.

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

September 23, 2019

MEMORANDUM FOR APPROVAL APPLICANTS

FROM: DENNIS FERLICH
Chief, MSHA Approval and Certification Center

SUBJECT: Approval Application Evaluation Process

MSHA has recently received many comments regarding the approval process in place for processing applications from equipment manufacturers. To address your concerns we are instituting changes to improve the efficiency and effectiveness of the application review process.

Effective October 1, 2019, the Approval and Certification Center (A&CC) will no longer continue the current practice of issuing multiple discrepancy letters for individual approval applications. After an applicant approves a fee estimate, we will conduct a thorough review of the complete application and conduct or observe any required performance tests. If we do not find any discrepancies and your product passes the performance tests, we will issue you an approval.

If we find discrepancies or your product fails the required performance tests, we will issue a letter of disapproval and provide a full list of discrepancies and/or test failures. The disapproval letter will state, "Your application has been canceled for failure to meet the requirements as detailed in the enclosed list of discrepancies. You may reapply after discrepancies have been addressed. Your application will be treated as a new application, and the order of precedence for investigation and testing will be based on the date you resubmit your application."

These changes in procedures will improve the efficiency and effectiveness of our approval application evaluation process. It will also result in quicker assignment and review of all applications, ensure equal and fair treatment of all applicants, and place a higher level of responsibility on the applicants to provide complete and accurate initial packages. We will no longer be providing multiple reviews and repeated feedback on applications.

The A&CC offers free consultation prior to submission of an application where you may discuss your proposed design and obtain assistance in understanding the approval application evaluation process. We recommend that you take advantage of this free service to help you avoid making common errors that we typically find during the technical evaluation process.

Figure 84 - Approval Process Change Memo

Later, on 21 November 2019, another memo was issued to clarify the policy change. In this letter, it was indicated that MSHA would contact applicants to provide an opportunity for corrections and clarifications for minor discrepancies, and that there would be a specified time frame for an applicant to provide these revisions before an application was canceled. Figure 85 shows a copy of this clarification memo.

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

November 21, 2019

NOTICE FOR APPROVAL APPLICANTS

Clarification of Approval Application Evaluation Process

On September 23, 2019, we sent notice to you and other current approval applicants about proposed changes for our approval application evaluation process. The primary change was to establish a new cancellation policy to streamline the processing of applications and allow new applications to be reviewed more promptly and to not extend the process indefinitely.

We received feedback suggesting to us that additional clarification was necessary. The primary concern expressed was that there was no opportunity for manufacturers to provide additional information in response to the discrepancies prior to cancellation of the application.

For approval reviews where minor discrepancies are identified, our staff will contact you to discuss necessary changes. We will determine a reasonable period of time, based on the nature of the discrepancies, to allow applicants to submit changes and modifications to correct discrepancies. Because the complexity of the applications vary, this time period will be determined on a case-by-case basis. If discrepancies are not corrected within the time period allowed, your application will be canceled.

We appreciate your feedback and look forward to providing the opportunity to all applicants to participate in the product approval process. Thank you for expressing your concerns and giving us the opportunity to improve the efficiency and effectiveness of the application process and to work with you to improve the safety and health of miners.

Sincerely,

Dennis Ferlich
Center Chief
MSHA Approval and Certification Center

Figure 85 - Clarification of Approval Application Evaluation Process

PRELIMINARY APPROVAL APPLICATION REVIEWS

A preliminary draft of the diesel power package approval application was developed and shared with representatives of MSHA A&CC for initial review. Discussion over the design was ongoing, and some minor revisions were performed. The application consisted of a request letter, a list of drawings, specifications of critical components such as shutdown devices, air filter, cooling fan, general layout and detail drawings of the power package, intake and exhaust systems, cooling system, safety shutdown system and a permissibility checklist. The permissibility checklist was a document that specified a periodic inspection which must be performed by the operator to maintain the permissible status of the machine, and consisted of weekly checks of flame arresting paths and critical joint areas on the power package.

During some preliminary evaluation, an item in the permissibility checklist needed addressed. As stated, the purpose of the inspection was to ensure the permissible integrity of the machine, and particularly that any flame proof joints were maintained. A required weekly checklist item was to check that the exhaust manifold bolts were tight. The particular design of the prototype exhaust system did not provide for direct access to the manifold bolts, which would make this check difficult and time consuming. Therefore, alternative methods of ensuring the integrity of the exhaust manifold fasteners were discussed with MSHA representatives, and it was mentioned that a locking device on the manifold fasteners to prevent loosening combined with a weekly check of the joint with a feelers gage would satisfy this requirement. Designers reviewed available devices and changed the manifold design to use locking devices manufactured by Stage 8 locking fasteners, to secure the manifold nuts.

During this time, the contractor was notified that MSHA needed to contact the engine OEM to offer them the opportunity to submit a design for an A-plate rating before proceeding with assigning an A-plate to a power package manufacturer. The OEM responded with an initial interest in pursuing the A-plate approval. This process caused some delay in moving forward with the diesel power package application process.

Concurrently, a preliminary diesel electric approval application was also developed. Like the diesel power package approval, the application consisted of an approval request letter, list of drawings, general layout drawing, schematic drawing, system bill of materials, individual component specifications and drawings, and a permissibility checklist. The draft electrical application documents were sent to the MSHA A&CC electrical division and a consultation meeting was requested.

MSHA A&CC MEETING 31 OCTOBER 2019

A meeting was held at MSHA A&CC, Triadelphia, WV, on 31 October 2019 at 10:00 am. Eight representatives of the Electrical and Mechanical divisions of MSHA A&CC met with representatives of ROHMAC INC to discuss the proposed machine design, the approval process, and preliminary application paperwork. The contractor presented two draft copies each of the diesel power package application and the diesel electric application information, for MSHA consultation review.

The meeting began with an overview of the machine function and purpose, and a basic explanation of the design. Three-dimensional computer-generated models of the machine and diesel engine power package, as well as photographs of certain components were shown via projector as visual aids during the discussions. The first design feature discussed was the on-board battery used to power the radio remote control system and energize the hydraulic valve coils to provide for remote engine start. The use of the battery to power the on-board controls, necessary to operate the safety system, override, and engine start features remotely until the alternator generates power, were explained. It was further explained that the current design isolated the battery from alternator power to prevent battery charging on-board the machine. It was discussed that hydrogen gas liberating from a battery was of primary concern and could not be permitted in a permissible environment.

The proposed design of a battery external to the XP enclosure was discussed. It was mentioned that any battery would need to be assembled in an enclosure, and that for a standalone battery it would either need to be designed as intrinsically safe, with a limiting resistor that reduces available current output to a maximum of 1A, or meet Part 18 requirements, which include a battery box with minimum 1/8” steel plate, lined with insulating material, and a plug connector that meets Part 18-41. A new battery assembly would also need to have its own separate approval. A scenario of changing a battery or transporting a battery through the mine was discussed as one of the reasons the approved enclosure assembly was needed. Discussion continued on battery arrangements and design requirements. A few of the points mentioned are listed below:

- The maximum cable length from the Battery to the XP enclosure and overcurrent protection device was 36 inches. The cable connection to the battery posts must be double bolted connections and protected with an insulator from contacting any metal surfaces such as the lid of the battery box.
- The battery cable sizing and current protection device may be sized based on the expected load of the down line circuit.
- Whereas the primary concern of battery charging is hydrogen gas release, it could be possible that a battery that would not give off hydrogen gas during the charging cycle may be charged on board the machine, further, batteries such as AGM that are sealed to prevent hydrogen gas release could possibly

be charged on board the machine, if a hydrogen gas sensor was installed, that would deenergize the charger and all circuits if hydrogen gas were detected.

- Alternative battery chemistries, such as Nickel or Lithium base, were discussed. While they did not tend to release hydrogen during charging, some required special charger features and protective circuits to prevent overcharge and overheating breakdown that can occur. It was specifically mentioned that large format Lithium based batteries would need a battery management system, and that any battery cells would need to meet the UL 1642 standard. It was also mentioned that if these batteries are located inside of an XP enclosure, that the volume of the battery could not exceed 10% of the free internal volume of the enclosure.

After discussion on the battery, focus shifted to the XP enclosure that housed the machine controls. It was mentioned that an approval evaluation for a new enclosure would add a substantial amount of time requirement to the overall approval process. Designers had been attempting to locate an enclosure with an existing approval that fit the space requirements of this machine. At that time, a suitable candidate had not been found, and it was determined that if an existing enclosure design could not be used, that it would be necessary to proceed with an approval application for the enclosure for this machine. Common pitfalls and failures in enclosure design were discussed, and it was mentioned that flame paths such as plane flanges, gland fits, and clear polycarbonate covers tend to experience failures during testing. Printed copies of Standard Application Procedure documents that contain details on the requirements for battery and xp enclosure applications were provided to the Rohmac representatives by MSHA.

Other electrical apparatus on the machine were discussed such as the function valve coils, the alternator, lights, camera housings, and radio remote control system. As these components were already approved or under evaluation for approval, they required no separate approval from the diesel electric system evaluation. The antenna isolator used for the radio remote control system was discussed and the print of the device was reviewed. This led to a question about wireless data transmission and the interest in transmission of video data from the machine and/or extended wireless control of the machine. It was mentioned that a similar isolator to any external antenna should allow such a device to meet permissible requirements. It was also discussed that the transmission power of the unit could not exceed 5 watts, and that a concern with any transmission source was the possibility of unintentionally setting off explosive devices in the mine. This sometimes required a placard fixed to the machine dictating that it must be at least 50 feet from any area where said devices are located.

After reviewing the electrical design, a rough timeline estimation for an approval was discussed, it was expected that review of the application drawings and design could be 3 months, and that if the XP enclosure requires approval, that the process for it alone could be 6-8 months.

Discussion shifted to the diesel power package. The design of the engine cooling system was reviewed, and it was mentioned that the expansion reservoir would need to be the high point of the system. The hydraulic start and safety control circuit was discussed, as well as the location of components on the power package. A point of caution was mentioned, that cold hydraulic oil could present a problem to the function of the safety shutdown circuit and cause added delay to the shutdown time, which was limited to 15 seconds after activation of a shutdown device. The exhaust system design was reviewed and the passage of exhaust gasses through the system was explained, as well as the oxidation catalyst and particulate filter. It was mentioned that with these devices installed, altitude deration of the engine was not likely to be required by MSHA. Discussion was also held regarding the engine A-plate, in which is the ventilation rate for the engine is specified. It was mentioned that the engine manufacturer had expressed an interest in applying for and owning the A-plate when they were contacted, and that this could affect the approval process. Whereas the design of this power package would alter emissions from the original non-permissible engine approval, it was speculated that it could be possible to issue two A-plates for the engine, one for this design and one to the engine OEM should they follow through with a separate design. MSHA requested that the diesel power package application not be submitted immediately to allow time to sort out the solution for the engine A-plate. It was stated that the diesel power package design seemed likely to meet all approval requirements, and that the evaluation process could be done within a couple of months once started. It was mentioned that coordinating the power package evaluation and electrical evaluation timelines to finish at nearly the same time would be desirable.

A brief discussion was held on the fire suppression system and the coverage requirements, it was stated that due to the compact size of the machine, only a couple of nozzles should be necessary to cover all the necessary components.

At the end of the meeting, the approval requirements for this machine were discussed. The machine would need a part 36 approval, which is an overall approval including the major components such as the power package and electrical system. The

Diesel power package must be approved, which also required the A-plate approval for the engine. The Diesel Electric system must be approved, which is the sum of the electrical components on the machine. The XP controller enclosure must be approved, either from an existing approved enclosure, or a new design submitted for evaluation. Any external battery must be approved as a battery assembly. It was stated that depending on the final design, this machine could require 4-6 approval evaluations. It was mentioned that the XP enclosure should be approached with the highest priority as it would dictate much of the timeline requirement for other approvals. The meeting was adjourned at 12:00 pm.

There was discussion between the contractor and CDC NIOSH representatives on project status after this meeting. With the preliminary application documents under review by MSHA, it was determined that the project could transition past Phase II. Therefore, an interim report was submitted. Work done after this report focused on the approval application documentation and necessary revisions, with the goal of documentation being ready to formally submit for evaluation by the end of this project. Following the Phase II Interim Report, the contractor and CDC NIOSH discussed the approval timeline and agreed to a three and one-half month No Cost Time Extension for this contract, to allow additional time to work through some of the unexpected delays encountered with the approval process, including the time requested by MSHA to determine a solution regarding the A plate approval for the engine.

EXPLOSION PROOF ENCLOSURE DEVELOPMENT

After the Triadelphia meeting, work focused on finding a suitable explosion proof electrical enclosure, and selecting a battery suitable for the machine. Several enclosure manufacturers were contacted to request quotes on an enclosure that met the dimensional requirements of the machine. In addition, a vendor / manufacturer with experience approving enclosures was contacted, and if no suitable approved enclosure was found, this vendor indicated that they would be able to offer a quote to design, build, and approve a new enclosure; which was thought to be a way to simplify and expedite the process as compared to performing the work in house. After discussions with several manufacturers of enclosures, no suitable existing enclosure was found that fit the envelope of the prototype machine. Preliminary concept drawings were received from two vendors for the custom fabrication of an approved xp enclosure. Upon receiving a formal proposal, the quoted price of the fabrication with the approval testing needed was significant, with the cost of approval exceeding over half of the budgeted approval fees for the project. With this proposal being deemed cost prohibitive. The decision was made to design and build the permissible enclosure in-house. The enclosure design not only required meeting the needs and size constraints for the mine rescue machine, but also needed to satisfy criteria established by 30 CFR part 18. There were several publications on MSHA’s website meant to assist with design and application development, by clarification of code requirements, as well as testing procedures and documentation protocols. Designers also periodically discussed the enclosure with MSHA representatives during the design process. Figure 86 shows a preliminary drawing design proposal for electrical enclosure assembly. This design no longer included a battery compartment, after discussions held at the meeting on 31 October 2019, the design was changed to place the battery inside of the enclosure.

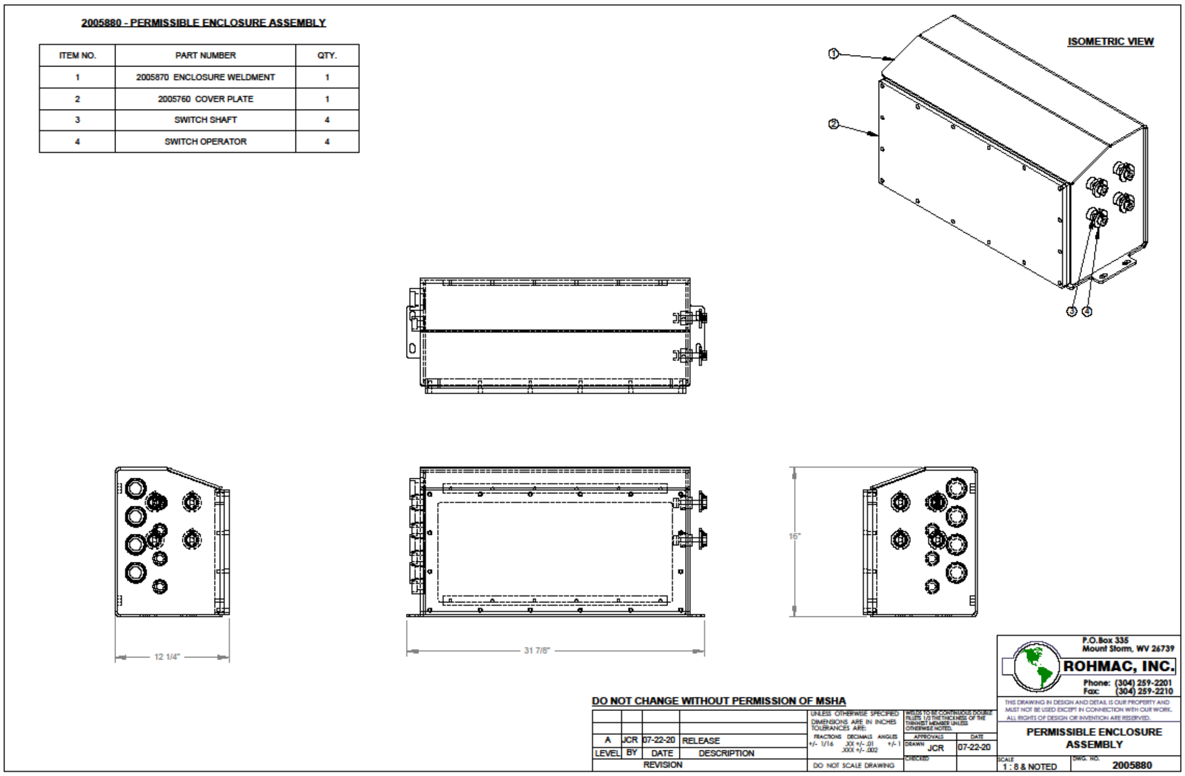


Figure 86 - Electrical Enclosure Assembly

This electrical enclosure was designed to bolt on the machine beside the exhaust treatment system. The four control switches were shown toward the front of the machine, the eight gland entrances were toward the exhaust system, and the lid opened toward the side. The enclosure measured approximately 16 inches tall by 32 inches wide by 12 inches deep. The top of the enclosure was angled toward the front to create clearance for the side covers on the machine. Moving the switches to the side of the enclosure simplified maintenance by allowing the cover to be completely removed without the need to handle the switch wiring. Relocating the cable entrances to the side of the enclosure instead of the back allowed more clearance for the hydraulic control valves, and helped organize the available internal volume for the enclosure components. A minor modification to the machine was necessary to mount the new enclosure; the hydraulic hand pump used to manually charge the accumulator was relocated. The following figures are additional preliminary drawings showing details of the enclosure components.

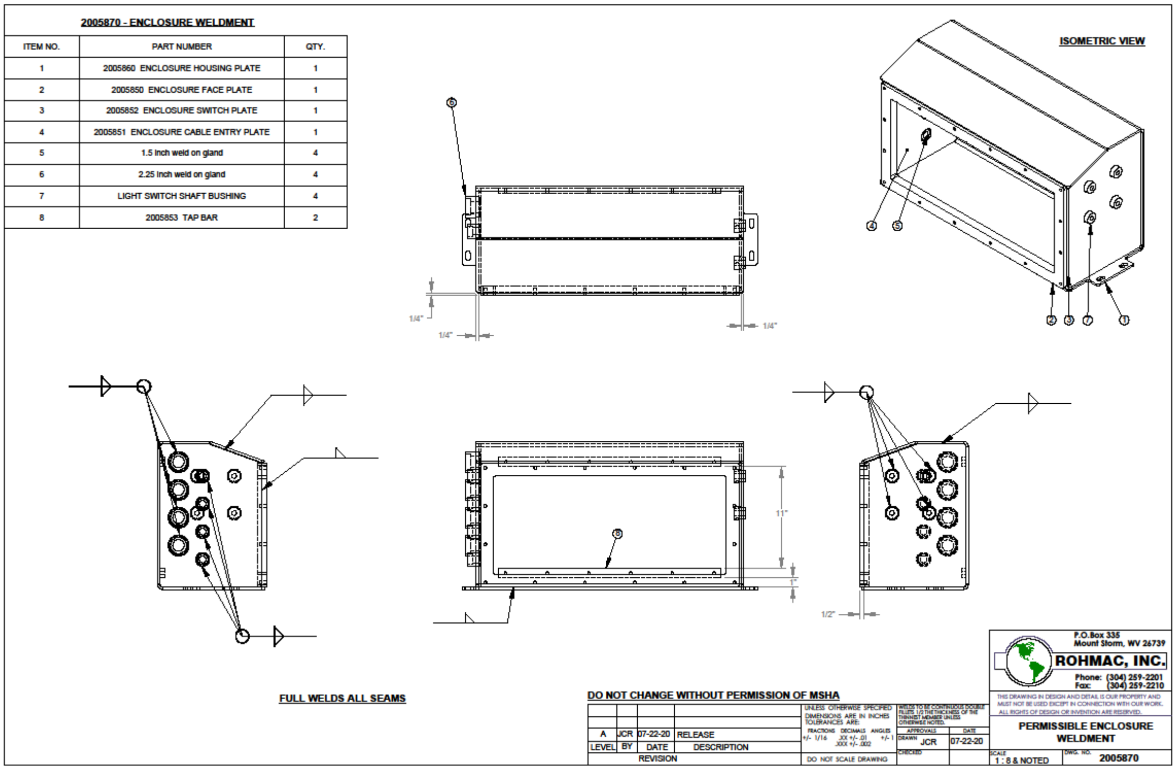


Figure 87 - Electrical Enclosure Weldment

Figure 87 shows the electrical enclosure weldment. All exterior seams on explosion proof enclosures were required by MSHA to be fully welded. The walls of the enclosure were initially proposed to be made of ¼” steel, which was listed as a minimum thickness requirement by MSHA based on the volume inside of the enclosure. Weld-on glands and bosses were used to create the electrical cable entrances, and the external switch operator assemblies. Two bars with tapped holes were welded to the back wall inside of the enclosure to mount panels which hold internal components. Figure 88 shows the aluminum cover for the redesigned enclosure. The cover formed a plane flange with the enclosure, and surface finish requirements must be met for the flame path as shown.

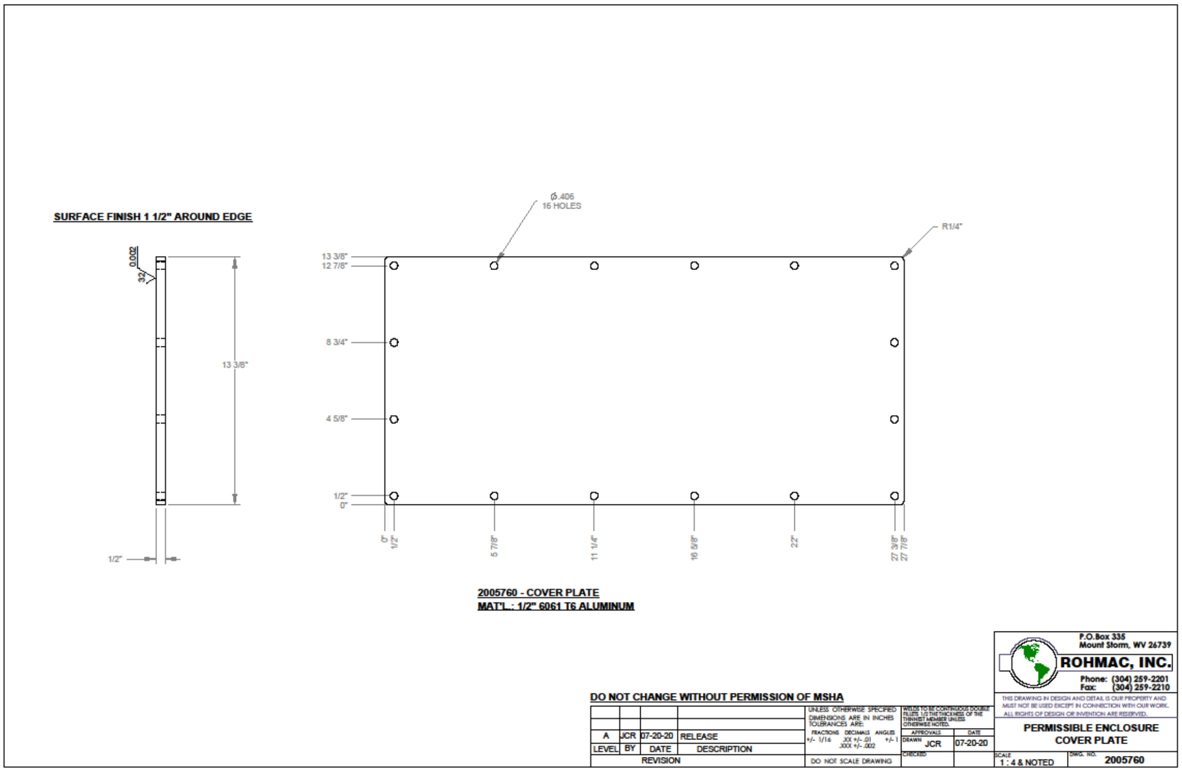
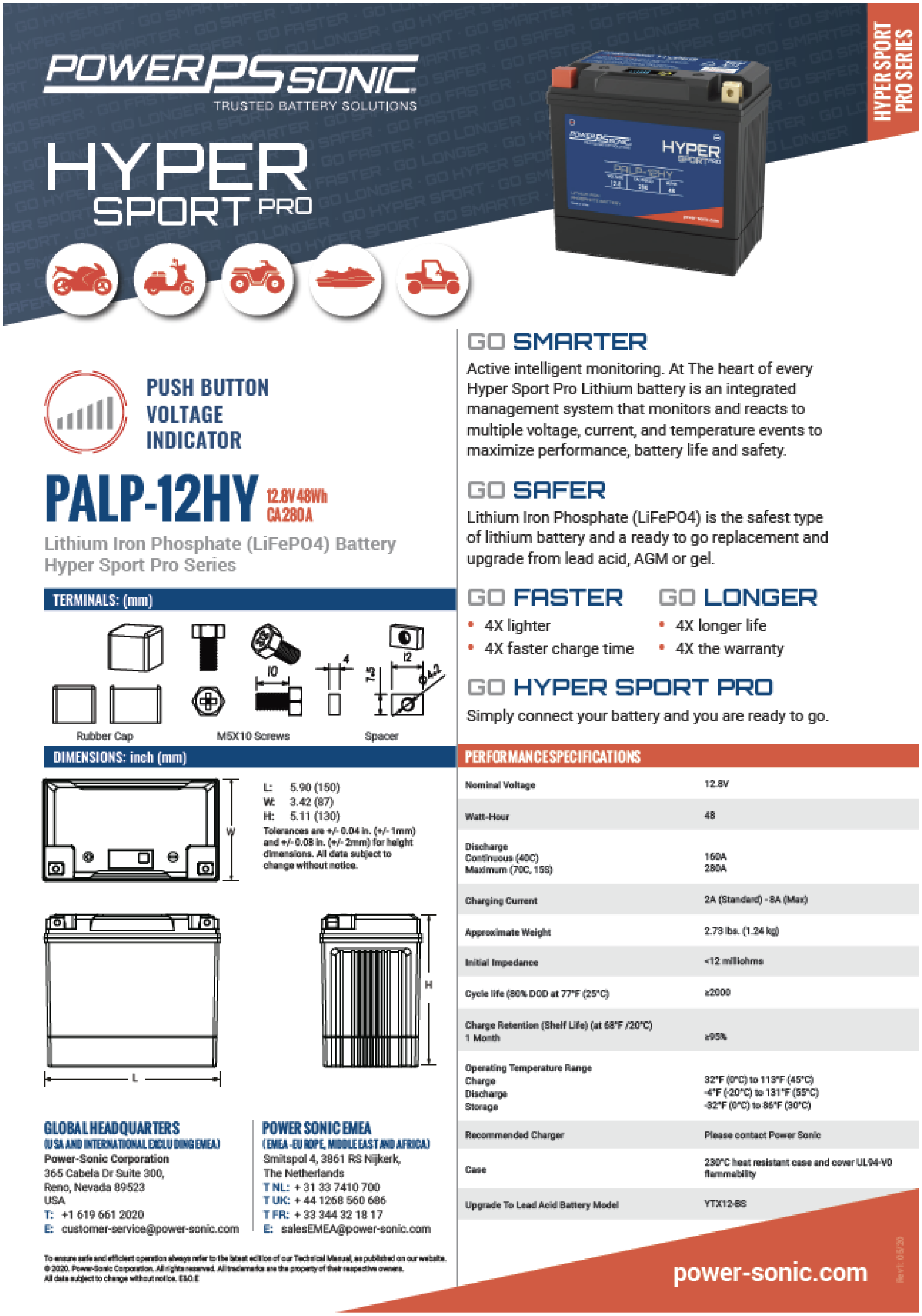


Figure 88 - Electrical Enclosure Lid

Given that the decision was made to move the battery inside of the explosion proof enclosure, and following the discussion with MSHA representatives on 31 October, research was conducted on batteries. Review of available battery technologies and commercially available components revealed that there were Lithium-based batteries used on motorcycle and powersports equipment, that were designed to be charged by the engine driven alternators / generators on these machines. The batteries used Lithium Iron Phosphate (LiFePO4), which was considered the safest lithium-based battery available at that time, and they also had built-in management systems to monitor and react to voltage, current, and temperature events, to protect the battery and maintain safe operation. These batteries used Iron as a cathode material and were not as prone to thermal runaway as Lithium Cobalt Oxide, or other Lithium-ion battery chemistries.

Figure 89 shows a specification flyer for a subject battery built by a reputable manufacturer. A discussion with this manufacturers technical support personnel indicated that the battery cells had been tested to, and met UL requirements, and that the manufacturer was awaiting the official certification at that time. It was requested that the manufacturer forward the listing certification information when it became available. It was proposed that this battery be placed on the clean power side of the power supply, which may have also made it possible to recharge from alternator sourced power with the engine running. The compact size of this battery was important, given the volume restriction previously mentioned by MSHA. The approximate volume of this battery case was 103 cu in and it weighed 2.73 lb. Lithium-based batteries provided more power density for size as compared to other available battery chemistries at that time. This 12-volt battery was rated at 48 Wh with an available maximum discharge output of 280 A. The operating temperature range of this battery also appeared to fit well with the typical underground mining environment.

As mentioned previously, discussions with MSHA representatives were common during the design process of the new explosion proof enclosure. Initial drawings were reviewed and some general comments were received. After revising the design, the next step was to send the drawings to MSHA and request a preliminary review.



POWER PS SONIC
TRUSTED BATTERY SOLUTIONS

HYPER SPORT PRO

HYPER SPORT PRO SERIES

PUSH BUTTON VOLTAGE INDICATOR

PALP-12HY

12.8V 48Wh
CA280A

Lithium Iron Phosphate (LiFePO4) Battery
Hyper Sport Pro Series

TERMINALS: (mm)

DIMENSIONS: inch (mm)

L: 5.90 (150)
W: 3.42 (87)
H: 5.11 (130)

Tolerances are +/- 0.04 in. (+/- 1mm) and +/- 0.08 in. (+/- 2mm) for height dimensions. All data subject to change without notice.

GO SMARTER

Active intelligent monitoring. At The heart of every Hyper Sport Pro Lithium battery is an integrated management system that monitors and reacts to multiple voltage, current, and temperature events to maximize performance, battery life and safety.

GO SAFER

Lithium Iron Phosphate (LiFePO4) is the safest type of lithium battery and a ready to go replacement and upgrade from lead acid, AGM or gel.

GO FASTER

- 4X lighter
- 4X faster charge time

GO LONGER

- 4X longer life
- 4X the warranty

GO HYPER SPORT PRO

Simply connect your battery and you are ready to go.

PERFORMANCE SPECIFICATIONS

Nominal Voltage	12.8V
Watt-Hour	48
Discharge Continuous (40C) Maximum (70C, 15S)	 160A 280A
Charging Current	2A (Standard) - 8A (Max)
Approximate Weight	2.73 lbs. (1.24 kg)
Initial Impedance	<12 milliohms
Cycle life (80% DOD at 77°F (25°C)	≥2000
Charge Retention (Shelf Life) (at 68°F /20°C) 1 Month	≥95%
Operating Temperature Range Charge Discharge Storage	 32°F (0°C) to 113°F (45°C) -4°F (-20°C) to 131°F (55°C) -32°F (0°C) to 86°F (30°C)
Recommended Charger	Please contact Power Sonic
Case	230°C heat resistant case and cover UL94-V0 flammability
Upgrade To Lead Acid Battery Model	YTX12-BS

GLOBAL HEADQUARTERS
(USA AND INTERNATIONAL EXCLUDING EMEA)
Power-Sonic Corporation
365 Cabela Dr Suite 300,
Reno, Nevada 89523
USA
T: +1 619 661 2020
E: customer-service@power-sonic.com

POWER SONIC EMEA
(EMEA - EUROPE, MIDDLE EAST AND AFRICA)
Smitspol 4, 3861 RS Nijkerk,
The Netherlands
T NL: + 31 33 7410 700
T UK: + 44 1268 560 686
T FR: + 33 344 32 18 17
E: salesEMEA@power-sonic.com

To ensure safe and efficient operation always refer to the latest edition of our Technical Manual, as published on our website.

All data subject to change without notice. E&O.E

power-sonic.com

Figure 89 - Lithium Battery Specification Sheet

On 22 Oct 2020, a consultation meeting was held via video conference with representatives of MSHA A&CC, along with representatives from CDC NIOSH and Rohmac Inc. The discussions during the meeting were to explain the concepts and design of the mine rescue prototype machine, specifically the electrical system and approvals for the machine electrical system and the explosion proof enclosure, and to discuss the approval process and any recommendations. Particular items of interest were the radio remote control and hydraulic valve control systems, the battery used to initially power the control system for startup, and the explosion proof enclosure.

The approved radio control transmitter was shown to meeting participants, and it was explained that the machine required an on-board battery for initial startup, until the alternator became the main power source. The control system of the radio communicating to the PLC, which drove the necessary outputs for machine control was explained. Particular questions were raised regarding the valve solenoids and the connection blocks for the solenoids, a picture of the apparatus was requested, and was later sent to MSHA. It was also stated that any radio antenna outside of the explosion proof enclosure must be made intrinsically safe by design or through a barrier. The approved barrier used on this machine was described. Battery composition and chemistry was discussed, and a representative battery was displayed. It was explained that designers wished to use a Lithium Iron Phosphate (LiFePO4) powersports battery built by a reputable manufacturer on this machine; reasons cited included: compact size as compared to other battery chemistries for the same amount of power, industry trend toward use of the LiFePO4 battery for future availability, the powersports batteries were designed to be in circuit with an engine driven alternator / generator, and they had built-in safety controls for over- and under-voltage conditions. It was also mentioned that recharging the battery from alternator voltage was desirable, and that the power supply should control the voltage to prevent battery damage. One key feature of Lithium compared to Lead-acid batteries was that Lithium was much less likely to liberate Hydrogen gas during charging, which was a stated safety concern from previous discussions. There were, however, safety concerns involving Lithium batteries as well, since excessive heat had been shown to cause breakdown. It was mentioned that any lithium battery used underground must meet UL 1642 or 2054 to be considered for this application. It was also clarified that designers intended to locate the battery inside of the explosion proof enclosure; earlier discussions of developing a separate battery enclosure had been cause for some confusion among meeting participants. The presence of the battery raised questions as to whether or not a master disconnect / emergency stop would be needed, typically this was required on electrically powered equipment; as this was a diesel-powered machine though, power removal was typically achieved by engine shutdown.

Discussion moved on to the explosion proof enclosure design, and it was stated that a brief review found some small discrepancies that needed to be corrected, and it was mentioned that the material thickness seemed thinner than other enclosures of similar size. MSHA representatives agreed to take a closer look at the application and drawings and report discrepancies to Rohmac. An e-mail from MSHA representatives containing comments and recommendations was later received.

A request was made to estimate the time requirements for the approval process. It was stated that the enclosure approval should be give the first priority as it was a necessary component for the Diesel Electric Approval, and that enclosure approvals typically took at least 6 months to complete. The Diesel Electric Approval was estimated at 3 months once the enclosure was approved. For these reasons, a no cost time extension was requested to extend the project 12 months to 31 December 2021, which was granted.

A request was also made to estimate the approximate costs for the approvals, the enclosure approval was estimated at $28,000.00, and the Diesel Electric $10,000.00. An estimate for the diesel power package approval had been previously discussed and was expected to be approximately $20,000.00. At the conclusion of any further questions and comments, the meeting was adjourned.

On 26 October 2020, MSHA sent an email describing items found in the drawings after a brief review. It was mentioned that these items did not cover all discrepancies, but should assist in revising drawings prior to submitting the approval application, the list of items contained in the email were as follows:

- Lock washer thickness with tolerances need to be added. This is needed to calculate minimum thread engagement.
    - Typically flat washers are used under lock washers when the cover is aluminum. You are not required to use flat washers but the lock washer tend to bite into the aluminum cover damaging it when flat washers are not present. If you do choose to use flat washers the thickness with a tolerance of the lock washer must be included on drawings.
- The drawings which you included for the shaft and glands are other companies drawings. I believe these are components which are on file with MSHA (the few we checked appear to be at least).

The way these parts need to be shown on your drawings is you need to point to the components (possibly make each of them an Item #), and the description of the item and to See “COMPANCY XYZ Drawing No. 12346789”. Basically the component call outs must be listed on your drawings so we know what drawings to go look for in our system.

- Example of your certification plate, with material and thickness specified must be shown on the drawing. The certification plate must have at minimum the information listed in 30 CFR Section 18.13 . https://www.ecfr.gov/cgi-bin/text-idx?SID=68383ef8f2d8762e9ce2d8a9af8841b0&mc=true&node=se30.1.18_113&rgn=div8
- Maximum chamfers must be specified on the internal/external side of the flange and on the edge of the cover. If no chamfers are included then a note is needed to document there are no chamfers.
- The “deburr” of the fastener hole must document the maximum size/chamfer because this will be deducted from the minimum “edge of bolt hole to interior” calculation.
- When using your general tolerance on the cover fastener thru hole, you do not meet the required maximum diametrical clearance as listed in Section 18.31(a)(6) maximum allowable 1/16”.

  (0.406” + 1/16” tolerance) – (3/8” fastener) = 0.935” > 1/16” maximum allowable clearance

- The wall thickness (cable entry plate and housing plate) is listed as ¼" (+/- 1/16" general tolerance) this does not meet our minimum requirements as listed in 30 CFR Section 18.31(a)(6) due to the tolerance.
    - Please note that the minimum requirements are just a "required minimum" for steel plate. Typically enclosures similar in size to your design have wall thicknesses which are greater than the minimum ¼".
- The cover thickness is listed as ½" (+/- 1/16" general tolerance) this does not meet our minimum requirements as listed in 30 CFR Section 18.31(a)(6) due to the tolerance.
    - Please note that the minimum requirement of ½" is for **standard steel plate**. Since you are using **aluminum** it is expected that the aluminum cover is required to be designed to be equivalent as a ½" steel plate. Typically for enclosures similar in size to your design aluminum covers tend to be greater than ½" thickness.
- **Wall Thickness, Cover Thickness, and Bolt Spacing** – Please note that we will accept and test a minimum ¼" wall, ½" cover thickness and maximum bolt spacing of 6" (your spacing isn't 6" but it's on the larger spacing side that we typically see with 3/8" fasteners).

  We know you are new to designing explosion-proof enclosures for evaluation so we just wanted to let you know that a lot of the time the enclosures to be designed beyond the requirements minimum/maximums. Also please note that when explosion testing we will check for permanent deformation and if the enclosure deformed > 0.040" per linear foot the test will be deemed a failure.

- Your drawings must call out all other drawings where the parts are located. This would need to be done to the Weldement and Cover plate drawing. Additonally all drawings besides Drawing 2005880 (your main drawing) must have a note to refer back to the main drawing…Drawing 2005880.

  See example below from Drawing No. 2005880

ITEM NO.	PART NUMBER	QTY.
1	2005870 ENCLOSURE WELDMENT See Drawing No. 2005870	1
2	2005760 COVER PLATE See Drawing No. 2005760	1
3	SWITCH SHAFT	4
4	SWITCH OPERATOR	4

Figure 90 - Parts List Table from Drawing with Suggested Revision

The discrepancies mentioned in the e-mail covered items ranging from dimension tolerances with respect to required minimums, references and cross-references for parts and drawings and how to identify components sourced from other OEM entities, an approval tag drawing needed to be included, and we were advised that while the proposed material thicknesses met the minimum requirements as listed by MSHA in 30 CFR, that enclosures of this size tend to use thicker material. Revisions were made to the drawings and they were emailed the MSHA representatives on 10 November 2020 for review.

On 17 November 2020, MSHA representatives emailed additional findings from the revised documents. A video conference meeting was planned for 24 November 2020 to discuss the drawings. The email mentioned that revisions to dimensional tolerances were in an acceptable format, and designers were also cautioned to not specify tolerances that were too restrictive to effectively manufacture the enclosure. The following lists the other items mentioned in the e-mail:

- Lock washer thickness needs tolerance added or general tolerance will be used.
- Using a 1-1/8” long fasteners. You do not meet the minimum ½” required thread engagement. You will use Max LW Thickness, Max Flat Washer Thickness and Max Cover Thickness to determine minimum thread engagement.
- Cover Thickness

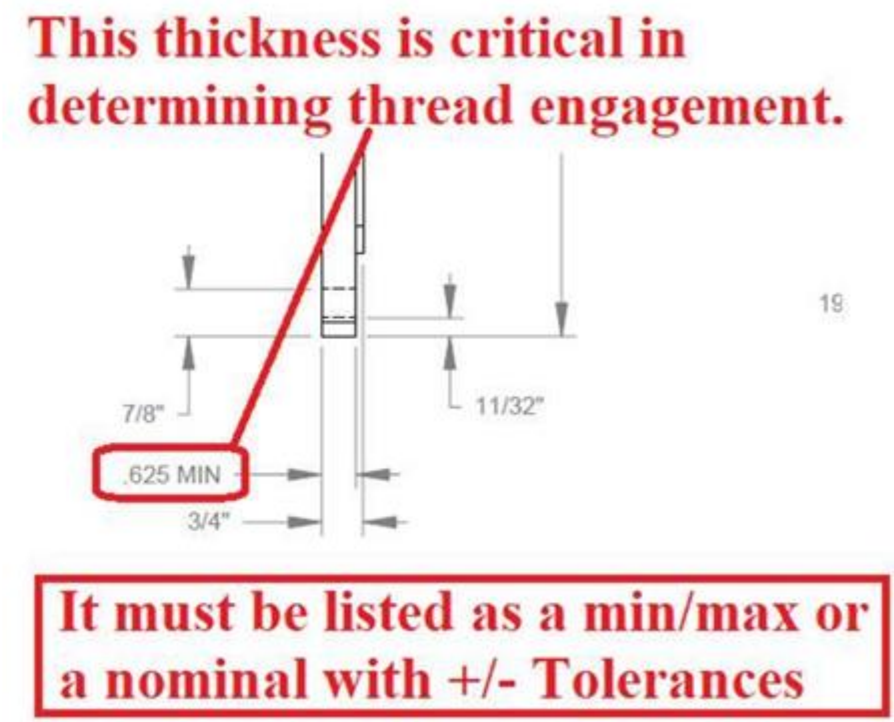


Figure 91 – Drawing Excerpt showing XP Enclosure Cover with Tolerance Comments

- Cover bolt spacing is in fractions and the flange bolt spacing is in decimals. The tolerances for fraction and decimal are different therefore, your bolt spacing may be off between the two pieces due to the tolerances.

- Flange – internal edge states “Machine Finish on Inner Edge” – does this mean chamfer? All maximum chamfers are required to be specified because it will be deducted from minimum flamepaths.
- Flange – is the tap depth (29/64”) or 21/32”?

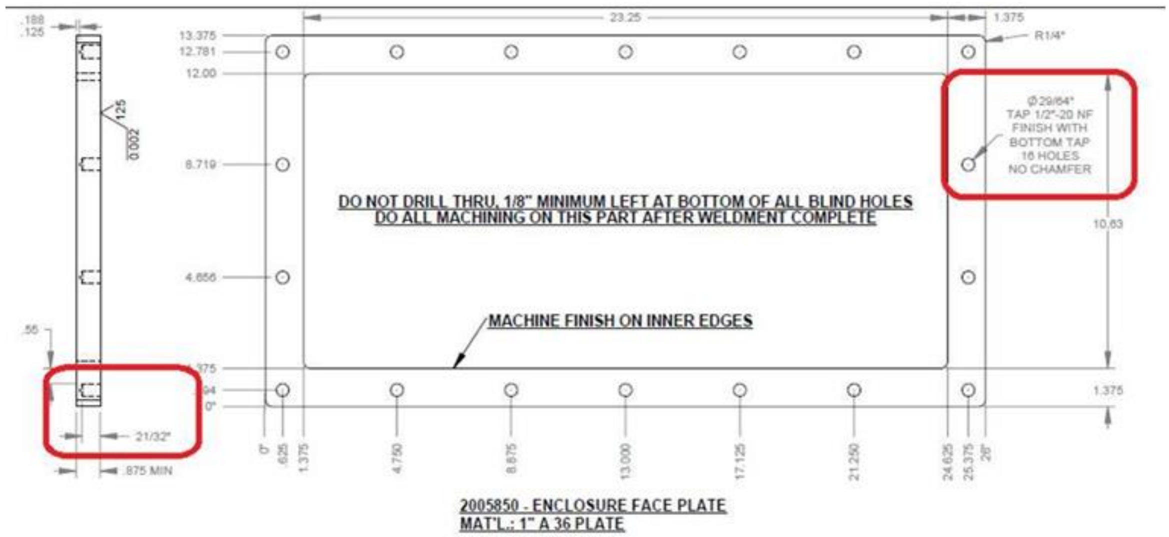


Figure 92 - Drawing Excerpt Showing XP Enclosure Flange with Thread Depth Comments

- I would suggest not referencing your rev level when you call our reference drawings. That way in the future if you need to change a drawing…you don’t need update unnecessary drawings just to change the Rev level.

ITEM NO.	PART NUMBER	QTY.	REFERENCE DRAWING
1	2005870 ENCLOSURE WELDMENT	1	ROHMAC 2005870 REV A
2	2005760 COVER PLATE	1	ROHMAC 2005760 REV A
3	010549008 XP SWITCH OPERATOR SHAFT	4	AMERICAN ELECTRIC EQUIPMENT, INC. A-6238
4	010549008 XP SWITCH OPERATOR	4	AMERICAN ELECTRIC EQUIPMENT, INC. A-6238
5	2005881 MSHA APPROVAL TAG	1	ROHMAC 2005881 REV A

Figure 93 - Drawing Excerpt Showing Table of Reference Drawings

- Item 3 and Item 4 above. I do not see a Drawing A-6238 on file with MSHA. Please verify this is the correct drawing for this shaft assembly.

The comments mostly focused on the flame path and thread engagement around the cover bolts. It was advised that minimum thread engagement was not adequate, and there were questions around machining the bolt flange and any chamfer used. Otherwise, comments again referred to proper drawing references and part callouts. During the 24 November video conference meeting, the discrepancy comments were reviewed and clarification of necessary dimensions and callouts was discussed. Upsizing the lid bolts to ½" diameter was also discussed and agreed upon. It was mentioned that the application documents appeared to be mostly ready, and that MSHA representatives would not be able to perform a more in-depth review of the documentation until it was formally submitted. The approval process change was discussed and it was mentioned that a thorough review of the application would be performed and then a discrepancy letter sent to the applicant, who would then have one week to issue corrections or the application would be cancelled.

Following the meeting, the documentation was revised and a few small questions were answered. Changes to the drawings were made to correct the callouts, specifications, and add optional quantities for cable entrance glands and switch operators, as well as general editing of dimension tolerances as advised by MSHA representatives; who also provided a link to documents with application instructions. The approval application for the explosion proof enclosure was deemed ready to submit.

EXPLOSION PROOF ENCLOSURE APPROVAL APPLICATION

The enclosure application was formally submitted to MSHA on 31 December 2020, and was assigned PAR 116463. The application documents included drawings of the enclosure and associated components as well as a certified statement of inspection. The documents submitted with the application are shown in the following figures:


Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

31 December 2020

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC (TIN: 52-1813657-001) is requesting approval for a new XP Enclosure Assembly Part Number 002205880 company code 200911.

The subject enclosure consists of a steel enclosure weldment with up to 6 Switch Shaft assemblies and / or up to 14 gland entrances for cables. An Aluminum bolt on cover is used on the enclosure assembly.

Since this is a new prototype enclosure, it will be completely assembled and available for inspection and testing upon request.

Enclosed are all of the drawings, documents, and specifications pertinent to this application. If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremy Rohrbaugh, P.E.
Manager of Engineering
Rohmac, Inc.
PO Box 335
Mt. Storm, WV 26739

Figure 94 - XP Enclosure Application Request Letter

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

INVESTIGATION NO. MR-

DRAWING LIST

ROHMAC INC
Explosion Proof Enclosure Assembly PN 0022005880
Built According to Drawing Number 2005880
Certification No. X/P-

TITLE	DRAWING	REVISION
ENCLOSURE ASSEMBLY	2005880	A
ENCLOSURE WELDMENT	2005870	A
HOUSING PLATE	2005860	A
ENCLOSURE PLATE DETAILS	2005850	A
COVER PLATE	2005760	A
SHAFT BOSS	A-30295	A
SWITCH SHAFT	B-6172	
SWITCH OPERATOR	A-10138	B
WELD GLAND 1.5" OD	1033-20114-4W	A
PACKING GLAND CHART	1-125	C
WELD GLAND 2" OD	B-5763	
WELD GLAND 2.375" OD	B-5765	A

CERTIFIED STATEMENT DATED 11 SEPTEMBER 2020

Figure 95 - XP Enclosure Application Drawing List

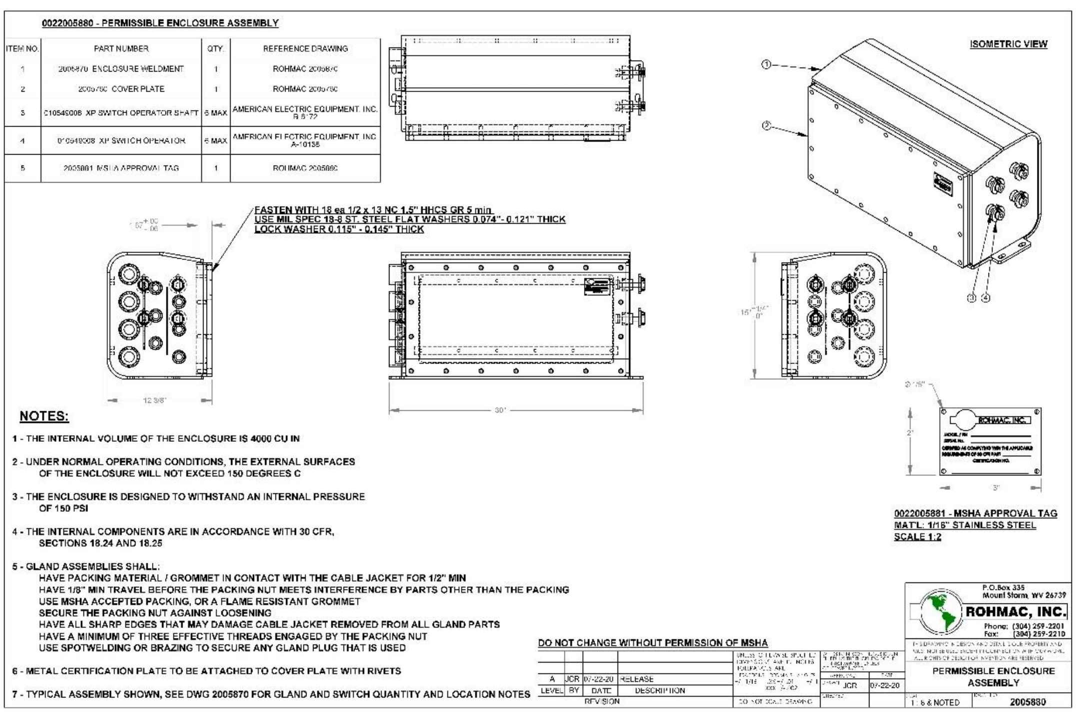


Figure 96 - XP Enclosure Application Assembly Drawing

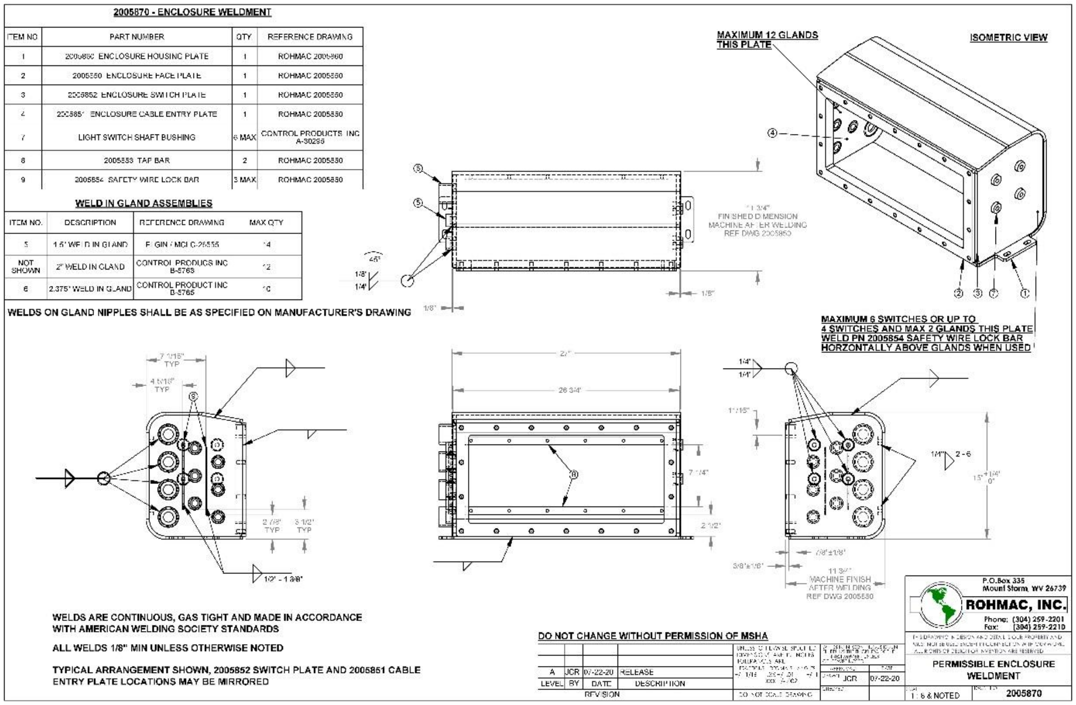


Figure 97 - XP Enclosure Application Weldment Drawing

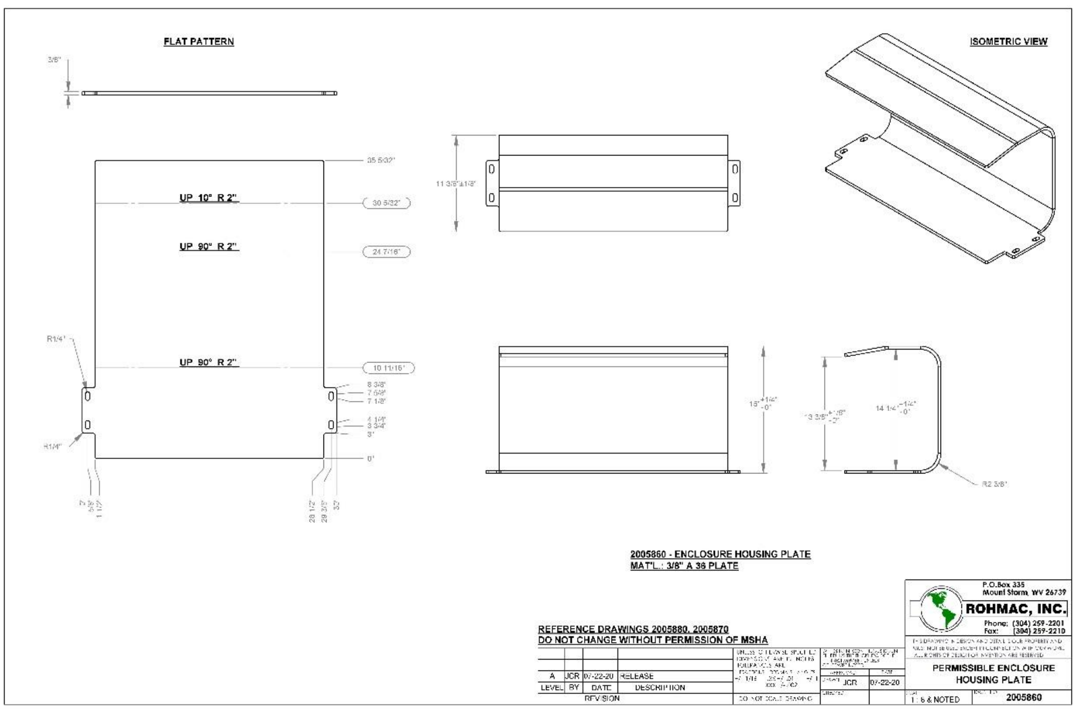


Figure 98 - XP Enclosure Application Housing Plate Drawing

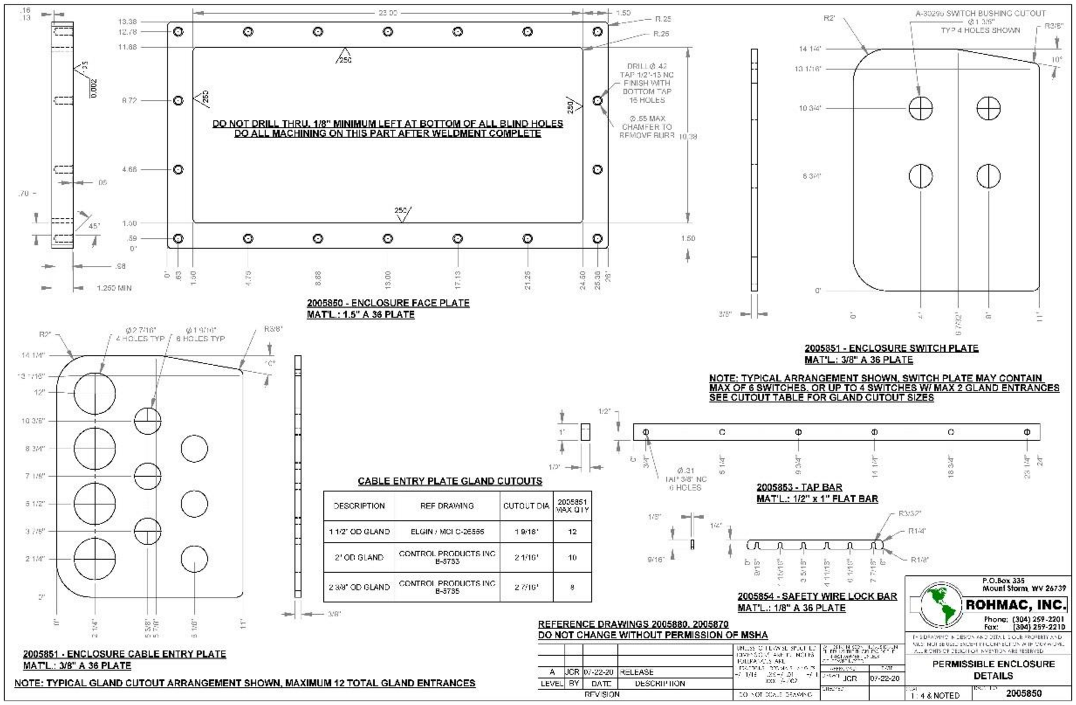


Figure 99 - XP Enclosure Application Detail Drawing

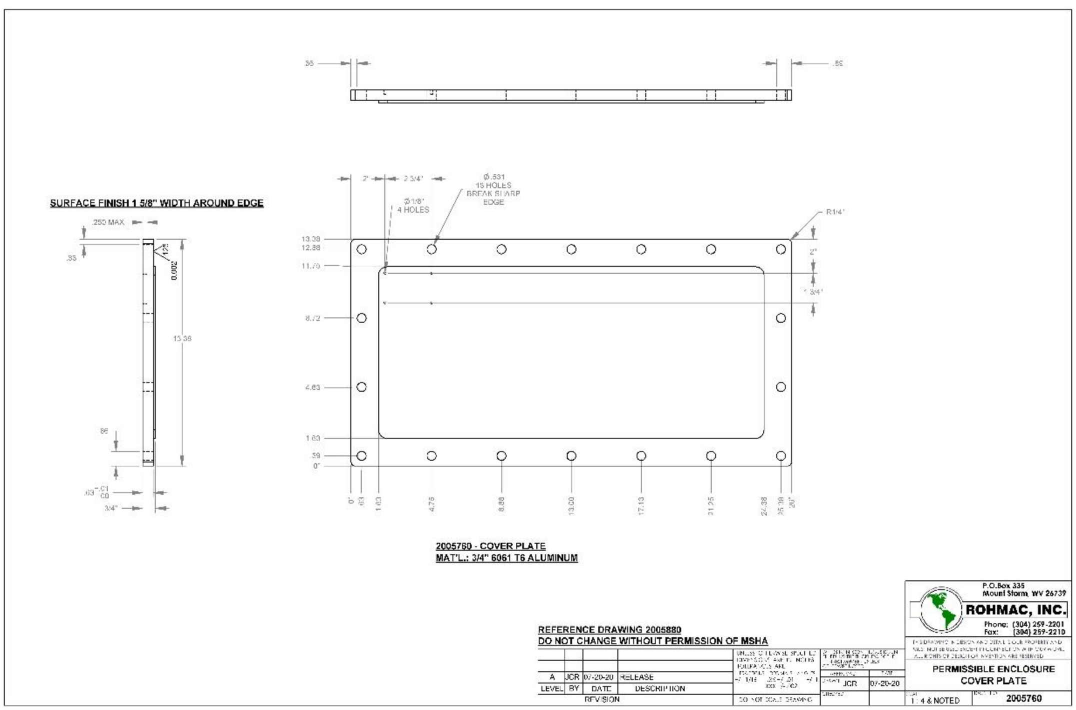


Figure 100 - XP Enclosure Application Cover Plate Drawing

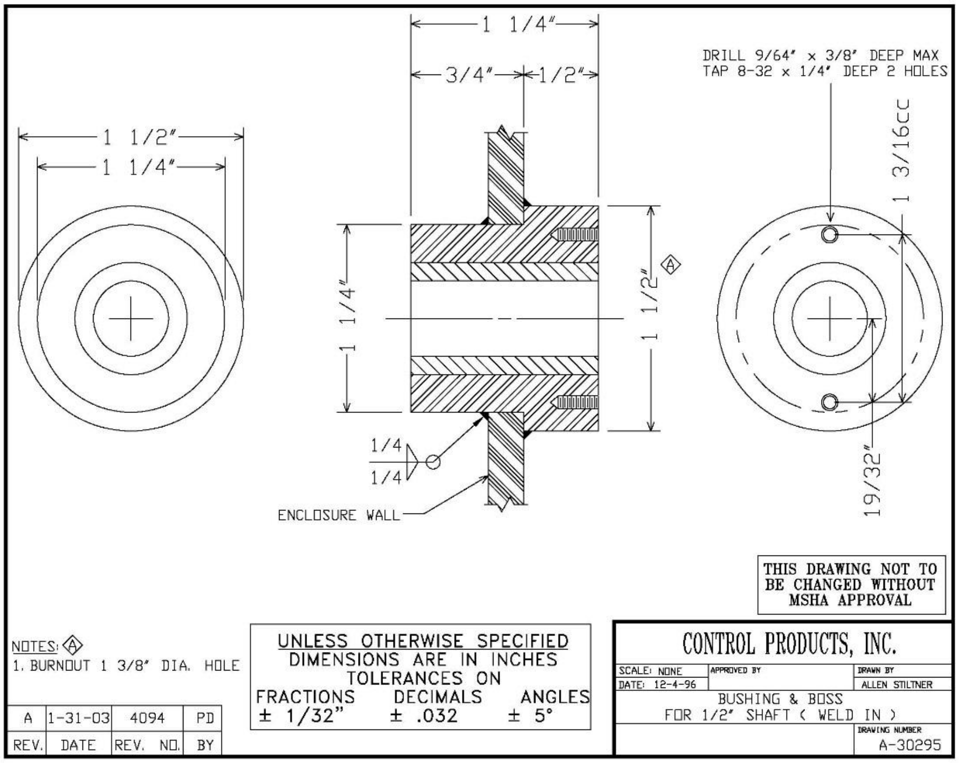


Figure 101 - XP Enclosure Application OEM Weld-in Boss Drawing

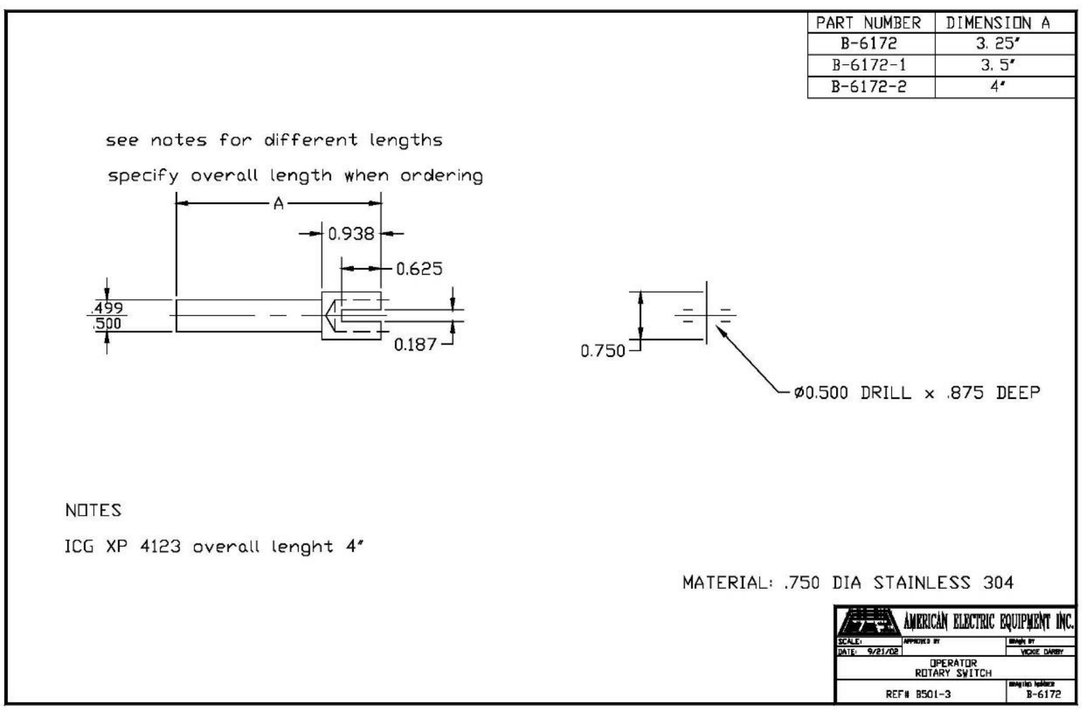


Figure 102 - XP Enclosure Application OEM Switch Shaft Drawing

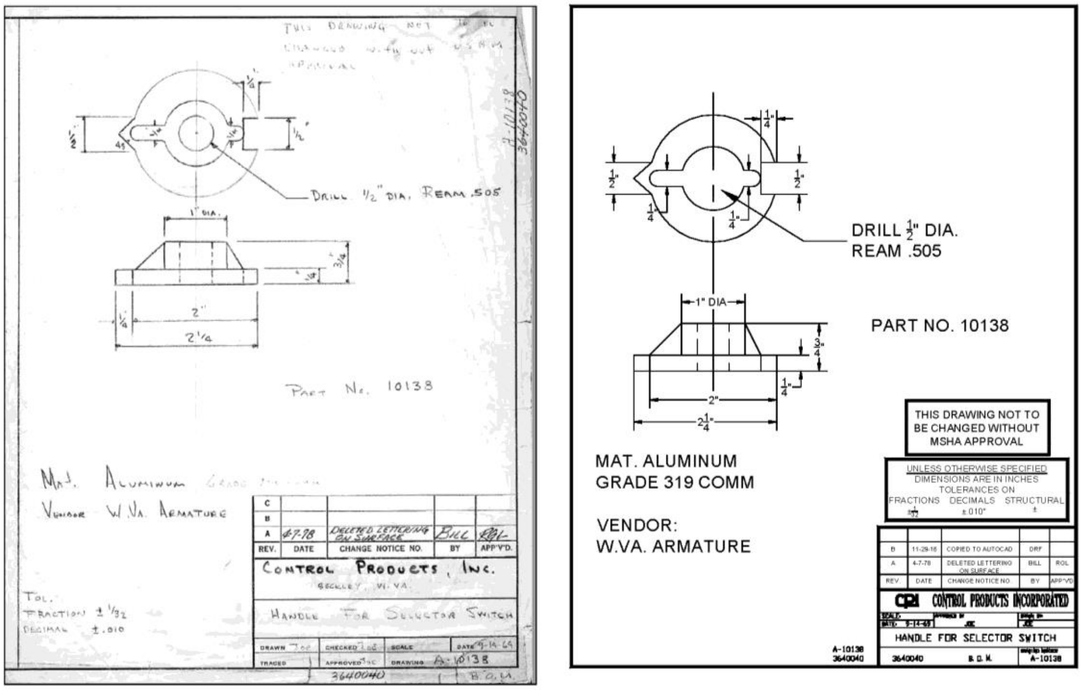


Figure 103 - XP Enclosure Application OEM Switch Operator Drawings

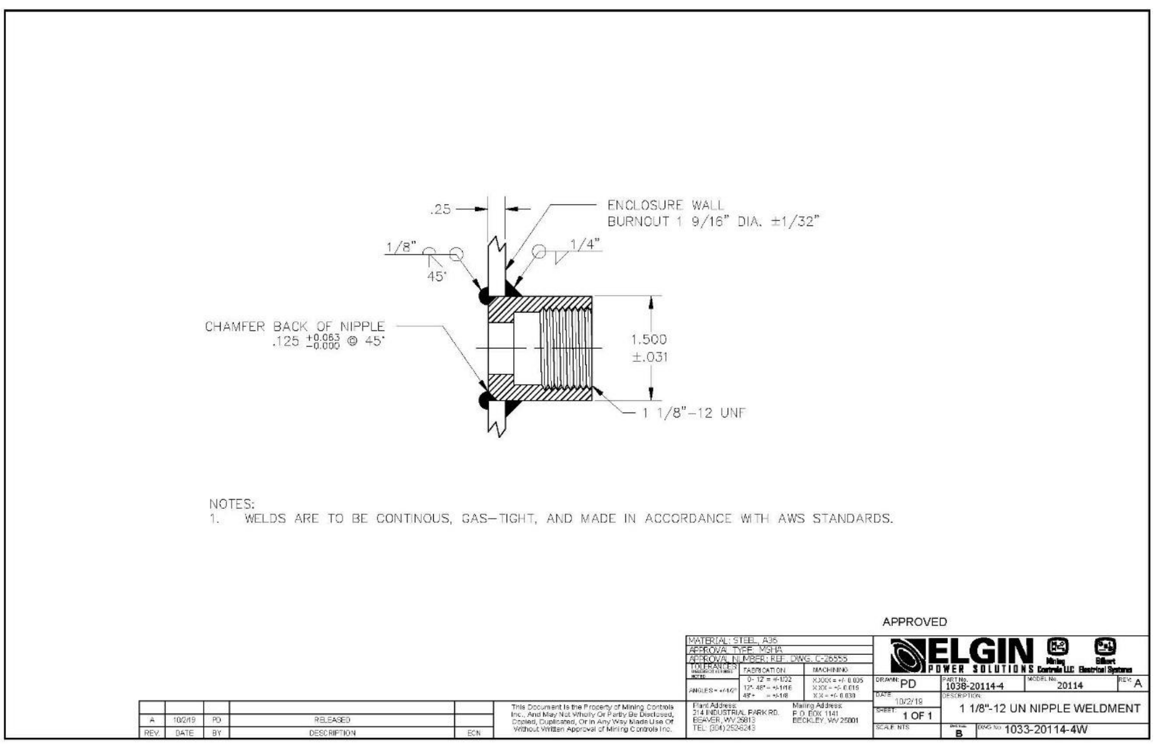


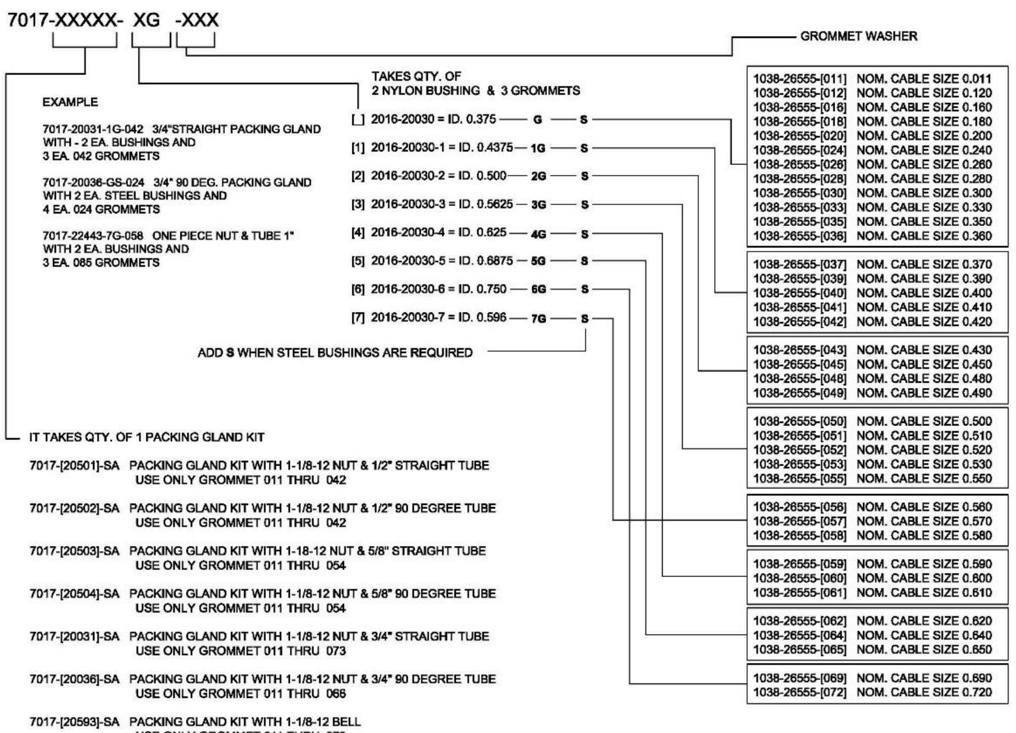
Figure 104- XP Enclosure Application OEM Weld-in Gland Nipple Drawing

1/4 ROPE PACKING

MCI STANDARD PACKING GLAND ASSEMBLY NO.	PACKING GLAND KIT			1/4 PACKING ROPE		BUSHING			CABLE RANGE
	QTY.	MCI PART NO.	TYPE	QTY.	MCI PART NO.	QTY.	NYLON PART NO.	I.D.	
7017-20503	1	7017-20503-SA	NUT & 5/8" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030	0.375	0.328 - 0.355
7017-20503-1	1	7017-20503-SA	NUT & 5/8" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-1	0.4375	0.328 - 0.417
7017-20503-2	1	7017-20503-SA	NUT & 5/8" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-20503-3	1	7017-20503-SA	NUT & 5/8" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-20504	1	7017-20504-SA	NUT & 5/8" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030	0.375	0.328 - 0.355
7017-20504-1	1	7017-20504-SA	NUT & 5/8" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-1	0.4375	0.328 - 0.417
7017-20504-2	1	7017-20504-SA	NUT & 5/8" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-20504-3	1	7017-20504-SA	NUT & 5/8" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-20031	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030	0.375	0.328 - 0.355
7017-20031-1	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-1	0.4375	0.328 - 0.417
7017-20031-2	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-20031-3	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-20031-4	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-4	0.625	0.458 - 0.605
7017-20031-5	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-5	0.6875	0.520 - 0.667
7017-20031-8	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-4	0.625	0.458 - 0.605
7017-20031-9	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-20031-10	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-6	0.750	0.583 - 0.730
7017-20031-11	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-20036	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030	0.375	0.328 - 0.355
7017-20036-1	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-1	0.4375	0.328 - 0.417
7017-20036-2	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-20036-3	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-20036-4	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-4	0.625	0.458 - 0.605
7017-20036-5	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59204	2	2016-20030-5	0.6875	0.520 - 0.667
7017-20593-1	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030	0.375	0.328 - 0.355
7017-20593-2	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030-1	0.4375	0.328 - 0.417
7017-20593-3	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-20593-4	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-20593-5	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030-4	0.625	0.458 - 0.605
7017-20593-6	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030-5	0.6875	0.520 - 0.667
7017-20593-7	1	7017-20593-SA	BELL	2 FT.	2017-59204	2	2016-20030-6	0.750	0.583 - 0.730
7017-22443-2	1	7017-22443-SA	ONE PIECE NUT & 1" TUBE	3 FT.	2017-59204	0			0.599 - 0.776
7017-29943-1	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030	0.375	0.328 - 0.355
7017-29943-2	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030-1	0.4375	0.328 - 0.417
7017-29943-3	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030-2	0.500	0.333 - 0.480
7017-29943-4	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030-3	0.5625	0.395 - .542
7017-29943-5	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030-4	0.625	0.458 - 0.605
7017-29943-6	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030-5	0.6875	0.520 - 0.667
7017-29943-7	1	7017-29943-SA	NUT & GRIP	2 FT.	2017-59204	2	2016-20030-6	0.750	0.583 - 0.730

3/8 ROPE PACKING

MCI STANDARD PACKING GLAND ASSEMBLY NO.	PACKING GLAND KIT			3/8 PACKING ROPE		BUSHING			CABLE RANGE
	QTY.	MCI PART NO.	TYPE	QTY.	MCI PART NO.	QTY.	NYLON PART NO.	I.D.	
7017-20501	1	7017-20501-SA	NUT & 1/2" STRAIGHT TUBE	2 FT.	2017-59205	2	2016-20030	0.375	0.114 - 0.335
7017-20501-1	1	7017-20501-SA	NUT & 1/2" STRAIGHT TUBE	2 FT.	2017-59205	2	2016-20030-1	0.4375	0.176 - 0.417
7017-20502	1	7017-20502-SA	NUT & 1/2" 90 DEGREE TUBE	2 FT.	2017-59205	2	2016-20030	0.375	0.114 - 0.335
7017-20502-1	1	7017-20502-SA	NUT & 1/2" 90 DEGREE TUBE	2 FT.	2017-59205	2	2016-20030-1	0.4375	0.176 - 0.417
7017-20504-4	1	7017-20504-SA	NUT & 5/8" 90 DEGREE TUBE	2 FT.	2017-59205	2	2016-20030	0.375	0.114 - 0.335
7017-20504-5	1	7017-20504-SA	NUT & 5/8" 90 DEGREE TUBE	2 FT.	2017-59205	2	2016-20030-1	0.4375	0.176 - 0.417
7017-20031-6	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59205	2	2016-20030	0.375	0.114 - 0.335
7017-20031-7	1	7017-20031-SA	NUT & 3/4" STRAIGHT TUBE	2 FT.	2017-59205	2	2016-20030-1	0.4375	0.176 - 0.417
7017-20036-6	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59205	2	2016-20030	0.375	0.114 - 0.335
7017-20036-7	1	7017-20036-SA	NUT & 3/4" 90 DEGREE TUBE	2 FT.	2017-59205	2	2016-20030-1	0.4375	0.176 - 0.417
7017-22443-3	1	7017-22443-SA	ONE PIECE NUT & 1" TUBE	3 FT.	2017-59205	0			0.505 - 0.656



7017-[20501]-SA PACKING GLAND KIT WITH 1-1/8-12 NUT & 1/2" STRAIGHT TUBE
USE ONLY GROMMET 011 THRU 042

7017-[20502]-SA PACKING GLAND KIT WITH 1-1/8-12 NUT & 1/2" 90 DEGREE TUBE
USE ONLY GROMMET 011 THRU 042

7017-[20503]-SA PACKING GLAND KIT WITH 1-18-12 NUT & 5/8" STRAIGHT TUBE
USE ONLY GROMMET 011 THRU 054

7017-[20504]-SA PACKING GLAND KIT WITH 1-1/8-12 NUT & 5/8" 90 DEGREE TUBE
USE ONLY GROMMET 011 THRU 054

7017-[20031]-SA PACKING GLAND KIT WITH 1-1/8-12 NUT & 3/4" STRAIGHT TUBE
USE ONLY GROMMET 011 THRU 073

7017-[20036]-SA PACKING GLAND KIT WITH 1-1/8-12 NUT & 3/4" 90 DEGREE TUBE
USE ONLY GROMMET 011 THRU 066

7017-[20593]-SA PACKING GLAND KIT WITH 1-1/8-12 BELL
USE ONLY GROMMET 011 THRU 073

7017-[22443]-SA PACKING GLAND KIT WITH 1-1/8-12 ONE PIECE NUT WITH 1" STRAIGHT TUBE
USE ONLY GROMMET 050 THRU 077 AND TAKES QTY. OF 4 GROMMET WASHERS

7017-[29943]-SA PACKING GLAND KIT WITH 1-1/8-12 NUT & GRIP
USE ONLY GROMMET 011 THRU 073

1-125 PACKING GLAND CHART REV-C
26555 SERIES CHART WITH GROMMET (10-24-11) CMY

Figure 105- XP Enclosure Application OEM Packing Gland Specification Chart

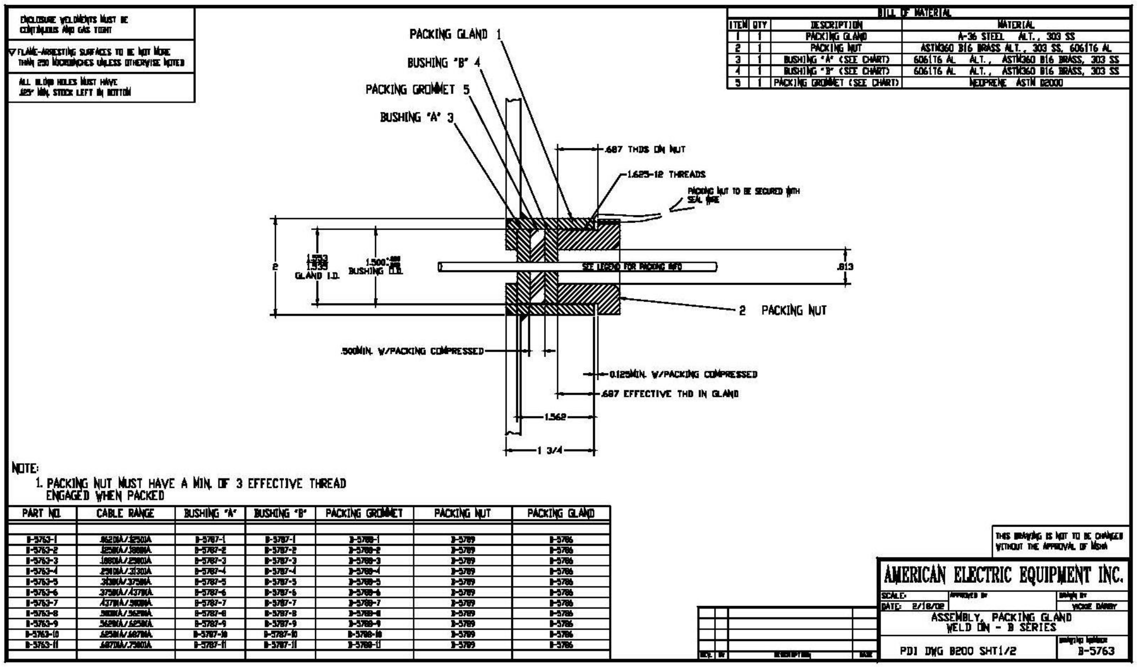


Figure 106 - XP Enclosure Application OEM Packing Gland Specification Drawing

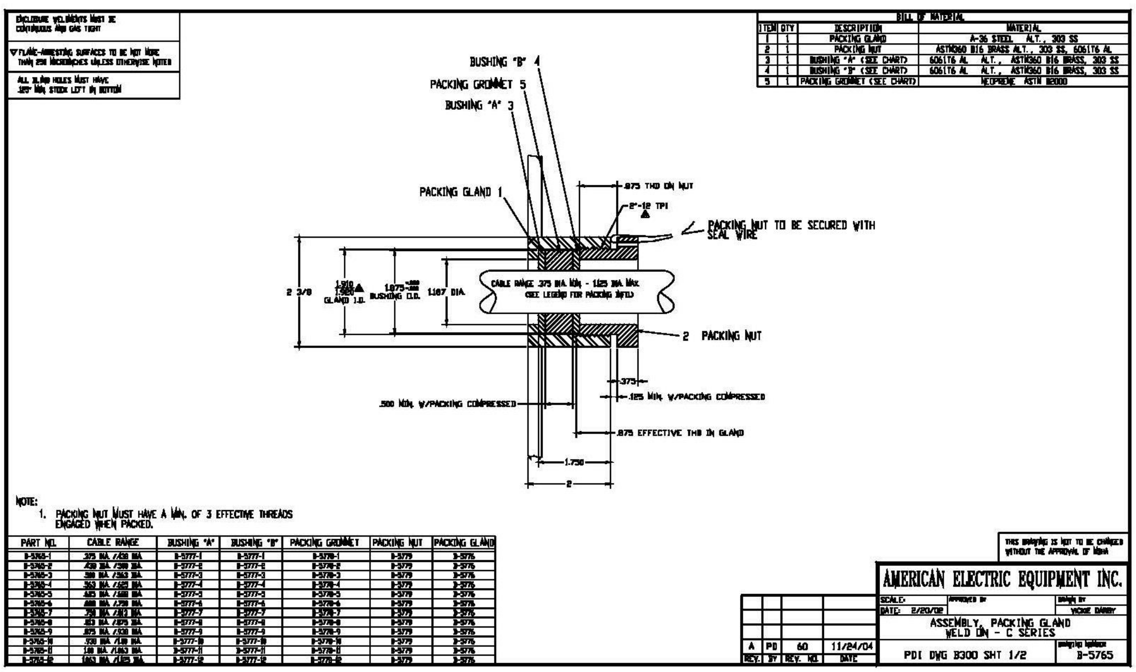
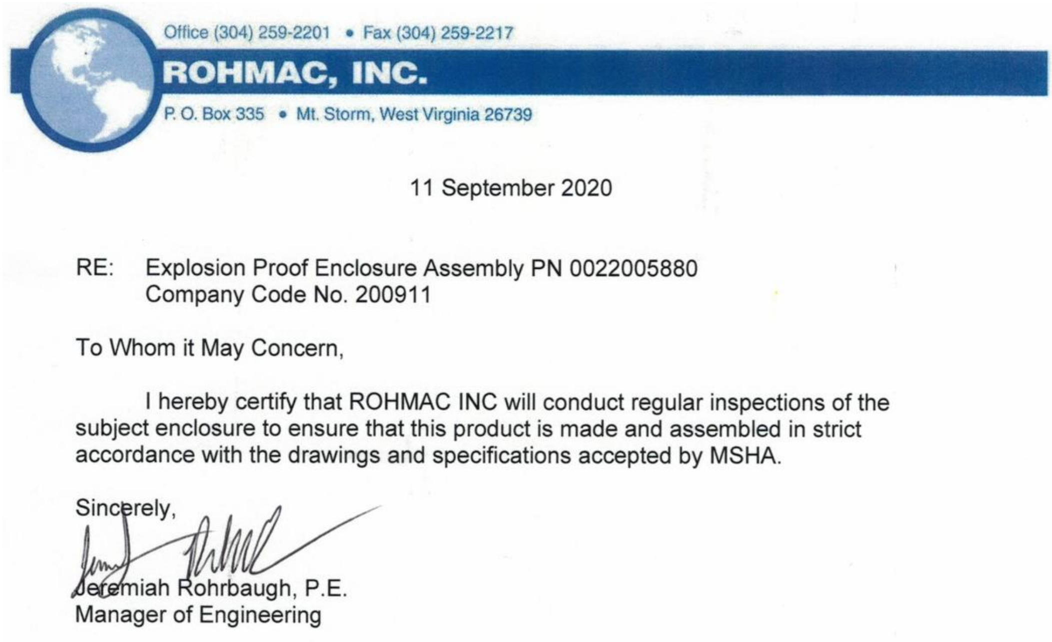


Figure 107 - XP Enclosure Application OEM Large Packing Gland Specification Drawing


Office (304) 259-2201 • Fax (304) 259-2217

ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

11 September 2020

RE: Explosion Proof Enclosure Assembly PN 0022005880
Company Code No. 200911

To Whom it May Concern,

I hereby certify that ROHMAC INC will conduct regular inspections of the subject enclosure to ensure that this product is made and assembled in strict accordance with the drawings and specifications accepted by MSHA.

Sincerely,

Jeremiah Rohrbaugh, P.E.
Manager of Engineering

Figure 108 - XP Enclosure Application Certified Statement of Inspection

An email was received on 5 January 2021 with an estimate letter / fee authorization form for the electrical enclosure approval application. The letter, shown in Figure 109, stated that the technical investigation was expected to begin within the next two to three months, and that the estimated cost of the approval review was $ 27,812.37. The authorization form was signed and returned to MSHA on 11 January 2021, a copy of the signed authorization is shown in Figure 110. Other attachments to this email included the letters that explained the new evaluation policy as detailed earlier in this report, and a letter that explained a policy requirement of including a Taxpayer Identification Number with any new applications as mandated by the Debt Collection Improvement Act of 1996. A copy of this letter is shown in Figure 111.

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

Refer to Attn of:

MSHA: A&CC: PAR 0116463

January 04, 2021

JEREMY ROHRBAUGH
ROHMAC INC.
POB 335
MOUNT STORM, WV 26739 USA

Dear JEREMY ROHRBAUGH,

We have received your application, company assigned application number 200911, and have assigned PAR number 0116463 for our tracking purposes. We anticipate beginning the technical investigation within the next 2 to 3 months . Based on the information provided with your application, we estimate the maximum fee to conduct this investigation is $27,812.37.

We have not included any costs for travel in the estimate. You will be charged on an actual cost basis should travel be necessary to evaluate or test your product at the manufacturing or installation site. Also, our estimate does not include repeat testing or evaluation that would result from design changes or test failures during processing. We will contact you should we encounter problems that would cause the fee to exceed the estimate. You will have the opportunity to authorize further action, at additional cost, or cancel the action. We anticipate the action will be fully processed at a cost below the estimate. You will be charged a lesser amount if our actual fee is less than the estimated amount.

You must complete and return the enclosed authorization response form within 30 days of the date of this letter. We will cancel your application if you do not respond within the time period. Please send your response by mail or fax it to us at (304) 547-2044.

You are not to submit payment of any kind at this time. We will bill you for the total cost of processing your application when our work is completed.

Please contact me at 304-547-0400 if you have any questions or comments.

Sincerely,

STEVEN KOTVAS — Digitally signed by STEVEN KOTVAS Date: 2021.01.04 14:51:12 -05'00'

Enclosure: Authorization Response Form

Figure 109 - PAR 0116463 Fee Estimate Letter

Fee Authorization Response Form

Date: 11 JANUARY 2021

Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

Dear :

With reference to my application, company-assigned code number: 200911, PAR number: 0116463

X Please initiate processing at the estimated cost of $27,812.37.

OR

____ Please cancel this action.

Signed:
[signature] VP ROHMAC INC.

Name
GALEN Rohrbaugh Jr.

Title
VICE - PRESIDENT

Company
ROHMAC INC

Figure 110 - PAR 0116463 Fee Authorization Form

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, WV 26059

DATE August 20, 2020

MEMORANDUM FOR APPROVAL APPLICANTS

FROM: DENNIS FERLICH
Chief, MSHA Approval and Certification Center

SUBJECT: Internal Revenue Service Taxpayer Identification Number Requirement for Approval Applications

The Debt Collection Improvement Act of 1996 (DCIA) requires the Approval and Certification Center (A&CC) to obtain an Internal Revenue Service Taxpayer Identification Number (TIN) from applicants requesting a Mine Safety and Health Administration (MSHA) approval. An agency is required to obtain a TIN in any case which may give rise to a receivable where the individual or entity is considered to be doing business with the government. Persons doing business with the government would include lenders and servicers under federal guaranteed or insured loan programs; applicants for and recipients of federal licenses, permits, rights-of-way, grants, or benefit payments; contractors; and entities and individuals owing fines, fees, royalties, or penalties to the agency. The text of the DCIA is available at https://www.fiscal.treasury.gov/files/dms/dmdcia.txt. Frequently asked questions concerning the DCIA are available at https://www.fiscal.treasury.gov/dms/faqs/faq-about-dcia.html.

Beginning July 1, 2020, MSHA has required a TIN be included with all new approval applications, and required this number from current applicants before continuing work on any existing approval applications. Approval applicants were notified of this change. We will void and return to the applicant all new applications that do not include a TIN. Existing applicants will receive a request for a TIN. If the applicant fails to provide this number within seven days of this request, the application will be canceled and you will receive an invoice for the cost of the time already spent evaluating your application.

MSHA protects the TINs from public disclosure consistent with applicable law, including the Privacy Act of 1974.

If you have any questions or need additional information, please contact Dennis Ferlich at ferlich.dennis@dol.gov or (304) 547-2029.

Figure 111 - Taxpayer Identification Number Requirement Letter

A review of the application was conducted by MSHA, and on 7 July 2021 an email was received with a list of discrepancies and questions. The notice with the document stated that all listed items needed to be addressed and returned to MSHA within 2 weeks. The list contained 35 items, consisting of comments, questions, and notation of conflicting dimensions and tolerances. Upon review of the discrepancy list, a call with the MSHA representative assigned to the documentation review was held on 13 July 2021, to discuss the discrepancy list and ensure clarity and understanding of each item and comment, and to establish the appropriate procedure for responding with the corrected documents. After the call, documentation changes were performed, and the discrepancy list was modified to add a brief description of the corrective measure to each listed item, in order to facilitate the review of the changes. Most changes were minor, and no major design flaws were indicated. The new documents were submitted on 22 July 2021, within the 2-week time frame, and are shown in the following figures. A copy of the discrepancy letter with the corrective measure description follows:

List of Discrepancies

ROHMAC, Inc.
XP Enclosure Assembly

PAR No. 116463

<u>General Discrepancies</u>

1. What is the model number for the assembly? Is it 0022005880, 2005880, or 002205880? It seems there are three (3) very similar numbers being referenced.

   ROHMAC INC
   Explosion Proof Enclosure Assembly PN 0022005880
   Built According to Drawing Number 2005880

   Enclosure Assembly Part Number 002205880 company code 200911.

   The 002 is a place holder designator added to our engineering part numbers by our accounting system, the engineering part number we will use for this enclosure is 2005880, and documentation has been adjusted

2. Component drawings for the glands and switches were submitted in your drawing package. These drawings belong to other companies. We cannot use the copies of the drawings you submitted with your application. The latest copy of the referenced component drawings on file with MSHA will be the copies of the drawings used when evaluating this enclosure.

   Per our discussion on 7/13/21, we are so advised, and have eliminated the drawings and used manufacturer part numbers in the documentation

3. The general weld note in the title block, shown below, is located on every drawing. This contradicts the general note located on Drawing No. 2005870, shown below. A general note should state the general weld size, the type, and document if it is inside, outside, or both.

Please note that a worst case test enclosure will be required, all welds will be requested to be at minimum specified. If 1/8" weld size is not practical to make the enclosure, please correct size.

All Drawing

> WELDS TO BE CONTINUOUS DOUBLE FILLETS 1/2 THE THICKNESS OF THE THINNEST MEMBER UNLESS OTHERWISE NOTED.

Drawing No. 2005870

ALL WELDS 1/8" MIN UNLESS OTHERWISE NOTED

Welding Callouts and general statement on drawings have been modified, the above referenced weld notes have been removed

Drawing 2005880 – Permissible Enclosure Assembly

4. The approval tag should have the Item 5 call out for it. Added Callout

5. Add a general note documenting the required minimum 1/8 in of stock at the bottom of all blind holes.

   Added Note

6. Item 3 – Switch Operator Shaft – The American Electric Equipment, Inc drawing B-6172 is not a drawing on file with MSHA. This switch assembly cannot be evaluated until a shaft is specified.
   Changed Callout and listed Manufacturer as Precision Design, AKA AEI, B501-3

7. Item 4 – XP Switch Operator – List the correct company for Item 4. This item is listed an American Electric Equipment, Inc drawing. The drawing we have on file for this is not owned by American Electric Equipment, Inc.

   Changed Manufacturer listed in table

8. Add a side view of the Switch Operator complete assembly. This is needed to show the orientation of how the shaft assembly parts are assembled together. Also include which side is the interior and which side is the exterior.

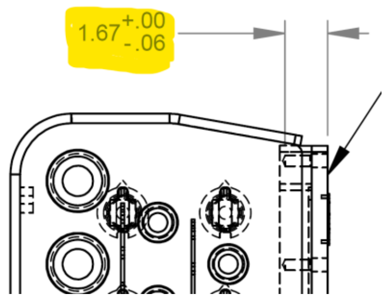
Added section view with detail view of switch operator assembly components on side of enclosure

9. Add details with how the Switch Operator is attached to the shaft. Added note for set screw

10. Add a note which documents that the maximum clearance between the flange and cover is 0.004 in.

    Added Callout

11. What is the purpose of this dimension? This is not a typical dimension shown on explosion-proof enclosure drawings. Please explain.

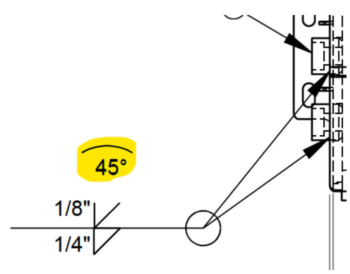


Discussed dimension during call as unnecessary to establish depth of bolt hole, removed

Drawing 2005870 – Permissible Enclosure Weldment

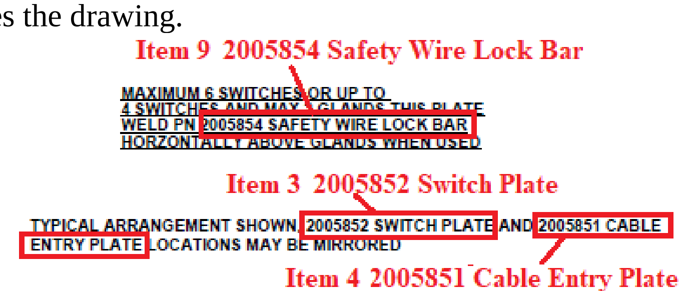
12. Add a note which references Drawing 2005880. Drawing 2005880 is the main drawing which leads to the other drawings and each drawing must have a reference to this main drawing.
Added Master Drawing Reference Note to drawings above MSHA note near title block

13. What is the notation shown highlight in the below view? Should it be removed from the drawing?



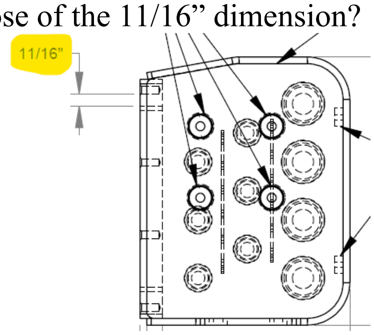
Discussed the notation used on the weld symbol and the reference for the gland weld, changed profile callout to flat so that interior surface is flush

14. Add the item number reference with each call out of parts, see below. It's difficult to distinguish if the '2005###' number referenced are for drawing numbers or part numbers. The addition of the item number will refer to the BOM on the drawing, which references the drawing.



Added Item number callouts as shown

15. What are these holes being shown thru the cover and flange? Also shown on Drawing 2005880. What is the purpose of the 11/16" dimension?



Discussed dimension as unnecessary reference for hole edge to inside flange and removed

16. What is the purpose of the note shown below? The weld nipples and entire gland assemblies are required to be from the manufacturer specified.

WELDS ON GLAND NIPPLES SHALL BE AS SPECIFIED ON MANUFACTURER'S DRAWING

Is this note trying to specify that ROHMac is making the gland nipple?

- If Yes, then all machining of gland nipples must be specified on ROHMac drawings.
- If No, remove this note. It is assumed when specifying the entire gland assembly, as listed in the"Weld in Gland Assembly" chart, that the enclosure is using the gland specified nipples.

Removed Note

17. Add an orientation view, side view, of the welded on Item 9 (2005854 Safety Wire Lock Bar). This is needed to demonstrate how 'holes' are created for the locking wire attachment.

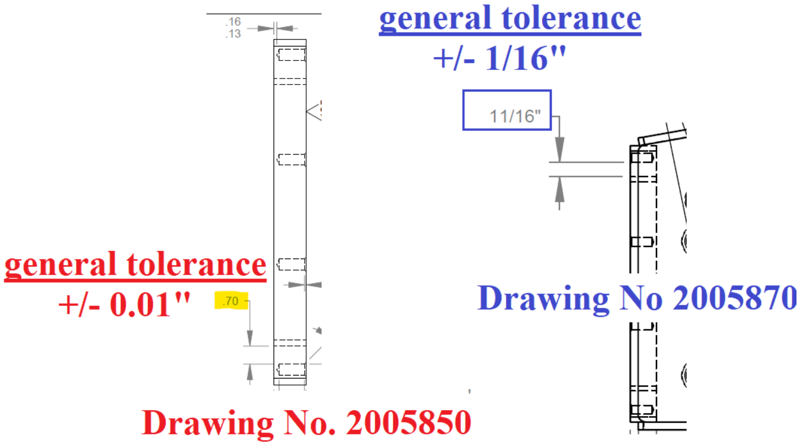
Added Section drawing showing bar mounted to side of enclosure with detail drawing showing hole for locking wires

Drawing 2005850 – Permissible Enclosure Details

18. The part number specified for the Enclosure Switch Plate (200585**1**). Correct the part number (200585**2**) to match Drawing 2005870.

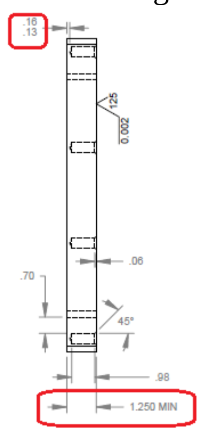
Corrected Number

19. The dimension highlighted on the flange, see below, does not match what appears to be the same dimensions on Drawing 2005870. See Discrepancy #15.



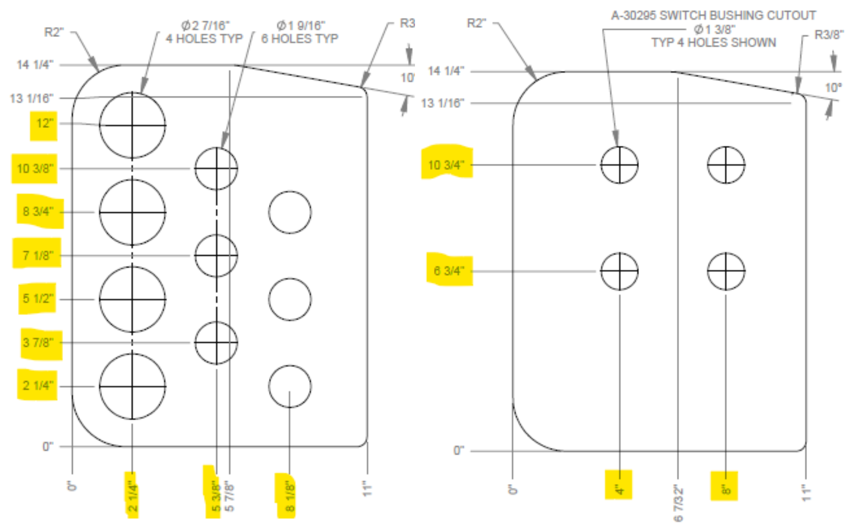
Discussed dimensions as confusing and unnecessary, removed

20. The dimension for the flange is listed as a minimum (1.250 in), but the dimension listed for the stock remaining at the bottom of the hole is a range. The dimension remaining should be a minimum, since the flange thickness is not tied down.



Changed dimension to minimum

21. Since the drawing is showing typical arrangement and allows for the gland/switch quantity can vary, the locating dimensions for the gland and switch are not required. It would be favorable not to put the exact dimensions, shown highlighted below to allow you more flexibility in the future.



Removed dimensions

22. The Cable Entry Plate Gland Cutouts Chart needs to have the max quantity listed for the 2005852 Switch Plate. Otherwise it is not clear which cable gland options could be used.

~~CABLE ENTRY PLATE~~ GLAND CUTOUTS

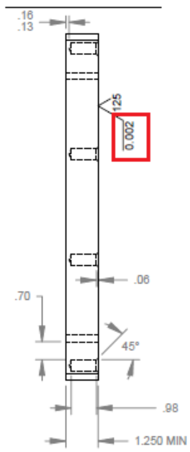
DESCRIPTION	REF DRAWING	CUTOUT DIA	2005851 MAX QTY	2005852 max qty
1 1/2" OD GLAND	ELGIN / MCI C-26555	1 9/16"	12	2 ???
2" OD GLAND	CONTROL PRODUCTS INC B-5763	2 1/16"	10	2 ???
2 3/8" OD GLAND	CONTROL PRODUCTS INC B-5765	2 7/16"	8	2 ???

Added Column with data

23. Add a note which documents there are no chamfers on the internal or external edge of the face plate (flange). If there edges of the flange are chamfered, the maximum chamfer(s) must be specified.

Added Notes showing no chamfers on flange edges

24. The flatness across the faceplate is specified as 0.002", as shown below. Is this a maximum? It may be in your best interest to document that the flatness is 0.002" maximum *between bolt holes.* We have had past applicants struggle to meet 0.002" across the entire flange.



§ 18.33 **Finish of surface joints.**
Flat surfaces between bolt holes that form any part of a flame-arresting path shall be plane to within a maximum deviation of one-half the maximum clearance specified in § 18.31(a)(6)....

Changed annotations to show flatness between holes

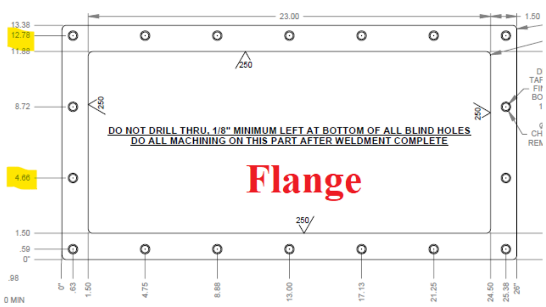
25. The face plate width of 26 in needs to have a tolerance listed or be listed as 26.00 in so the general tolerance chart can be used.

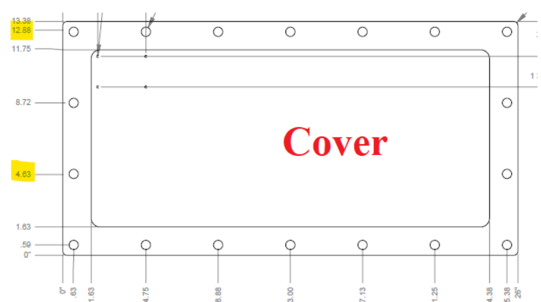
    Added decimals

<u>Drawing 2005760 – Permissible Enclosure Cover Plate</u>

26. Two (2) of the bolt hole locations contradicts the flange (face plate) bolt hole spacing. See below.

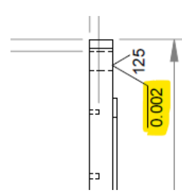
	2nd Vertical Bolt	Top Vertical Bolt
Flange	4.66”	12.78”
Cover	4.63”	12.88”





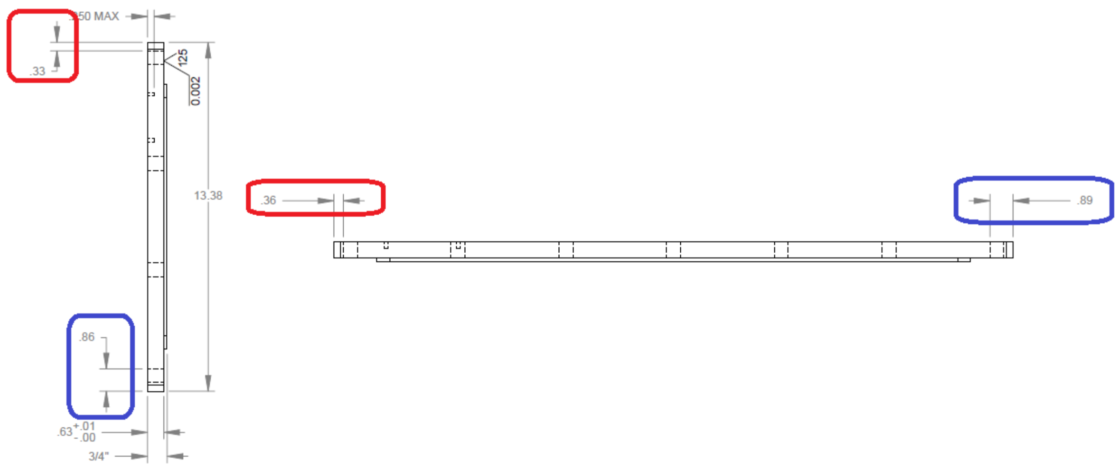
Corrected mismatched dimensions

27. The flatness across the cover is specified as 0.002”, as shown below. Is this a maximum? It may be in your best interest to document that the flatness is 0.002” maximum *<u>between bolt holes.</u>* We have had past applicants struggle to meet 0.002” across the entire flange.



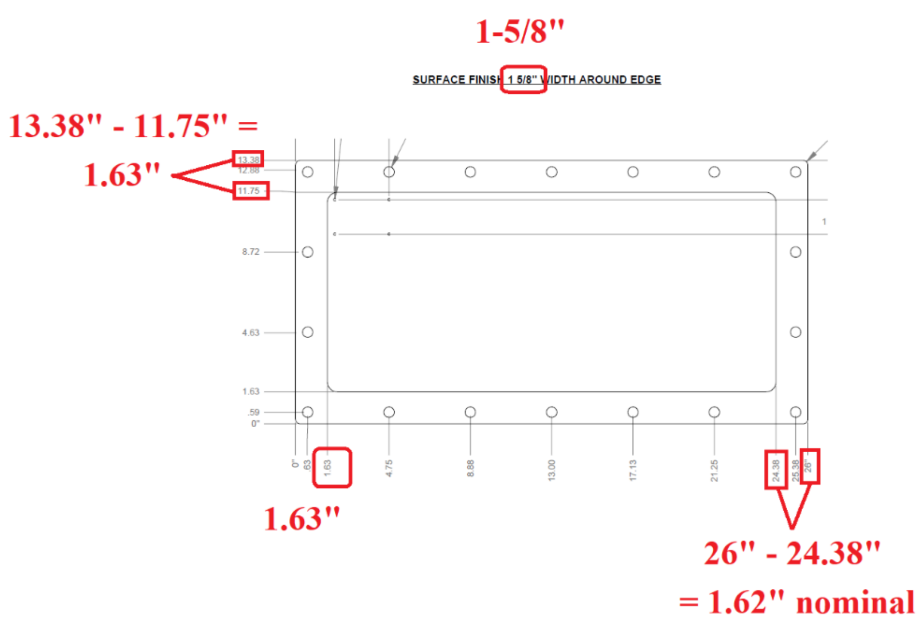
Changed annotations to show flatness between holes

28. Why do these dimensions not match? Are the bolt holes not centered?



Discussed dimensions, edge clearance on sides of plate is different than top and bottom. Further determined that dimensions are confusing and unnecessary, removed

29. The dimensions of the "machined surface area" is listed as three different dimension. Are these dimensions correct? Below are nominal dimensions. Using tolerances would cause variation across the dimensions too.



Corrected mismatched dimensions

30. The cover width of 26 in needs to have a tolerance listed or be listed as 26.00 in so the general tolerance chart can be used.

    Added decimals

Cable Glands

31. The gland drawings (B-5763 and B-5765) are listed as Control Products, Inc. on your drawing. This is not the correct manufacturer for these parts. This is referenced on Drawing 2005870 and 2005850.

    Changed Manufacturer listed in tables

32. B-5763 Gland – No gland plug is specified. A gland plug drawing must be specified. A note must document that the plug is fully threaded into gland nipple with a minimum of 5 threads engaged.

    - If you choose not to specify a gland plug it must be documented that the B-5763 gland cannot be plugged and always use a cable and gland parts.

    Added Gland Plug A-6583 specification to table dwg 2005870

33. B-5765 Gland – No gland plug is specified. A gland plug drawing must be specified. A note must document that the plug is fully threaded into gland nipple with a minimum of 5 threads engaged.

    - If you choose not to specify a gland plug it must be documented that the B-5765 gland cannot be plugged and always use a cable and gland parts.

    Added Gland Plug A-6584 specification to table dwg 2005870

34. Add a note which documents that all gland plugs have a minimum of five (5) threads engaged and are fully threaded into gland nipple. This could be added to Drawing No. 2005880 – Note 5.

    Added Note to dwg 2005880 note 5

35. Document how the glands are secured from loosening. If it is by a seal wire and the gland nipple is not machined with a hole, details must be given as to what the seal wire is tied thru.

    Added Note to dwg 2005880 note 5

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

31 December 2020

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC (TIN: 52-1813657-001) is requesting approval for a new XP Enclosure Assembly Part Number 2005880 company code 200911.

The subject enclosure consists of a steel enclosure weldment with switch operator assemblies and / or gland entrances for cables as specified in the attached drawings. An Aluminum bolt on cover is used on the enclosure assembly.

Since this is a new prototype enclosure, it will be completely assembled and available for inspection and testing upon request.

Enclosed are all of the drawings, documents, and specifications pertinent to this application. If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremiah Rohrbaugh, P.E.
Manager of Engineering
Rohmac, Inc.
PO Box 335
Mt. Storm, WV 26739

Figure 112 - Revised XP Enclosure Cover Letter

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

INVESTIGATION NO. MR-

DRAWING LIST

ROHMAC INC
Explosion Proof Enclosure Assembly PN 2005880
Built According to Drawing Number 2005880
Certification No. X/P-

TITLE	DRAWING	REVISION
ENCLOSURE ASSEMBLY	2005880	A
ENCLOSURE WELDMENT	2005870	A
HOUSING PLATE	2005860	A
ENCLOSURE PLATE DETAILS	2005850	A
COVER PLATE	2005760	A

CERTIFIED STATEMENT DATED 11 SEPTEMBER 2020

Figure 113 - Revised XP Enclosure Drawing List

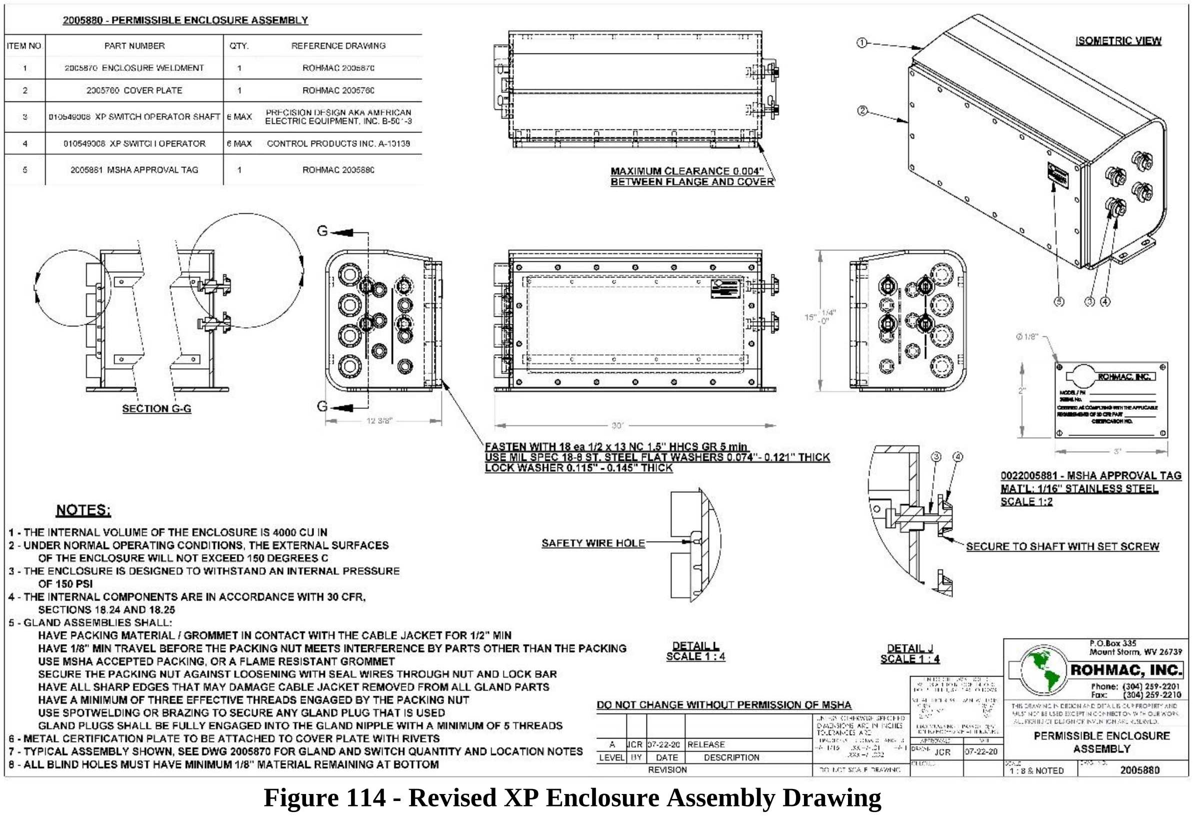


Figure 114 - Revised XP Enclosure Assembly Drawing

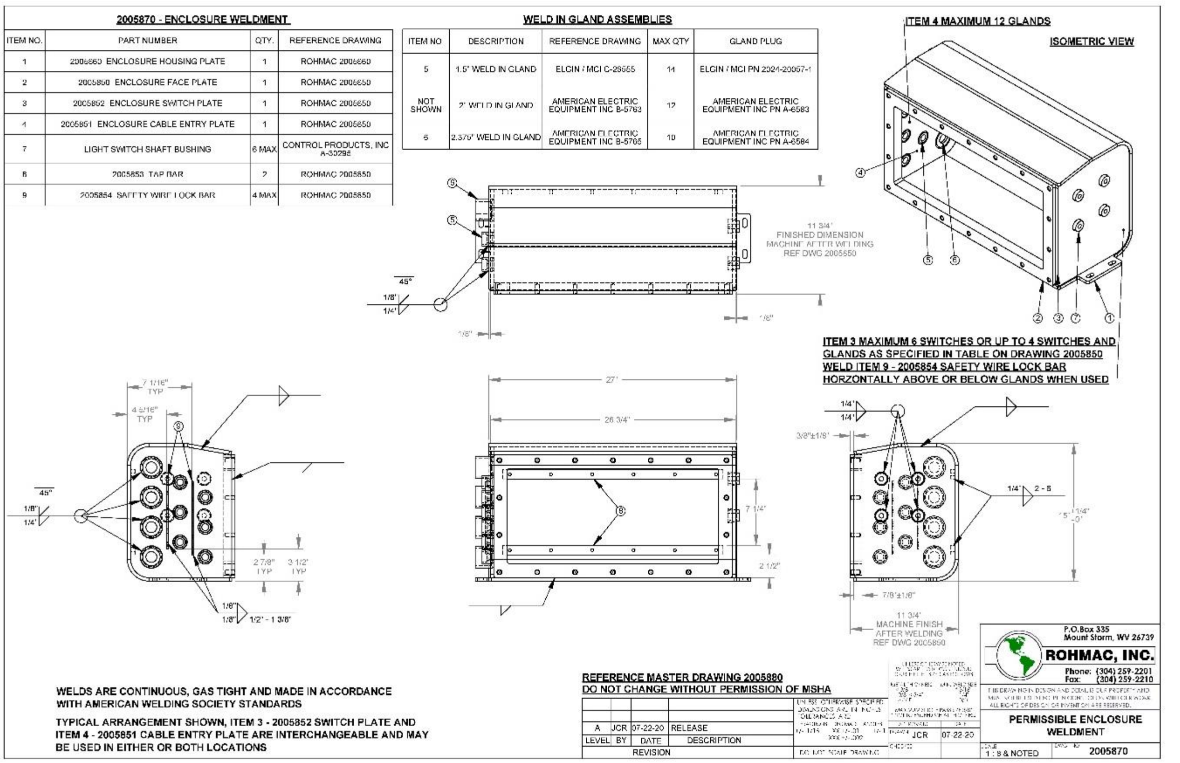


Figure 115 - Revised XP Enclosure Weldment Drawing

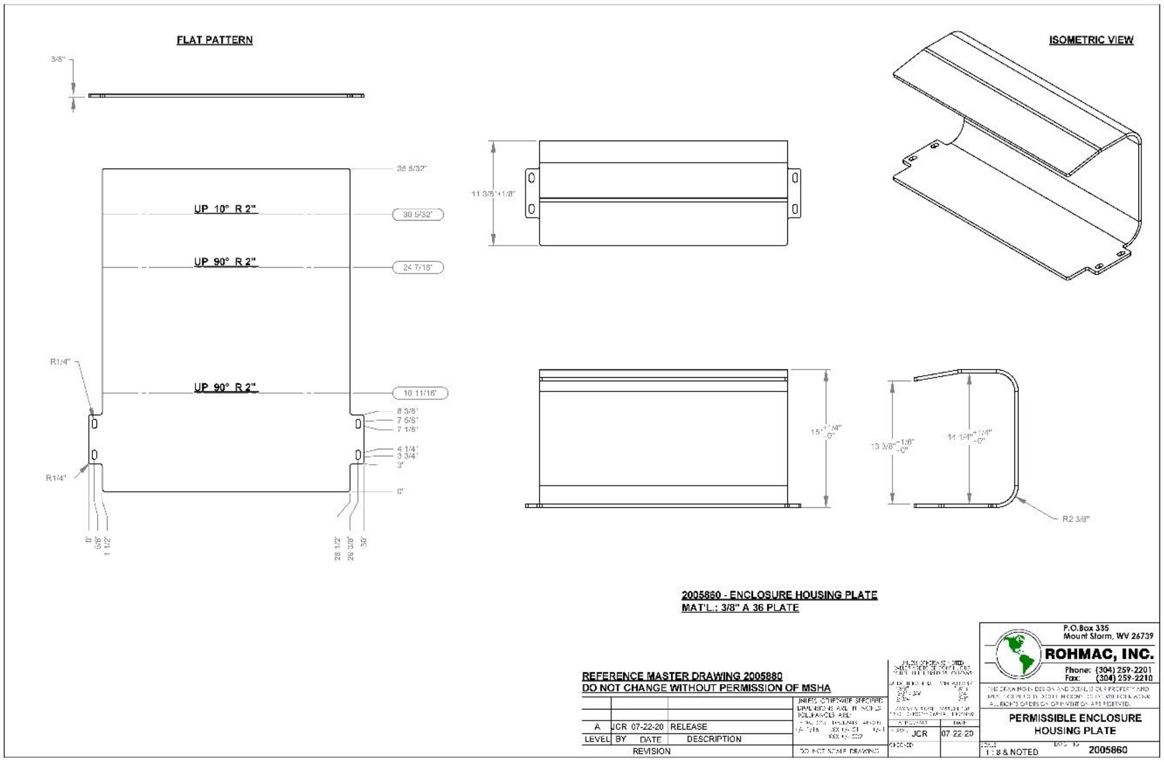


Figure 116 - Revised XP Enclosure Housing Plate Drawing

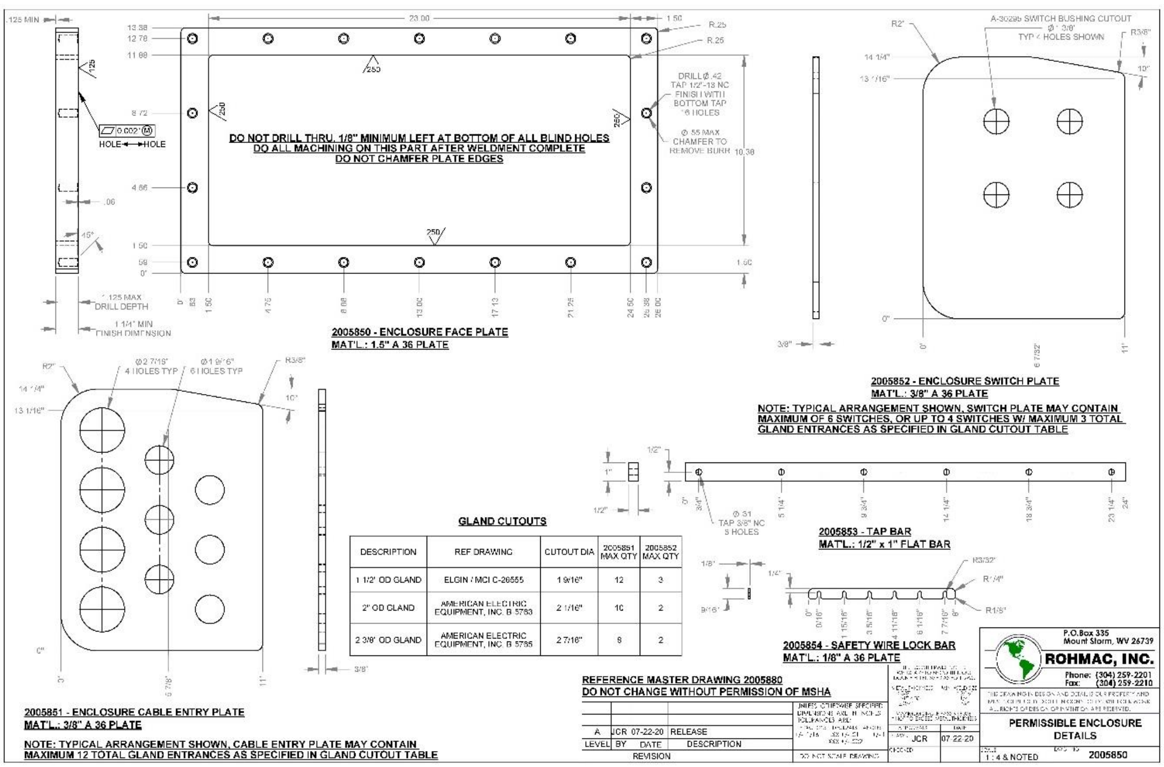


Figure 117 - Revised XP Enclosure Detail Drawing

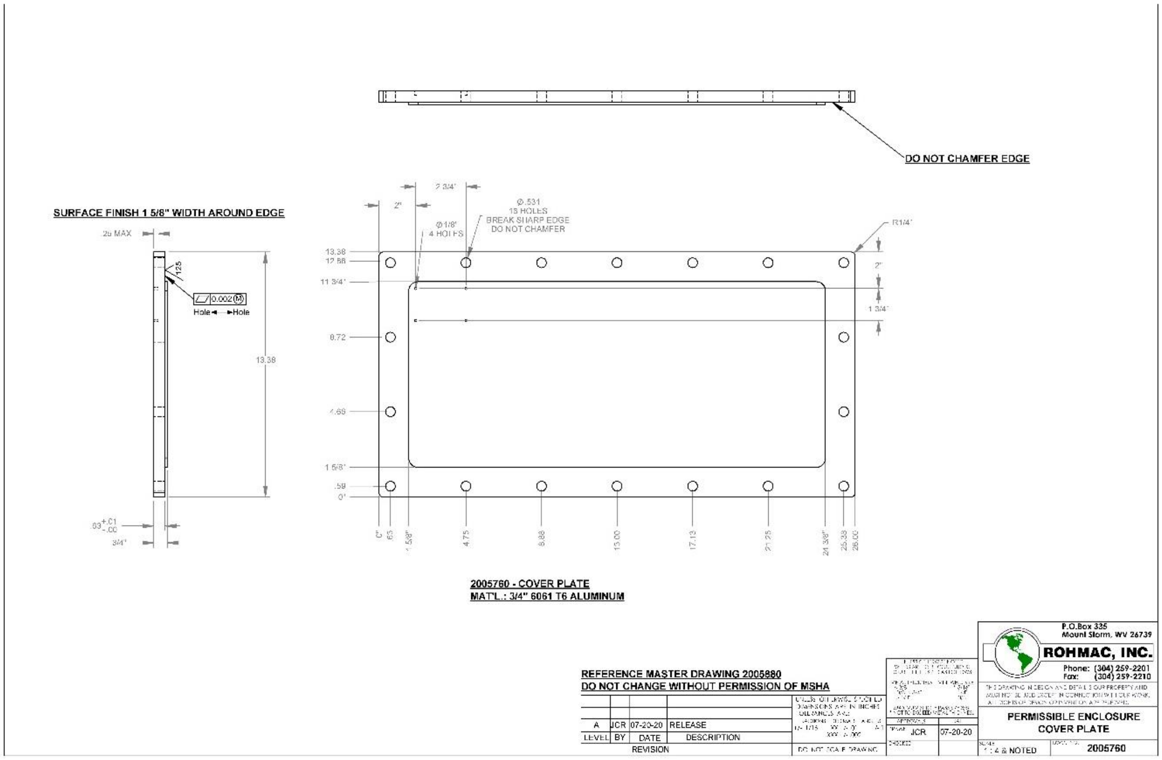
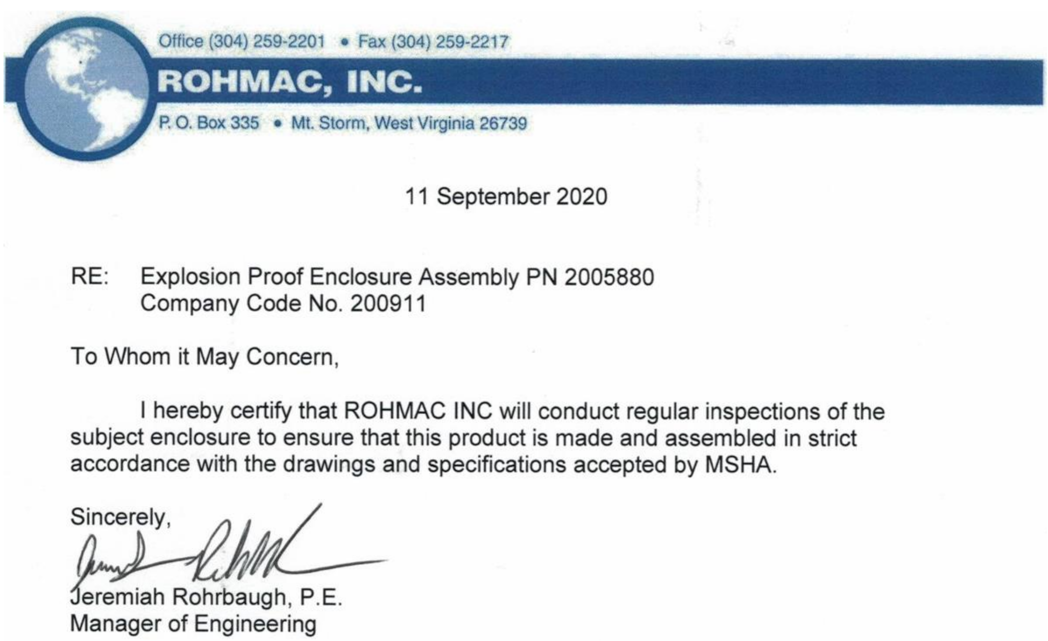


Figure 118 -Revised XP Enclosure Cover Plate Drawing



Office (304) 259-2201 • Fax (304) 259-2217

ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

11 September 2020

RE: Explosion Proof Enclosure Assembly PN 2005880
Company Code No. 200911

To Whom it May Concern,

I hereby certify that ROHMAC INC will conduct regular inspections of the subject enclosure to ensure that this product is made and assembled in strict accordance with the drawings and specifications accepted by MSHA.

Sincerely,

Jeremiah Rohrbaugh, P.E.
Manager of Engineering

Figure 119 - Revised XP Enclosure Certified Statement of Inspection

MSHA conducted additional review of the revised drawings, and on 27 October 2021, a discrepancy letter containing a list of 12 necessary clarifications and corrections was received. One of the issues was the callout of a switch operator and shaft, in that the listed components did not match the drawings MSHA had on file for these parts. The supplier of these parts was contacted, and it was requested that they contact the MSHA representative to discuss the matter and provide the correct information needed for the application drawings. After these discussions, it was decided that it would be best to create a new drawing to specify these components. One reason for this decision was that the shaft gets machined by the end user to receive a set screw for securing the switch operator, and the design of the enclosure can influence the dimensions of this modification. Therefore, it was prudent for the drawings of these parts to be developed by the enclosure manufacturer for proper quality control. Another change involved the size of the approval tag being increased to the same size as the tag used for the diesel power package, for commonality of parts. The changes to the XP Enclosure approval application drawings were completed and returned to MSHA on 11 November 2021, and these documents are attached in Appendix A. A copy of the discrepancy letter with explanation of the corrective measures applied is as follows:

List of Discrepancies

ROHMAC, Inc.
Model 2005880 Explosion Proof Enclosure Assembly

PAR No. 116463

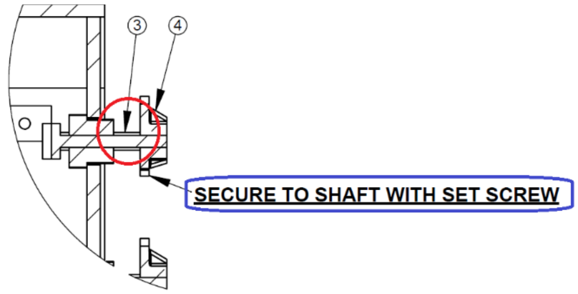
Drawing 2005880 – Permissible Enclosure Assembly

1. Item 3 – The Precision Design aka American Electric Equipment, Inc drawing B-501-3 is not a drawing on file with MSHA. This switch assembly cannot be evaluated until a shaft is specified.
   Have created Rohmac drawing 2106150 to specify this item

2. Item 4 – The company (Controls Products, Inc) listed for the “Switch Operator” still does not match the drawing we have on file.

Have created Rohmac drawing 2106150 to specify this item

3. Detail J – The Item 3 indicator does not look like it is pointing to the shaft (circled in **Red**). What is this part of the assembly? Update so that Item 3 is pointing at the shaft.



DETAIL J
SCALE 1 : 4

The cut line on the section drawing was not on the center of the shaft, so the arrow does point to the shaft, however the sectioned cut is between the viewer and center of the shaft, so the outside line of the shaft appears to be a collar or larger than the bushing sleeve. Have moved the section line closer to shaft center to clean up view.

4. Detail J - The added note (circled in **Blue**) above is not enough information.

    a. The handle (Item 4 – XP Switch Operator) does not appear to be machined for a set screw to secure to shaft. More details must be given to determine how a set screw is securing this handle to the shaft.
    b. Set Screw must be specified.

Have shown machining of shaft and handle on Rohmac drawing 2106150, added set screw specification to callout

Drawing 2005870 – Permissible Enclosure Weldment

5. Weld In Gland Assemblies

    a. Remove the reference to the MCI gland part number. We do not track parts by part number. Reference the gland drawing because the plug is specified on it.
    b. Remove the 'PN' in front of the number for the American Electric Equipment Inc. These are drawing numbers not Part Numbers.

Reference the gland drawing Elgin/MCI C-26555

WELD IN GLAND ASSEMBLIES

ITEM NO.	DESCRIPTION	REFERENCE DRAWING	MAX QTY	GLAND PLUG
5	1.5" WELD IN GLAND	ELGIN / MCI C-26555	14	~~ELGIN / MCI PN 2024-20057-1~~ Remove
NOT SHOWN	2" WELD IN GLAND	AMERICAN ELECTRIC EQUIPMENT INC B-5763	12	AMERICAN ELECTRIC EQUIPMENT INC PN A-6583
6	2.375" WELD IN GLAND	AMERICAN ELECTRIC EQUIPMENT INC B-5765	10	AMERICAN ELECTRIC EQUIPMENT INC PN A-6584

These are not Part Number (PN). These are drawing numbers.

Have changed to drawing numbers as shown, removed 2" gland see below

6. The weld is shown for Item 6 (2.375" gland) and the weld is specified for the 1.5" gland on the gland drawing, but no weld information is given for the 2" gland (not shown). This information must be added.

After review, items 5 and 6 encompass the range of cable we intend to use on this enclosure, so the 2" gland has been deleted as an option

7. Is horizontally correct? Should it be vertically like the Cable Entry Plate side? This is just a clarification.

ITEM 3 MAXIMUM 6 SWITCHES OR UP TO 4 SWITCHES AND
GLANDS AS SPECIFIED IN TABLE ON DRAWING 2005850
WELD ITEM 9 - 2005854 SAFETY WIRE LOCK BAR
HORZONTALLY ABOVE OR BELOW GLANDS WHEN USED

Removed notation for location

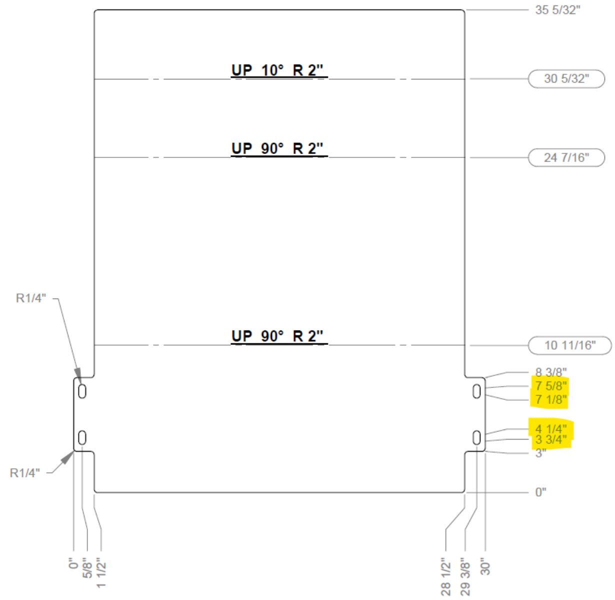
8. Further clarification is needed for the information added to the note below. After reviewing on the drawings, this note does not correspond with other drawing information. How could the plates be used on both sides? The other drawings are very specific the maximum number of glands. Adding "both locations" to this makes this contradict the Weld In Gland Assemblies chart on this page and the BOM switch quantity on Drawing No. 2005880.

TYPICAL ARRANGEMENT SHOWN, ITEM 3 - 2005852 SWITCH PLATE AND
ITEM 4 - 2005851 CABLE ENTRY PLATE ARE INTERCHANGEABLE AND MAY
BE USED IN EITHER OR BOTH LOCATIONS

Removed notation for both

Drawing 2005860 – Permissible Enclosure Housing Plate

9. What are the highlighted dimensions below trying to show? The outer edges of the slot? Or the center of each hole that is being drilled to create the slot? The lines do not seem to match up

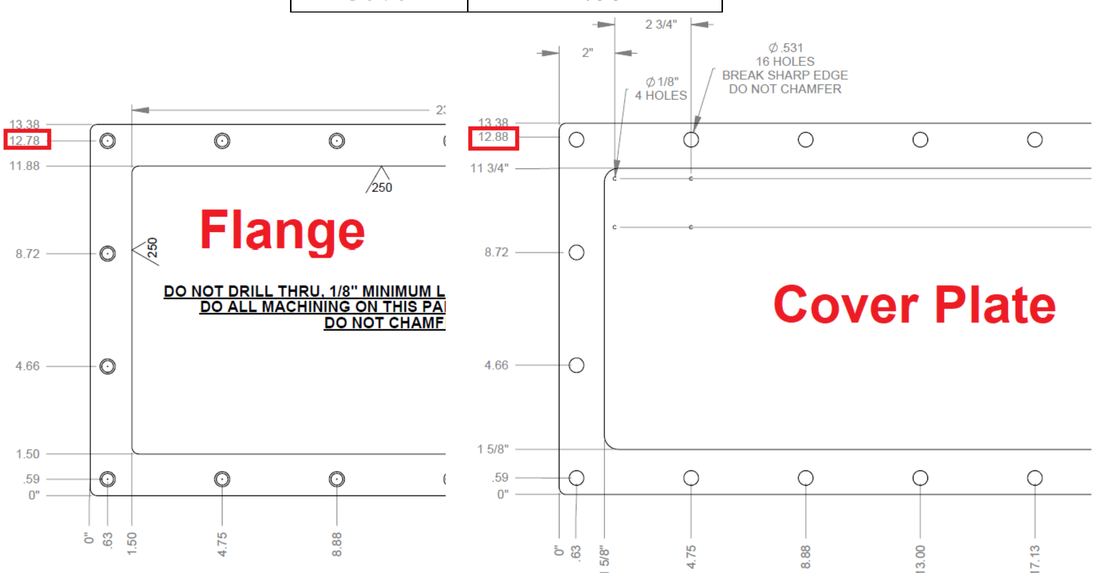


These show the hole centers used to create the slots

Drawing 2005760 – Permissible Enclosure Cover Plate

10. The "top vertical bolt" location was not corrected from previous discrepancy. The flange and cover bolt location does not match.

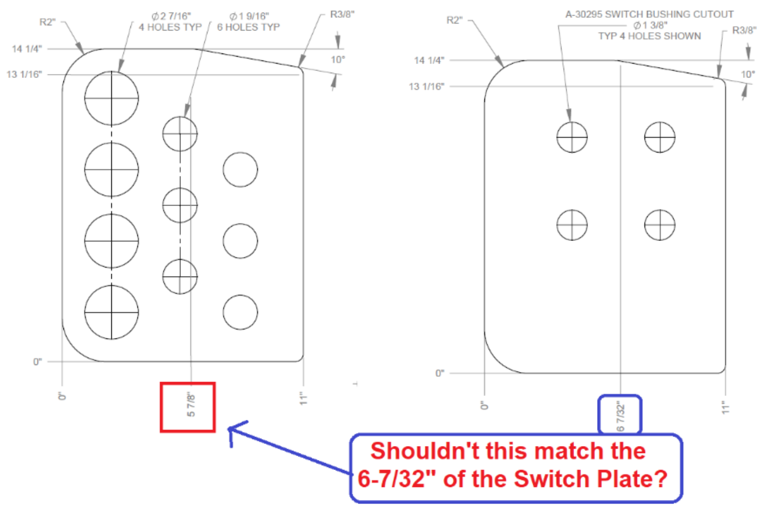
	Top Vertical Bolt
Flange	12.78"
Cover	12.88"



The cover dimension had grabbed something off of the center of the hole, corrected dimension

<u>Drawing 2005850 – Permissible Enclosure Details</u>

11. What is the 5-7/8” dimension circled below Cable Entry Plate? If it’s the angle of the plate, shouldn’t it match the dimensions on the Switch Plate?



Dimension was on opposite sides of a radius, corrected dimension to match

12. The tap depth must be specified. In the previous version of the drawing it was listed as 0.98 in, but this has been removed and a maximum drill depth has been added.

Added tap depth callout

During a phone conversation with an MSHA representative on 10 November 2021, the future timeline of the enclosure approval process was discussed; it was explained that once the drawings were approved, a request would be sent with specifications for the test prototype. It was then necessary to build and supply the prototype to MSHA. It was mentioned that testing typically required a day of measuring and inspecting the enclosure, then 3-5 days for explosion testing. It was discussed that while much of the approval work could be finished within the 2021 calendar year in a best-case scenario, that it would most likely continue into the next year.

On 24 November 2021, during a virtual meeting with MSHA representatives regarding the Diesel Electric Approval proposal, concerns about the battery were raised. Of primary concern was maintaining the explosion proof integrity of an XP enclosure should a battery thermal event occur, due to fire, and gas releases resulting in substantial pressure increases that have been reported in some tests. It was mentioned that modifications to the XP enclosure would be necessary to house a battery, such as adding a flame arrestor vent to allow gases to escape. A decision was made by MSHA to table the approval evaluation of the XP Enclosure until the concerns with the battery could be addressed. Due to the delay, a no cost time extension through 31 August 2022 was requested and granted.

Following the meeting on 24 November, research was done into available battery chemistry, battery thermal events, and possible flame arrestor modifications to the enclosure. One discussion point indicated a desire to know the free volume inside of the enclosure, and that at least a 10:1 ratio of free space to battery volume would be necessary to allow for expansion of gases vented during a thermal event. A calculation estimate was performed, and indicated that the free space was approximately 2500 cu in. The volume of the battery case proposed at the time was approximately 104 cu in. On 18 May 2022, a phone discussion was held with MSHA representatives about the system and it was explained that placing a battery inside of a XP enclosure was undesirable, so a recommendation was made, to consider building and approving a separate Part 7 battery enclosure to house the battery on the machine. This approach was advised as the most expeditious method to allow the XP enclosure evaluation to proceed, and simplify the approval process. At that time, investigation and design on a Part 7 battery enclosure was started. More details on the battery are discussed later in the report. While the approval application for the explosion proof enclosure was developed, and given priority, the diesel power package was concurrently developed, and an assembly was built for approval testing purposes.

DIESEL POWER PACKAGE TEST APPARATUS

In preparation for submitting the diesel power package approval application, a test engine assembly was fabricated for the necessary MSHA approval testing. Once the test unit was completed, preliminary testing and break-in of the engine were performed before the apparatus was taken to MSHA A&CC. Figure 120 shows the test unit, which consisted of the diesel engine with cooling, intake, and exhaust systems, mounted on a skid that adapted to a dynamometer test bed.

Figure 120 – Test Engine Unit

In order to install the exhaust system, the electrical starter had to be relocated to the other side of the engine, which required modification of the starter mounting plate. The test unit was permitted to use the OEM electric starter to simplify the laboratory testing process. Also visible in the picture was the flywheel adapter plate that was built to attach the engine flywheel to the dynamometer driveshaft. Figure 121 shows the exhaust manifold during installation. The fasteners and locking devices mentioned previously in this report are shown in the picture. The 7 mm nuts used on this engine were specialty copper fasteners, that had to be sourced by the lock manufacturer. Teardrop profile tabs, having a multipoint pattern that engages the hex nut, were placed over the manifold nuts after they were properly torqued, and they prevented the nut from turning by contacting the machined ledge on the manifold plate. Retainer clips were installed in a groove on the nuts, and held the locking tabs in place. Figure 122 shows the finished installation of the exhaust manifold. Also visible in the pictures were the exhaust sample port in the upper left, and the baffle plates against the wall of the chamber, note that the baffle openings alternated top and bottom as the baffles move close to the viewer.

Figure 121 - Exhaust Manifold Locking Nuts

Figure 122 - Exhaust Manifold Installed

Figure 123 shows the test unit stand from the exhaust exit side, the exhaust flame arrestor was visible in the lower right of the figure. The radiator was located in the middle of the picture, and the air intake filter, shutdown actuator, and coolant expansion tank were visible on the left side. The radiator cap was slightly lower than the pressure cap on the exhaust system, and the lines from these points to the expansion tank were connected together. Figure 124 shows a view of the test unit from the air intake side. The temperature sensor for the exhaust tank was visible in the upper left, and the coolant line from the radiator to the exhaust system was clamped to a bracket to secure it from movement. The intake flame arrestor and intake manifold were shown near the center, the intake shutdown device was attached to the flame arrestor, and a 90-degree reducer elbow connected the device to the air filter housing.

Figure 123 – Complete Test Engine Assembly Front View

Figure 124 – Air Intake Side of Test Engine Assembly

Once fabrication and assembly were complete, a 50-hour engine break-in operation was performed, during this time the engine speed and load were varied periodically. In order to perform this operation, alterations were made to the test unit. These modifications included making a flywheel adapter, and mounting a hydraulic pump to the engine with a torque arm, as well as adding a hydraulic tank and fittings, to connect to the load test unit that was used to control the engine loading. A manual throttle cable was installed to control the engine speed setting, and a vibration activated hour meter was installed to track the hours on the engine.

Preliminary testing of the device returned positive results, and operating parameters were within desired limits. A 20-minute full load scenario was conducted as part of the break in operation, and later, a 1-hour full load test was performed. To set the loads during the operation (an ECOM gas analyzer was used to sample the raw engine exhaust), the engine was placed at high idle, and load was increased until exhaust gases were indicative of a fully loaded engine. Data observed during this test were as follows: exhaust backpressure was approximately 35 inches of water as measured with a dial indicator gage, manifold exhaust temperature was approximately 1000 °F, cooled exhaust gas temperature was approximately 174 °F as measured with thermocouples in both exhaust streams, the coolant temperature at the engine exit appeared to be most nearly 180 °F, and the maximum exhaust surface temperature was most nearly 230 °F as measured with an IR temperature gun.

At or near 37 hours of total engine time as recorded on the hour meter, an oil residue was observed on the radiator fins, and a small leak was detected. After a short investigation, it was determined that the hose clamp on the coolant exit line of the exhaust cooling system had been in contact with the oil filter, and that vibration had caused a hole to form in the oil filter housing. Whereas the engine had been operated for over half of the break-in period, the decision was made to change the engine oil and filter with 10w30 oil, as recommended by the manufacturer's manual. The clamp was re-oriented such that it did not contact the oil filter. A small adjustment to the location of the coolant exit port on the exhaust cooler was made to prevent this problem in the future. A soap and water cleaning of the radiator was also performed to attempt to remove the oil residue from the radiator core. The engine was returned to operation.

At or around 45 total engine hours, a residue was observed on the inner wall of the exhaust pipe, and also on the radiator. Full load testing performed also showed that as the engine temperature increased, the Carbon Monoxide levels in the raw exhaust, measured with an ECOM analyzer sampling at the raw exhaust port, began to increase. Discussion of the observations led investigators to believe that the engine could have been burning some engine oil residue and that the exhaust filter may have been compromised. The decision was made to remove the exhaust filter lid and examine the filter. The examination concluded that exhaust was bypassing the filter, and that the copper gaskets used for the filter and filter bonnet were insufficient to seal the exhaust gases, and force them through the filter. The filter itself appeared to be in good shape. A level 1 cleaning of the filter was performed by blowing compressed air through the filter media in the direction opposite exhaust flow, as recommended by the filter manufacturer's manual. It was discovered that the filter housing had bolts that protruded above the gasket sealing surface, and caused the filter not to seat to the gasket. The protrusions were ground smooth and an attempt was made to reinstall the filter. At startup, it was evident that the gaskets were still not providing a sufficient seal. Two new gaskets were fabricated from a thin ceramic high temperature gasket material and installed to test, but they also were unable to form a seal. Two additional gaskets were fabricated using a graphite gasket material, with a history of use on some other exhaust systems, and upon testing, these sealed the exhaust. This graphite material was thicker than the copper or ceramic gaskets and was readily available, although it was a very fragile material and required careful handling. The material spec on the drawing was changed and spare gaskets were ordered. During this time, discussion about the engine heat during the 1-hour full load test raised concerns about oil breakdown and bypass, due to viscosity loss. The engine manufacturer's manual lists 10w30 or 15w40 oil weights for high ambient temperature operation. The decision was made to drain the 10w30 oil and replace it with a 15w40 oil to attempt to improve operation during the full load test. The engine was returned to operation to complete the break-in period.

At approximately 49 hours of engine operation a coolant leak was observed from the exhaust cooling assembly. Investigation determined that the leak occurred at a weld seam at the 12 o-clock position above the exhaust manifold, where the top lid of the exhaust cooler welds to a vertical plate. This appeared to form at a location where a weld was started, and may have also been a high stress area. The leak was repaired, and steps were taken to reduce the vibration and stress on the exhaust system.

The engine was operated to ensure that the leak was repaired, and an attempt was made to perform an additional full load operation. On 26 June 2020, at approximately 54 hours of engine operating time, the keyway on the hydraulic pump used to load the engine failed. The keyway failure caused significant damage to the pump shaft and coupler, such that repairs to return to service were not reasonable. At the time of the failure, the engine was operating near full load. Figure 125 shows a reading from the ECOM exhaust gas analyzer measuring the raw exhaust during this test. The Oxygen level is shown at 9.5% and the Carbon Monoxide reading is 692 ppm. This analyzer displayed a calculated Carbon Dioxide value of 8.4%. Figure 126 shows a reading from the Omega temperature instrument during this test. The instrument was displaying measurements from two J-type thermocouples. T2 was located in the raw exhaust stream and was nearly 930 °F, T1 was the cooled exhaust gas and was nearly 150 °F.

Figure 125 - Raw Exhaust Gas Reading

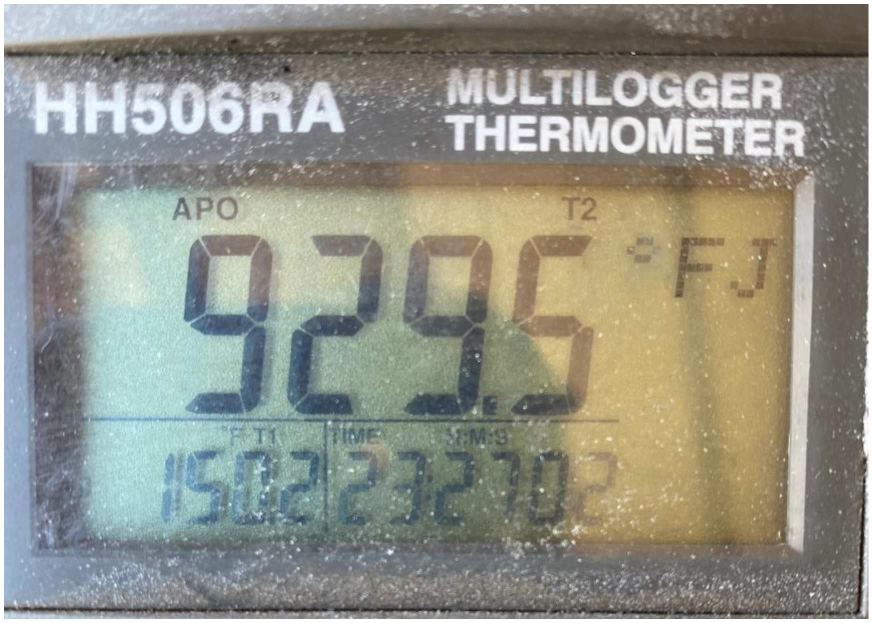


Figure 126 - Exhaust Gas Temperature Reading

After completing the engine break-in, an MSHA representative was contacted to discuss the progress. Prior to this conversation, MSHA had mentioned that their small engine dynamometer was out of service and in need of repairs. During this discussion, it was stated that the dynamometer repairs had been completed, and that it was operational. (The time needed to complete the dynamometer repair process was a significant contributor to a nine-month project extension request, that was enacted on 13 February 2020.) It was also mentioned, however, that due to the COVID-19 pandemic, that staff continued to work remotely and had not returned to normal on-site schedules, which affected the ability to schedule a meeting or perform testing. It was discussed that, when possible, a meeting to look at the prototype test unit and discuss any necessary changes would be beneficial to the approval process. During the discussion it was mentioned that due to the small size of this engine, the fasteners on the cylinder head for the intake and exhaust manifolds were smaller than the diameter listed by regulations. A hydrostatic test of the cylinder head and intake and exhaust manifolds was therefore necessary to test the fasteners, and prove that they were suitable to meet the requirements of permissible equipment.

It was explained that the hydrostatic test involved pumping water up to 150 psi into the intake and exhaust, and checking for deformation. The function of the test is to ensure that the pressure capacity of the components, that form the explosion proof system between the intake and exhaust flame arrestors, is adequate. During the test 150 psi water pressure is applied to an assembly for 10 seconds, and there must not exhibit a leak; change torque on, deform, or stretch any fasteners; crack or fail any welds, or exhibit any permanent deformation to any flame arresting path. As this test would otherwise require the removal of the cylinder head from the engine, and water being normally detrimental to interior engine components, the decision was made to procure a new cylinder head, and fabricate a new test apparatus assembly to perform the hydrostatic test. It was also later determined that the exhaust portion of the hydrostatic test apparatus needed only comprise the actual exhaust piping and that the outer panels of the cooling enclosure were not necessary. As well, the exhaust treatment filter did not need to be included in the test apparatus, as it did not contribute to any system flame path structure. Ported seal plates were fabricated and bolted to the flame arrestors to enable the hydrostatic pressure application. Additionally, a seal plate was made for the cylinder head to hold the intake and exhaust valves shut, to allow pressurization of the intake and exhaust volumes. The goal was to have the hydrostatic test apparatus assembly prepared, such that it could also be reviewed during the aforementioned MSHA meeting with the diesel power package test unit.

On 12 November 2020, the hydrostatic test unit, as well as the diesel power package test unit, were taken to MSHA A&CC to perform preliminary testing and review of the devices. A hydrostatic test of the intake and exhaust systems was performed to verify the strength of the components used in the design. The test apparatus filled the system with water to eliminate air, and pressurized the water to 150 psi for 10 seconds. Flame paths were measured with feelers gages before and after the pressure tests, to ensure there was no deformation that could open a flame path. Figure 127 shows a picture of the water line hooked to the intake side of the test unit during the test. Figure 128 shows the test apparatus during the test, the hydrostatic pump used to pressurize the system was visible near the center of the picture

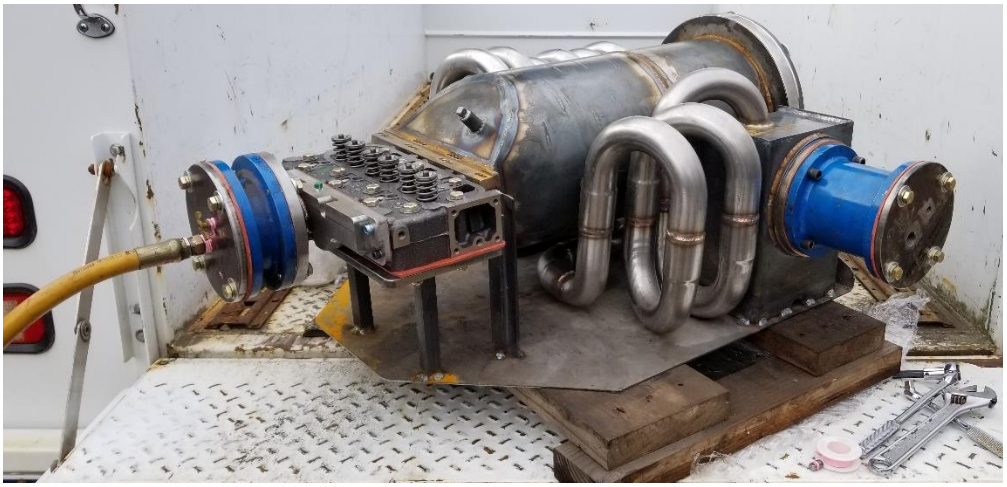


Figure 127 - Hydrostatic Test Unit Intake Side Test


Figure 128 - Hydrostatic Test Apparatus During Intake Side Test

Figure 129 shows the hydrostatic test pump during a test. The picture displayed the adjustment of system pressure by turning a bypass valve closed, and a pressure on the gage of approximately 150 psi. Figure 130 shows the test apparatus installed on the exhaust side of the test unit.

Figure 129 - Hydrostatic Test Pump

Figure 130 - Test Apparatus on Exhaust Side

Figure 131 - Exhaust Side Hydrostatic Test

Figure 131 shows the test unit during the hydrostatic test. Note that the test unit was placed on an incline to elevate the exhaust exit, which ensured that air was completely evacuated from the system. It was necessary to remove all air prior to pressurizing the water, as compressed gas inside of the system could have created a safety hazard. The picture also shows the use of a video camera that was used to record the tests. The test results indicated that the system fasteners were sufficient to meet the necessary performance criteria. After the tests were performed, there was a general discussion and review of the design, and the diesel power package. It was indicated that the test unit appeared ready and complete for performing the necessary tests, and it was therefore decided to leave the diesel engine test unit at the laboratory.

Revisions to the diesel power package design and drawings were discussed and included adjustment of tolerances and ensuring correct specifications. The copper gaskets used on the power package were discussed, and it was mentioned that the thinner gaskets tended to not maintain seals as well as thicker materials. It was mentioned that the gaskets used on the engine manifold must be made of or reinforced by metal. The OEM exhaust manifold gasket was inspected and deemed acceptable. Additionally, fabrication procedures for the intake and exhaust weldments were discussed, and it was advised to specify machine finishing of the sealing surfaces after weldments were completed. This modification served to reduce or eliminate any distortion caused by welding.

Research was conducted, and another gasket material was found for the intake manifold, and exhaust filter and bonnet gaskets. Initially the gaskets were a 0.040" thick copper, they were changed to a 0.078" thick CS-830 graphite / fiber material with metal tang. Figure 133 shows a specification sheet for the updated gasket material. This material was rated for 1400 °F, and was less fragile than the graphite gaskets that were previously discussed and tested on the exhaust filter. After review and consideration of this material, it was decided to replace the other system gaskets for commonality. Figure 132 shows a picture of the updated exhaust filter, flame arrestor, and intake gaskets.

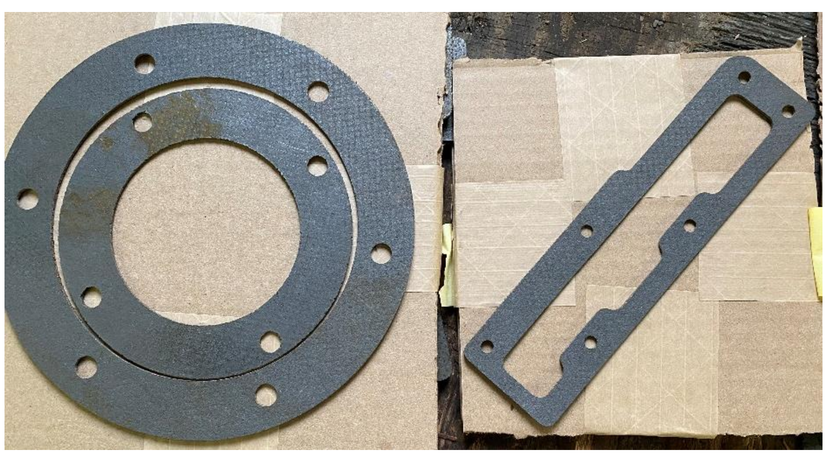
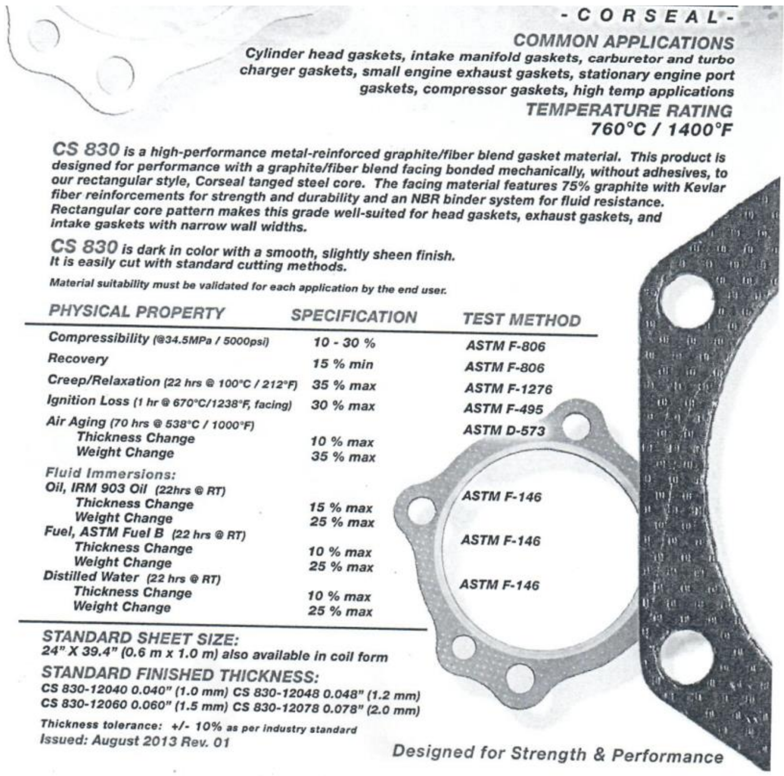


Figure 132-Exhaust and Intake Gaskets



- C O R S E A L -

COMMON APPLICATIONS

Cylinder head gaskets, intake manifold gaskets, carburetor and turbo charger gaskets, small engine exhaust gaskets, stationary engine port gaskets, compressor gaskets, high temp applications

TEMPERATURE RATING

760°C / 1400°F

CS 830 is a high-performance metal-reinforced graphite/fiber blend gasket material. This product is designed for performance with a graphite/fiber blend facing bonded mechanically, without adhesives, to our rectangular style, Corseal tanged steel core. The facing material features 75% graphite with Kevlar fiber reinforcements for strength and durability and an NBR binder system for fluid resistance. Rectangular core pattern makes this grade well-suited for head gaskets, exhaust gaskets, and intake gaskets with narrow wall widths.

CS 830 is dark in color with a smooth, slightly sheen finish. It is easily cut with standard cutting methods.

Material suitability must be validated for each application by the end user.

PHYSICAL PROPERTY	SPECIFICATION	TEST METHOD
Compressibility (@34.5MPa / 5000psi)	10 - 30 %	ASTM F-806
Recovery	15 % min	ASTM F-806
Creep/Relaxation (22 hrs @ 100°C / 212°F)	35 % max	ASTM F-1276
Ignition Loss (1 hr @ 670°C/1238°F, facing)	30 % max	ASTM F-495
Air Aging (70 hrs @ 538°C / 1000°F)		ASTM D-573
Thickness Change	10 % max	
Weight Change	35 % max	
Fluid Immersions:		
Oil, IRM 903 Oil (22hrs @ RT)		ASTM F-146
Thickness Change	15 % max	
Weight Change	25 % max	
Fuel, ASTM Fuel B (22 hrs @ RT)		ASTM F-146
Thickness Change	10 % max	
Weight Change	25 % max	
Distilled Water (22 hrs @ RT)		ASTM F-146
Thickness Change	10 % max	
Weight Change	25 % max	

STANDARD SHEET SIZE:
24" X 39.4" (0.6 m x 1.0 m) also available in coil form

STANDARD FINISHED THICKNESS:
CS 830-12040 0.040" (1.0 mm) CS 830-12048 0.048" (1.2 mm)
CS 830-12060 0.060" (1.5 mm) CS 830-12078 0.078" (2.0 mm)

Thickness tolerance: +/- 10% as per industry standard
Issued: August 2013 Rev. 01

Designed for Strength & Performance

Figure 133 - CS 830 Specification Sheet

In addition to new gasket material, minor changes were made to the intake manifold, and a new manifold was fabricated for the diesel power package test unit. These changes were made to utilize the same 6mm x 20 mm length screws in every location on the manifold, this prevented the wrong bolt from being used in a location, and either insufficient thread engagement or bottoming out of the bolt, which would compromise the explosion proof joint. Also, the finish machining of the manifold side of the plate was specified to be performed after completing the weldment, to compensate for any heat induced distortion. Figure 134 shows a picture of the new intake manifold plate with recessed pockets for bolt heads.

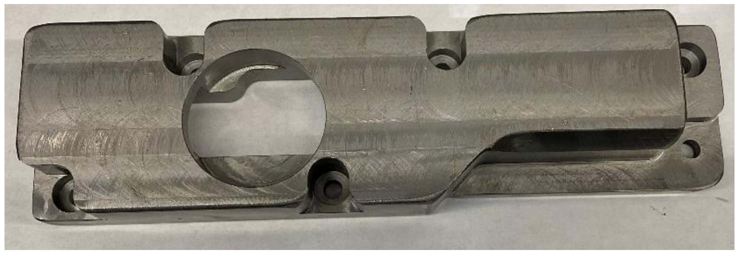


Figure 134 - Intake Manifold Plate

On 17 March 2021, the contractor travelled to MSHA A&CC test lab to install the updated intake manifold on the test engine, and assist in placing the engine on the small engine dynamometer. Figure 135 shows a picture of the original (bottom) and replacement (top) intake manifolds. The recessed bolt hole is visible on the top right corner of the new intake manifold. The new intake manifold gasket was also installed.

Figure 135 - Intake Manifolds

Figure 136 shows the new intake manifold installed on the test engine, Figure 137 shows a close-up of the intake manifold and gasket.

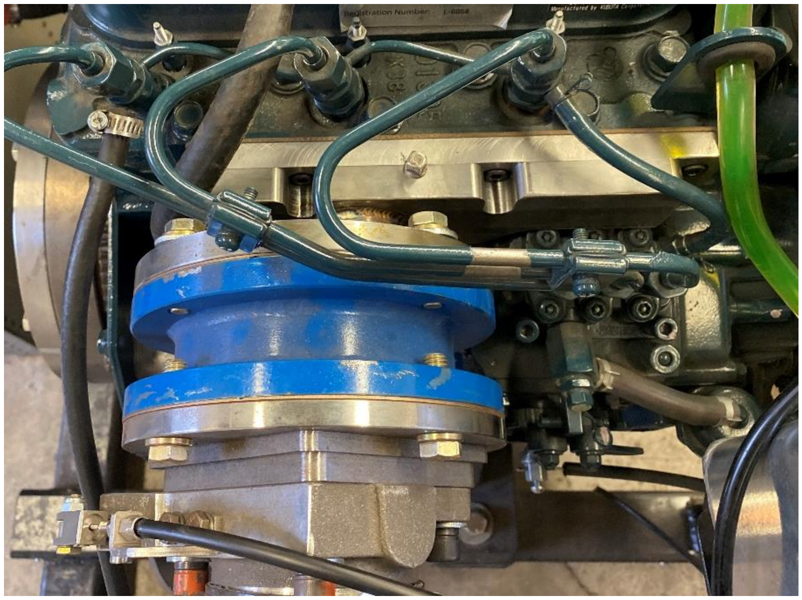


Figure 136 - Intake Manifold Installed

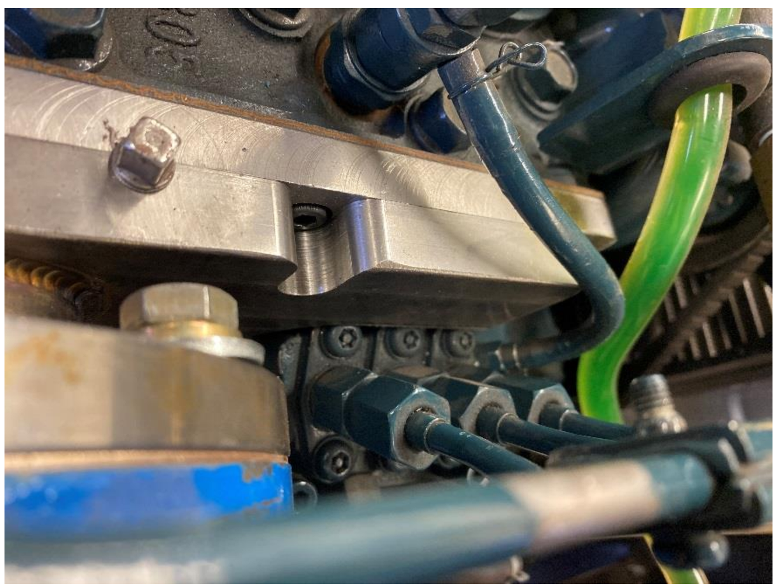


Figure 137 - Intake Manifold Installed Close-up

During the intake manifold replacement work, MSHA representatives prepared the small engine dynamometer to install the test engine. Once this work was complete, the power package test unit was placed onto the dynamometer test bed, and connections needed to operate the engine were made. It was also decided to remove the catalytic converter / dpm filter assembly and install the catalytic converter only device, to prevent damage to the dpm filter during initial tests. An initial startup was performed to check the engine and dynamometer functions, and the systems appeared to operate normally. Figure 138 shows the test unit installed on the dynamometer stand.

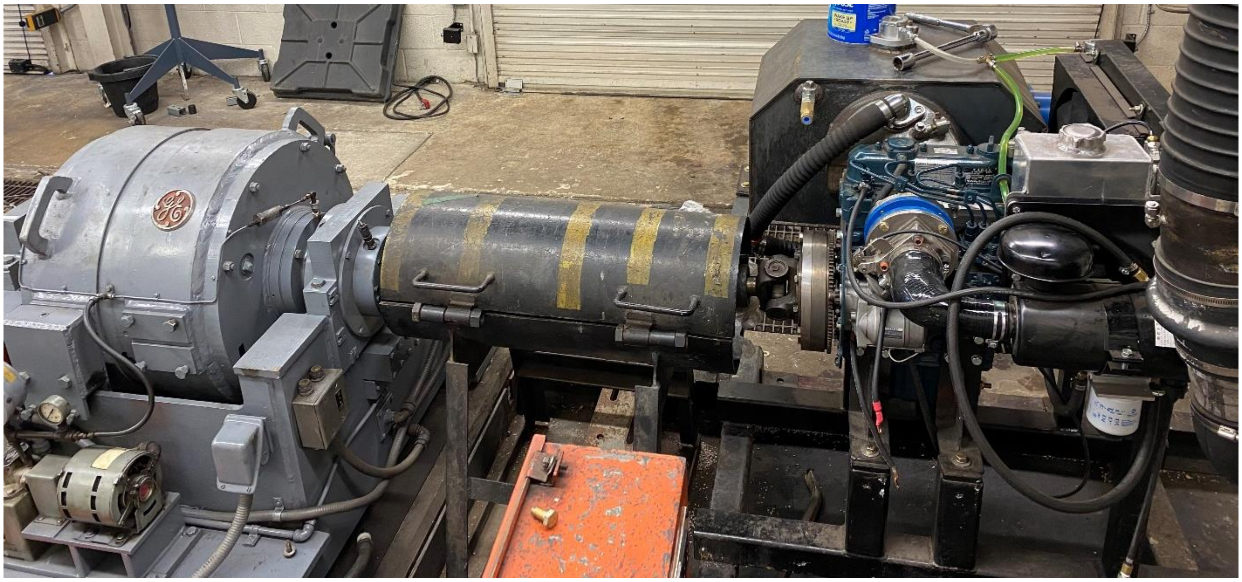


Figure 138 - Test Engine Dynamometer Installation

DIESEL ENGINE AND POWER PACKAGE APPROVAL WORK

During the development of the test apparatus, the drawings and application documentation for the power package were also reviewed by MSHA, and revisions based on suggestions from MSHA representatives were performed. Documentation included drawings of the power package, intake and exhaust systems, and cooling system, as well as specifications of components, and a permissibility checklist. The power package application documents were formally submitted on 4 March 2021. PAR 116566 was the identification number issued for this approval evaluation by MSHA. The application documents as submitted are attached to this document as Appendix B. A Fee Authorization Letter for this application was received on 8 March 2021, which estimated the cost for this evaluation to be $ 42,000.00. A copy of this letter is shown in Figure 139. The authorization was signed and returned on 9 March 2021 and is shown in Figure 140.

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, WV 26059

Refer to Attn of: MSHA:
A&CC: PAR 116566

March 8, 2021

JEREMY ROHRBAUGH
ROHMAC, INCORPORATED
P.O. BOX 335
MOUNT STORM, WV 26739

Dear Jeremy Rohrbaugh,

We have received your application requesting a Part 7 Subpart F Diesel Power Package Approval, company code 190830, and have assigned PAR number 116566 for our tracking purposes. Based on the information provided with your application, we estimate the maximum fee to conduct this investigation is $42,000.

We have not included any costs for travel in the estimate. You will be charged on an actual cost basis should travel be necessary to evaluate or test your product at the manufacturing or installation site. Also, our estimate does not include repeat testing or evaluation that would result from design changes or test failures during processing. We will contact you should we encounter problems that would cause the fee to exceed the estimate. You will have the opportunity to authorize further action, at additional cost, or cancel the action. We anticipate the action will be fully processed at or below the cost estimate. You will be charged a lesser amount if our actual fee is less than the estimated amount.

You must complete and return the enclosed authorization response form within 30 days of the date of this letter. We will cancel your application if you do not respond within the time period. Please send your response by email, mail, or fax it to us at (304) 547-2071.

You are not to submit payment of any kind at this time. We will bill you for the total cost of processing your application when our work is completed.

Please contact Jeffrey Moninger at 304-547-2324 if you have any questions or comments.

Sincerely,

Jeffrey Moninger

Jeffrey Moninger
Team Leader, Mechanical and Engineering Safety Division

Enclosure: Fee Authorization Response Form

Figure 139 - PAR 116566 Fee Estimate Letter

Fee Authorization Response Form

Date: 9 March 2021

Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

Dear Mr. Moninger:

With reference to my application requesting a Part 7 Subpart F Diesel Power Package Approval, company code 190830, PAR number 116566.

___X___ Please initiate processing at the estimated cost of $42,000.

OR

_______ Please cancel this action.

Signed: Gal Rohrbaugh (VP ROHMAC INC.)

Name

Galen Rohrbaugh, Jr.

Title

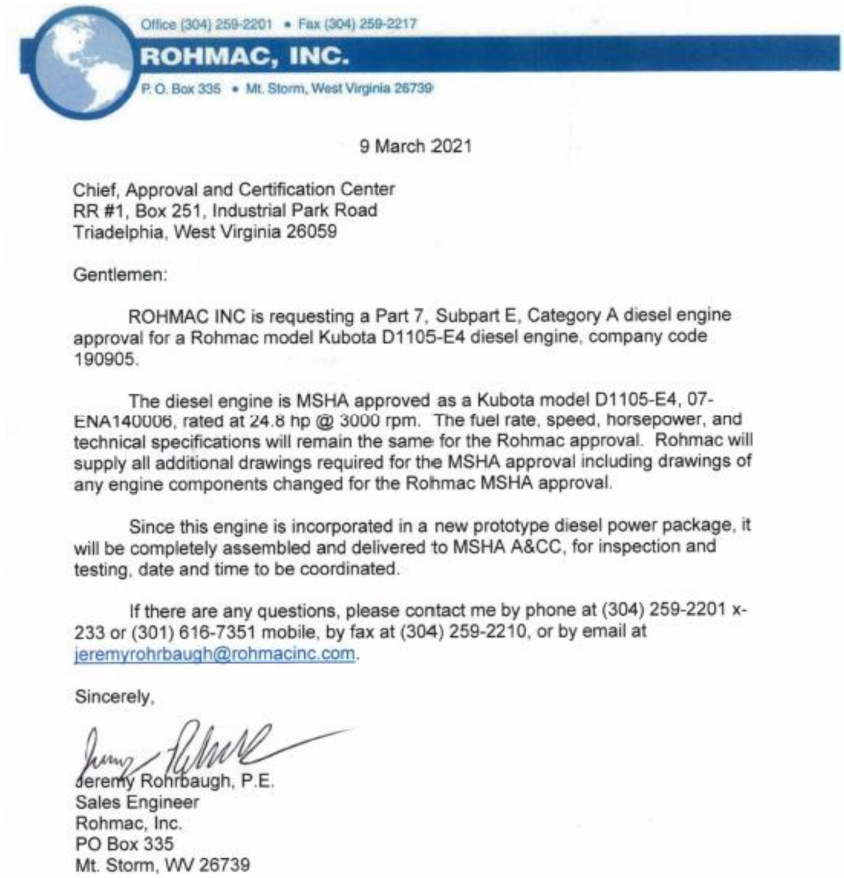
Vice-President

Company

Rohmac Inc.

Figure 140 - PAR 116566 Signed Fee Authorization Form

Throughout the development of the diesel power package, there was uncertainty and delay encountered regarding the approval of the subject engine. In order for the power package to be approved, the engine used in the power package must be issued a part 7A approval, and a ventilation rate determined for use in permissible areas. These approvals were typically applied for and held by the engine manufacturers; however, this engine was not previously approved under 7A. While there was a provision for power package manufacturers to apply for the 7A engine approval, MSHA felt it was prudent to contact the manufacturer of this engine to see if they wished to pursue the approval. It was discussed that the manufacturer did express an interest to MSHA of seeking the 7A engine approval, and therefore time was added to the project to allow for the manufacturer to work through this process. MSHA representatives also suggested that it may benefit both parties if the engine manufacturer and Rohmac could discuss the engine approval, and it was requested that MSHA forward contact information to the engine manufacturer to facilitate such a discussion, but this did not transpire. Therefore, it was later determined that it was in the best interest to move forward with submitting an approval request for the engine separate from the engine manufacturer. The 7A engine approval application was submitted on 9 March 2021 and was assigned PAR 116579. A copy of the application letter is shown in Figure 141.



Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

9 March 2021

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC is requesting a Part 7, Subpart E, Category A diesel engine approval for a Rohmac model Kubota D1105-E4 diesel engine, company code 190905.

The diesel engine is MSHA approved as a Kubota model D1105-E4, 07-ENA140006, rated at 24.8 hp @ 3000 rpm. The fuel rate, speed, horsepower, and technical specifications will remain the same for the Rohmac approval. Rohmac will supply all additional drawings required for the MSHA approval including drawings of any engine components changed for the Rohmac MSHA approval.

Since this engine is incorporated in a new prototype diesel power package, it will be completely assembled and delivered to MSHA A&CC, for inspection and testing, date and time to be coordinated.

If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremy Rohrbaugh, P.E.
Sales Engineer
Rohmac, Inc.
PO Box 335
Mt. Storm, WV 26739

Figure 141 - Engine Approval Application Letter

A fee estimate letter for this approval, shown in Figure 142, was received on 9 March 2021. The amount of the estimate was $ 38,000.00. The fee authorization form was signed and returned on 16 March 2021 and is shown in Figure 143.

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, WV 26059

Refer to Attn of: MSHA:
A&CC: PAR 116579

March 9, 2021

JEREMY ROHRBAUGH
ROHMAC, INCORPORATED
P.O. BOX 335
MOUNT STORM, WV 26739

Dear Jeremy Rohrbaugh,

We have received your application requesting a Part 7 Subpart E Category A Diesel Engine Approval for Rohmac Model Kubota D1105-E4, company code 190905, and have assigned PAR number 116579 for our tracking purposes. Based on the information provided with your application, we estimate the maximum fee to conduct this investigation is $38,000.

We have not included any costs for travel in the estimate. You will be charged on an actual cost basis should travel be necessary to evaluate or test your product at the manufacturing or installation site. Also, our estimate does not include repeat testing or evaluation that would result from design changes or test failures during processing. We will contact you should we encounter problems that would cause the fee to exceed the estimate. You will have the opportunity to authorize further action, at additional cost, or cancel the action. We anticipate the action will be fully processed at or below the cost estimate. You will be charged a lesser amount if our actual fee is less than the estimated amount.

You must complete and return the enclosed authorization response form within 30 days of the date of this letter. We will cancel your application if you do not respond within the time period. Please send your response by email, mail, or fax it to us at (304) 547-2071.

You are not to submit payment of any kind at this time. We will bill you for the total cost of processing your application when our work is completed.

Please contact Jeffrey Moninger at 304-547-2324 if you have any questions or comments.

Sincerely,

Jeffrey Moninger

Jeffrey Moninger
Team Leader, Mechanical and Engineering Safety Division

Enclosure: Fee Authorization Response Form

Figure 142 - PAR 116579 Fee Estimate Letter

Fee Authorization Response Form

Date: 10 March 2021

Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

Dear Mr. Moninger:

With reference to my application requesting a Part 7 Subpart E Category A Diesel Engine Approval for Rohmac Model Kubota D1105-E4, company code 190905, PAR number 116579.

x Please initiate processing at the estimated cost of $38,000.

OR

______ Please cancel this action.

Signed: (V.P ROHMAC Inc.)

Name

Galen Rohrbaugh, Jr.

Title

Vice-President

Company

Rohmac, Inc.

Figure 143 - PAR 116579 Fee Authorization Form

In conversations with MSHA, the billing process for approvals was described, and it was stated that the final amounts may differ from the estimates. Should the estimated amount be reached during an evaluation, an applicant would be given the option to continue at increased cost, or terminate the application and pay the amount due. Billing for the application would be finalized at the completion of the approval evaluation. As shown, the costs for the submitted approval applications had grown to an unexpected level, and with at least two more approvals needed beyond that which had been submitted, this had a significant impact on the ability of the contractor to perform the work necessary to complete them. It was therefore necessary to request additional project funding assistance for the approval process, which was approved on 15 April 2021. It was later discussed that this additional funding had been dedicated to the approval work, and that the contractor would submit the actual bill for the approval evaluation to access these funds.

On 22 April 2021 at 1 pm, the prototype diesel power package was tested and observed by MSHA representatives at the A&CC engine lab in Triadelphia, WV. A representative of Rohmac was also present to observe the test. The tests performed were the surface temperature and exhaust gas cooling efficiency tests, which are performed simultaneously and described by 30CFR 7.101-102. MSHA document ASTP 3002 further explains the standard test procedure. To conduct the test, the engine was warmed up and operated at 100% rated load for one hour, while holding the coolant exit temperature at 212 °F, and adding 0.5% by volume Methane to the intake of the engine. To pass the test, no surface temperature, nor the exhaust gas exit temperature could exceed 302 °F. To monitor the surface temperature, a temperature sensitive paint was applied to the exhaust surfaces, the paint would melt if the temperature exceeded the allowed temperature. Also, a thermal imaging device was used periodically during the test to observe surface temperatures. The exhaust gas temperature was measured by a thermocouple installed at the exhaust exit.

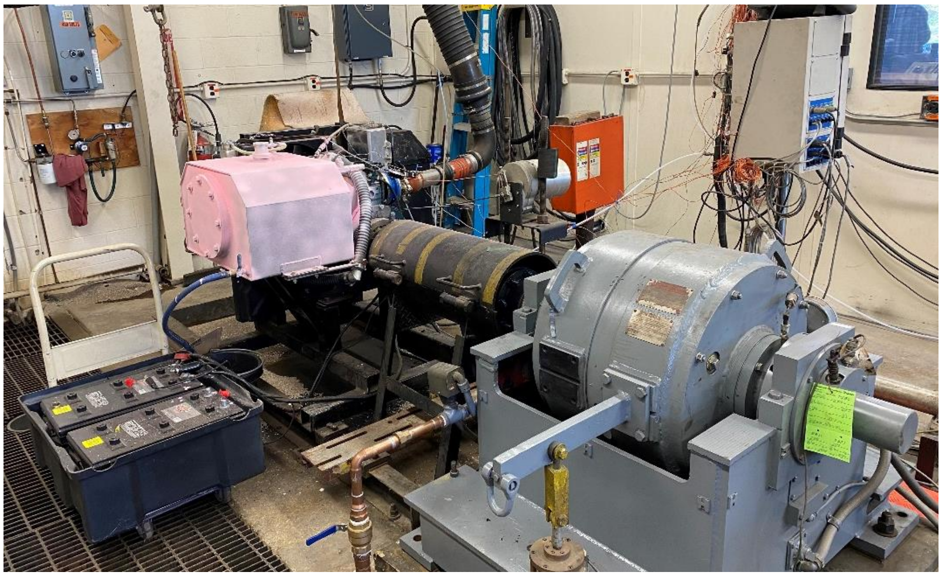


Figure 144 – Test Lab Setup

Figure 144 is a picture of the diesel power package on the dynamometer test stand before the test. The pink temperature sensitive paint was applied on the exhaust system. Figure 145 shows a closer view of the temperature sensitive paint on the exhaust system and engine surfaces, also visible are thermocouples that were installed at the engine coolant exit, and the coolant inlet neck and raw exhaust port on the exhaust system.

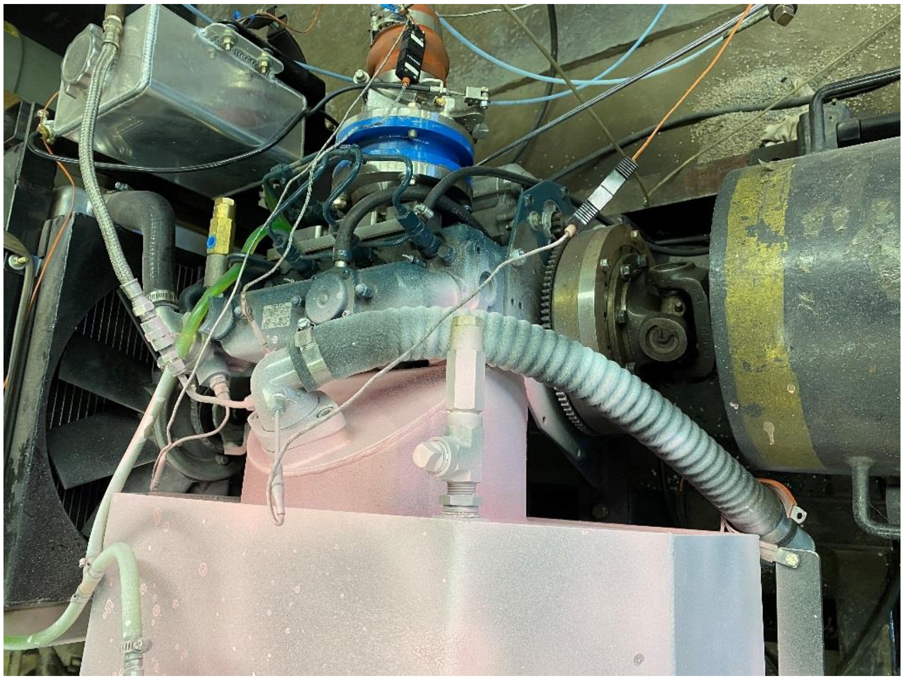


Figure 145 – Temperature Sensitive Paint

Figure 146 shows the control room monitor readout of data during the test. In the top of photo, the engine speed was 2999 rpm and it was producing 36.3 ft-lb of torque, resulting in 20.7 hp. The torque and horsepower were corrected for dynamometer loss, which was stated to be 17 hp. The raw exhaust temperature was 1006 °F, which was shown both on a bar graph in the lower left corner, and a digital readout near the center of the screen. The cooled exhaust gas was approximately 250 °F, as shown on the bar graph. The engine coolant exit temperature and inlet temperature were approximately 212 °F and 200 °F respectively, as displayed on the bar chart in the lower right of the photograph, and digital readouts near the center. It was noted that the cooling efficiency of the radiator and the system made reaching the 212 °F coolant temperature a challenge, and that in fact the radiator cooling area had to be partially blocked from airflow for the test to reach the required temperature. Figure 147 shows the power package on the dynamometer before the test with the airflow restriction in place. The cooled exhaust gas thermocouple was also visible in the picture.

Figure 146 – Control Room Data Monitor

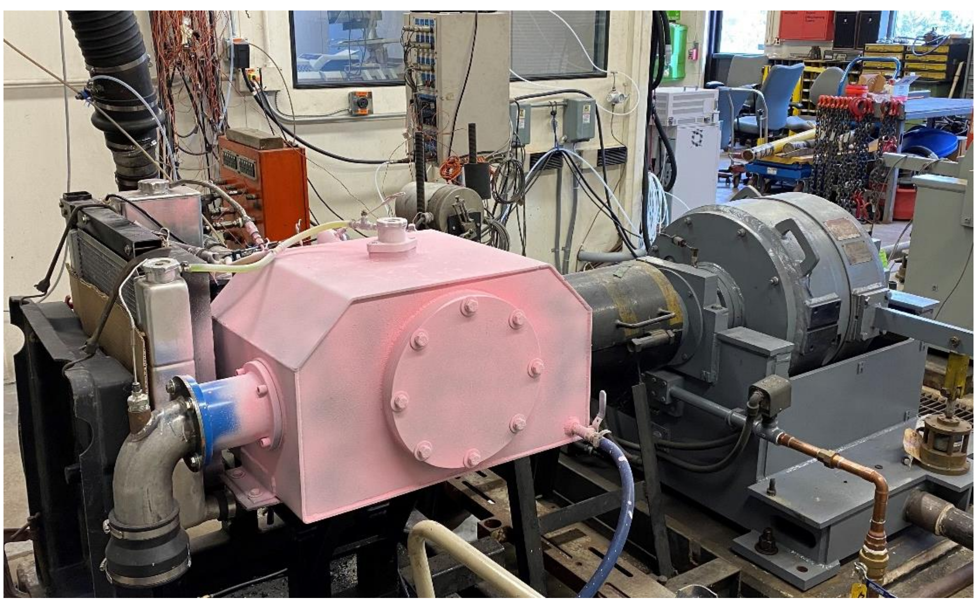


Figure 147 – Test Setup with Radiator Restriction

At the end of the hour-long test, the prototype unit passed and met the criteria requirements for surface temperature and cooling efficiency. Figure 148 shows a picture of the exhaust system after the test, and Figure 149 shows a closer view near the exhaust manifold area. The pictures show that the temperature sensitive paint was still intact, and had not changed to give an indication of exceeding the maximum temperature. It was mentioned that this test was normally the most difficult to pass, and that the tests that remained were for determining the gaseous and particulate ventilation rates, and the explosion test.

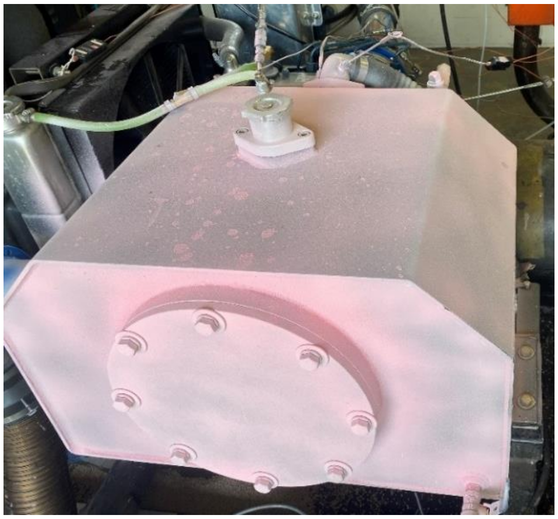


Figure 148 - Exhaust System After Temperature Test

Figure 149 - After Test Exhaust Manifold Area

At the conclusion of the test, it was stated that setup would begin for the emissions and ventilation rate test, and that notification would be sent when MSHA was ready to perform this test. Also, during this time, some minor adjustments were requested to drawing titles and the drawing list to match the titles on both documents, and additional information for clarification was requested regarding the flow of coolant and exhaust, inside of the exhaust treatment device. The revised documents were sent to MSHA on 27 April 2021, and are shown in the following figures:

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

3 March 2021

DRAWING LIST
Rohmac Inc Diesel Power Package Model DP 25XP

TITLE	Drawing / File No.	Rev
DP 25XP Power Package General Layout	1906850	A
DP 25XP Power Package Coolant Flow Diagram	1900013	A
DP 25XP Power Package Cooling System Elevation	1900012	A
DP 25XP Power Package Coolant Filling Procedure	190830JCR01	A
Radiator Cooling Fan Specifications	20180209	
Flame Arrestor (0.018")	M386-500-01	2
DP 25XP Power Package Intake Manifold Details	1807620	A
DP 25XP Power Package Intake Manifold Weldment	1807630	A
Intake and Exhaust Gaskets	1807640	A
Intake Shutoff Device	DS-RB3A-1214	2
Air Filter Specification	1661611014-SOS-0	4
DP 25XP Power Package Intake Assembly	1906880	A
Exhaust Cooler Details		
DEC 1062 Exhaust Manifold Plate	1805460	A
DEC 1062 Exhaust Chamber Flange Details	1806080	B
DEC 1062 Exhaust Exit Flange	1807120	A
DEC 1062 Exhaust Chamber Lid Details	1806270	A
DEC 1062 Exhaust Outer Plate Details	1807140	A
DEC 1062 Exhaust Coolant Jacket Details	1807180	B
DEC 1062 Exhaust Top and Base Plate Details	1807190	A
DEC 1062 Exhaust Chamber Plate Details	1807200	C
DEC 1062 Exhaust System Details	1807400	A
DEC 1062 Exhaust Pipe Details	1906070	A

Page **1** of **2**

Figure 150 - Revised Diesel Power Package Application Drawing List Page 1

Office (304) 259-2201 • Fax (304) 259-2217

ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

DRAWING LIST

Rohmac Inc Diesel Power Package Model DP 25XP

TITLE	Drawing / File No.	Rev
DEC 1062 Exhaust System Cooler Weldment	1807270	A
DEC 1062 Exhaust System Filter Chamber Subweldment	1807280	A
DEC 1062 Exhaust System Outer Jacket Subweldment	1807290	A
DEC 1062 Exhaust Cooler Coil Weldment	1906090	A
DEC 1062 Exhaust Cooler Exit Coil	1906100	A
DEC 1062 Exhaust System Exit Chamber	1906110	A
DEC 1062 Exhaust System Assembly	1906120	A
DEC 1062 Exhaust Chamber Access Cover Weldment	1806280	A
Exhaust Filter Bonnet	1905390	A
Exhaust Exit Baffle	1905500	B
Flame Arrestor (0.038")	M386-501-01	1
DP 25XP Power Package Safety Shutdown Circuit	1802006	A
DP 25XP Power Package Safety Shutdown System Description	190830JCR02	A
Coolant Temperature Sensor	Datasheet_2230_4430_2-way_sensing_valve_0614	1
Exhaust Gas Temperature Sensor	Datasheet_4075_4475_High_Temperature_ Valve_Feb18	4
Oil Pressure Sensor Spec Sheet	1201076	006
Starter	M10-DWZ46	0
Custom Manifold Circuit Hydraulic Schematic	SGM361493	0
E-Stop Valve	1202981	09
DP 25XP Diesel Power Package Permissibility Checklist	191905JCR01	A

Page 2 of 2

Figure 151 - Revised Diesel Power Package Application Drawing List Page 2

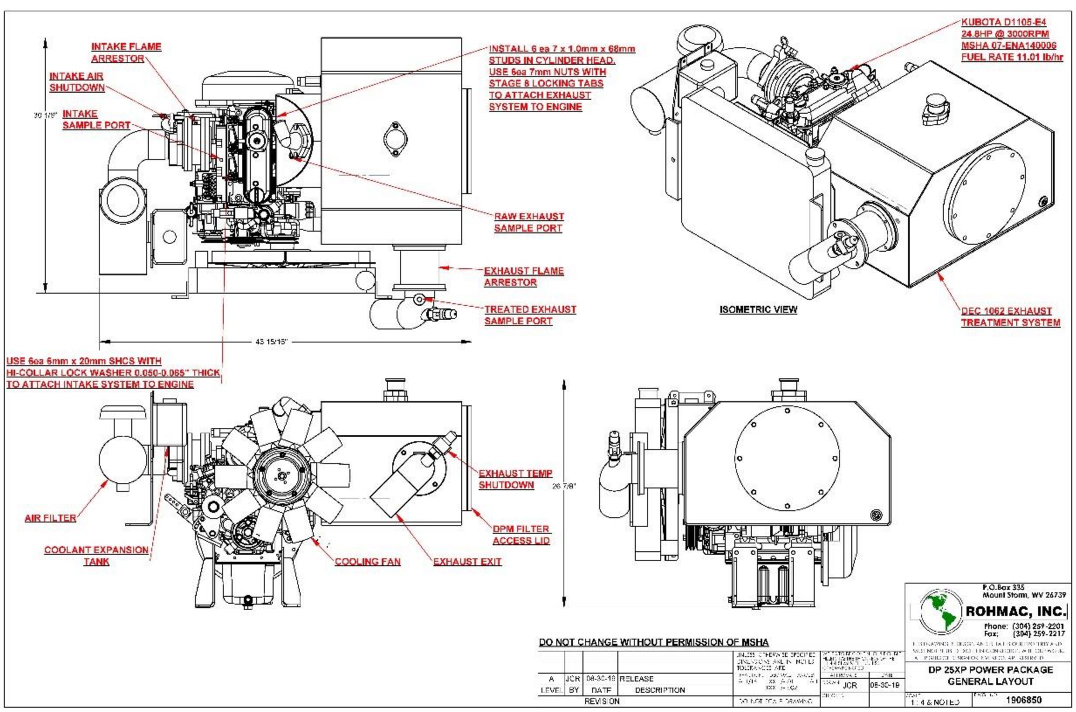


Figure 152 - Revised Diesel Power Package General Layout Drawing

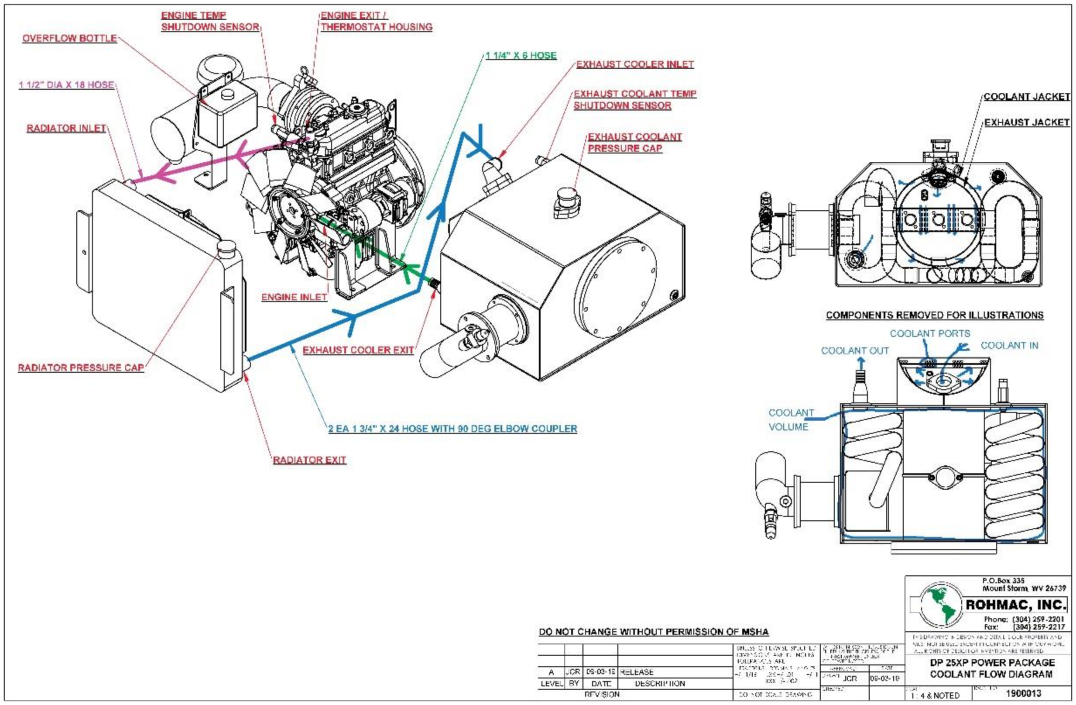


Figure 153 - Revised Diesel Power Package Coolant Flow Diagram

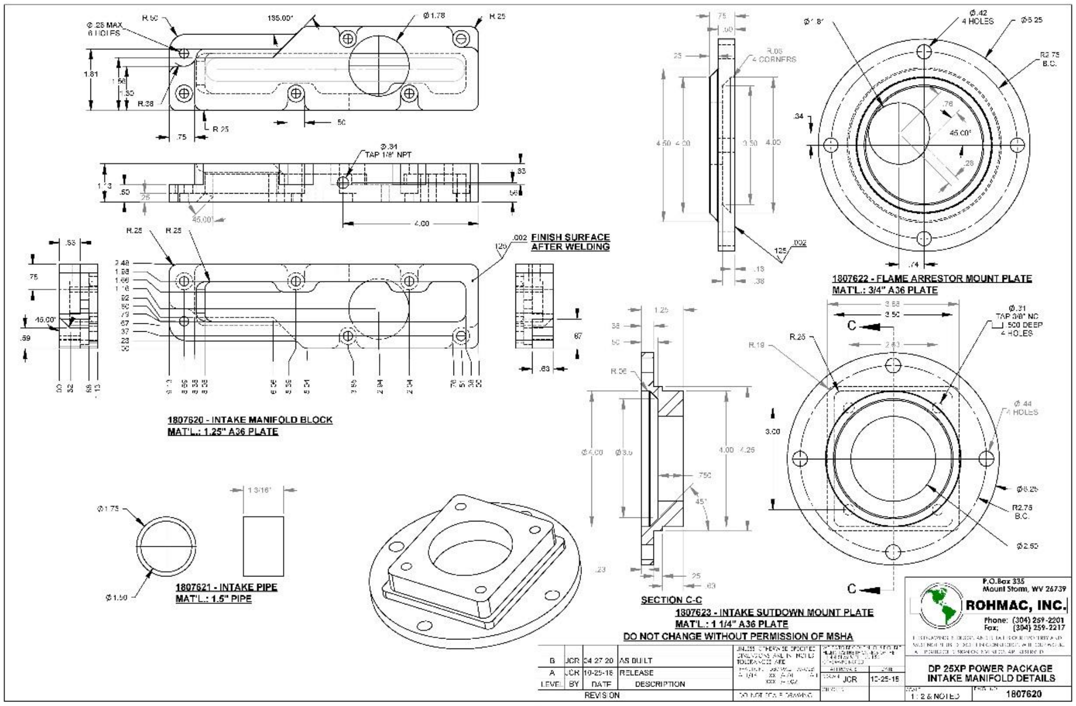


Figure 154 - Revised Diesel Power Package Intake Manifold Detail Drawing

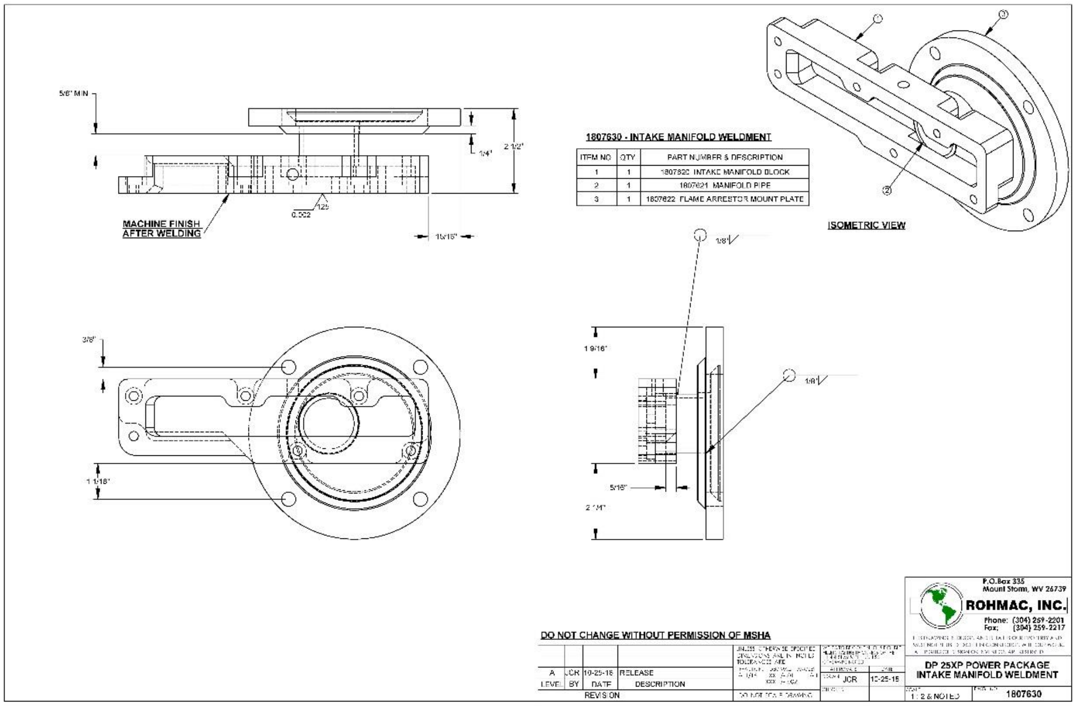


Figure 155 - Revised Diesel Power Package Intake Manifold Weldment Drawing

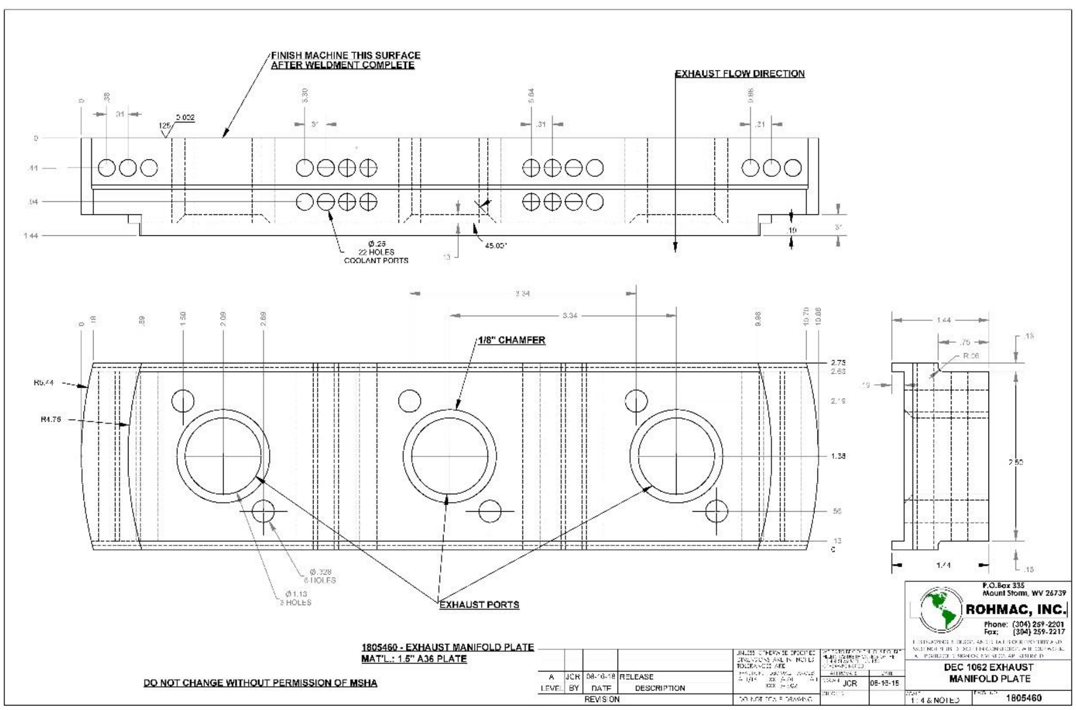


Figure 156 -Revised Diesel Power Package Exhaust Manifold Plate Drawing

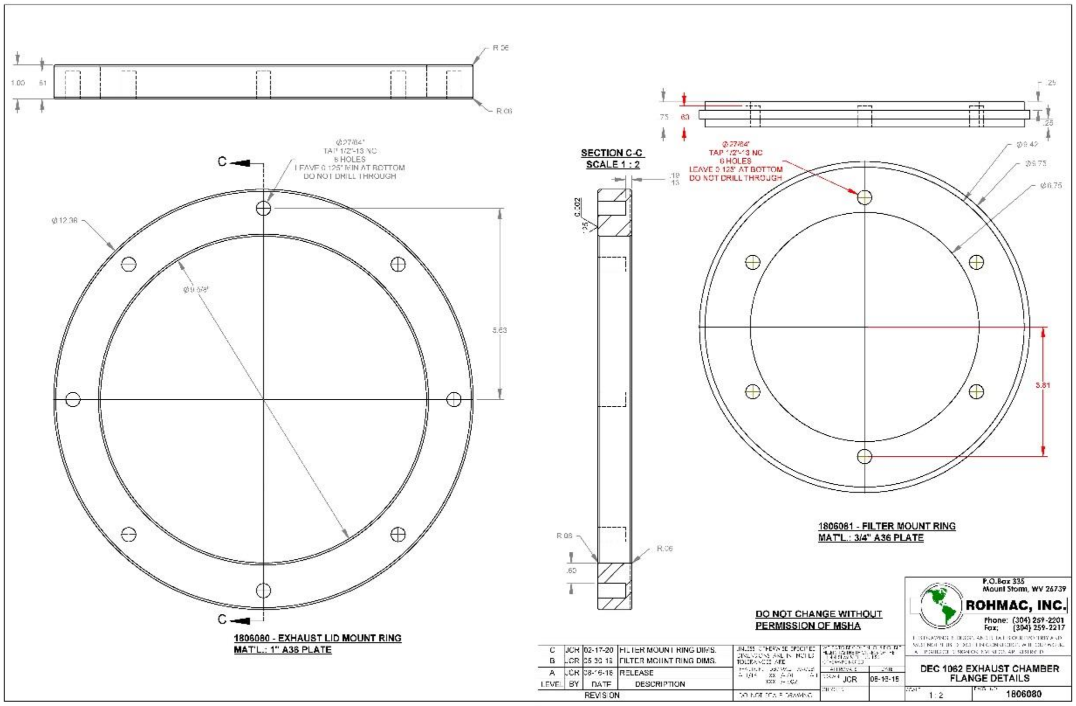


Figure 157 - Revised Diesel Power Package Flange Detail Drawing

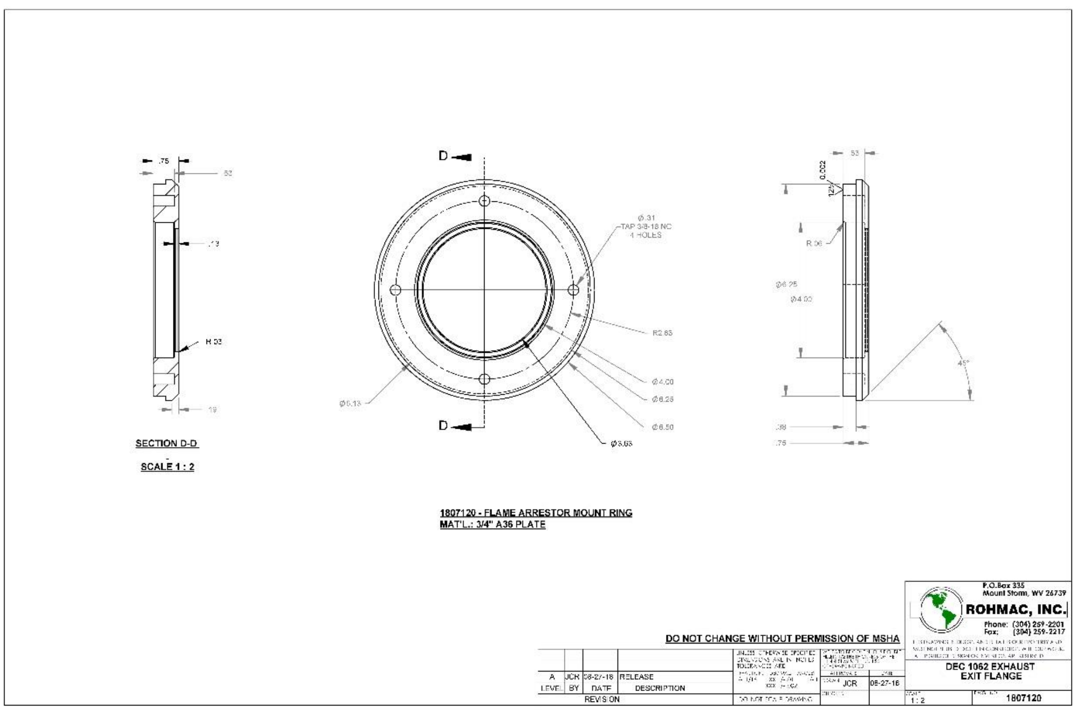


Figure 158 - Revised Diesel Power Package Exhaust Exit Flange Drawing

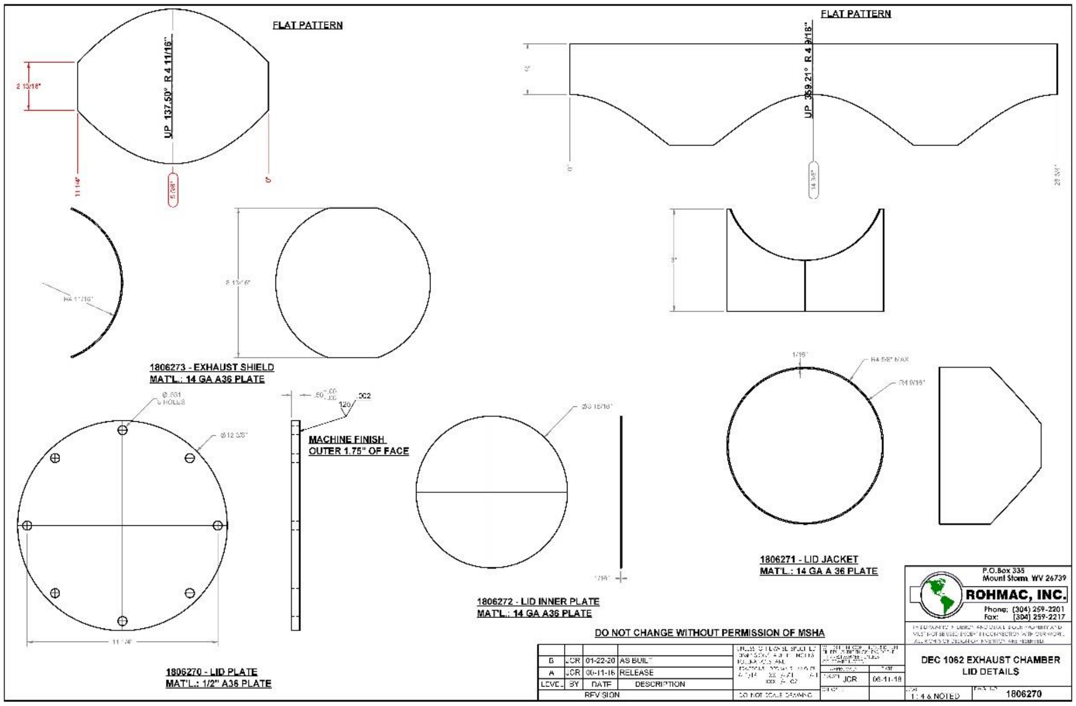


Figure 159 - Revised Diesel Power Package Exhaust Lid Detail Drawing

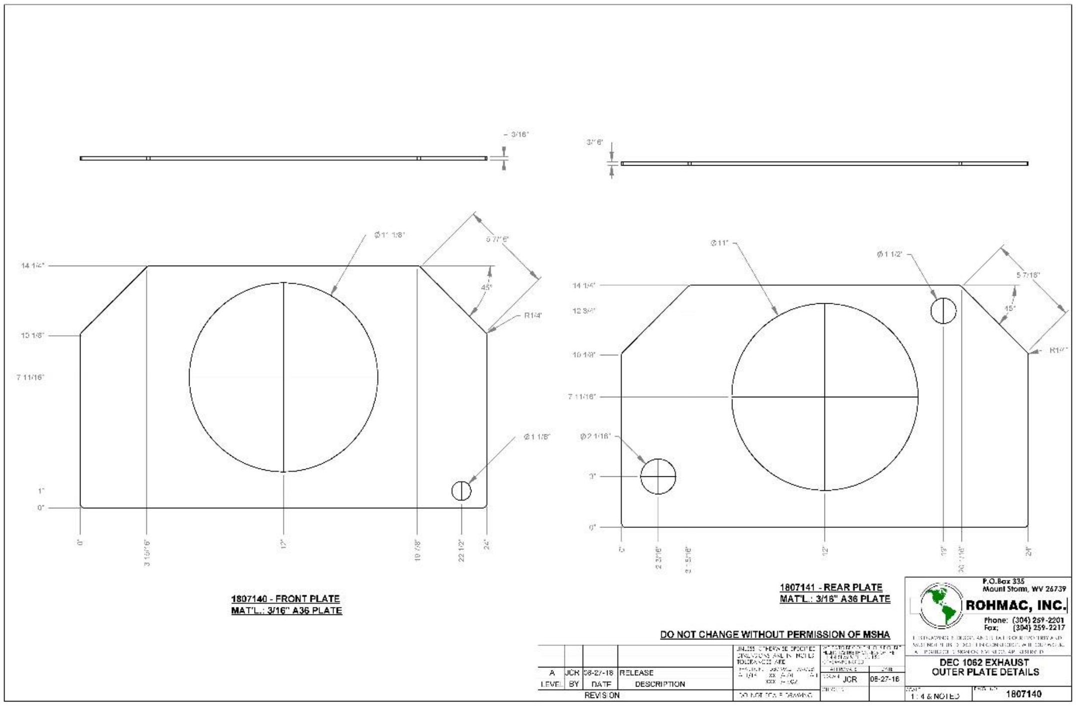


Figure 160 - Revised Diesel Power Package Exhaust Cooler Plate Detail Drawing

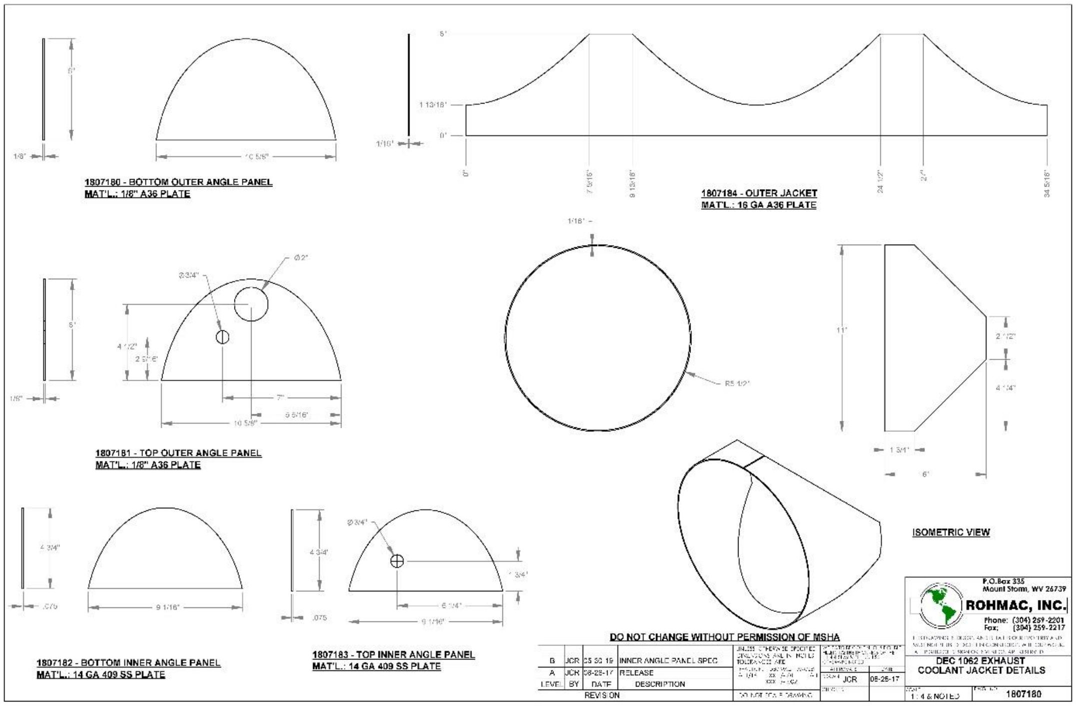


Figure 161 - Revised Diesel Power Package Exhaust Coolant Jacket Detail Drawing

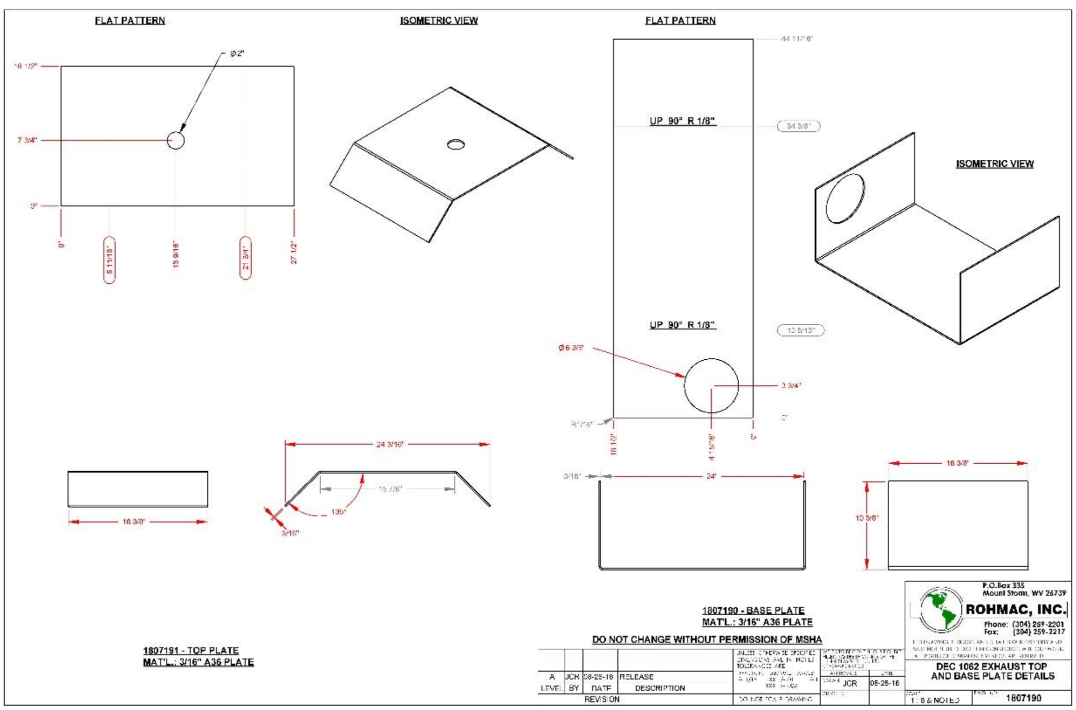


Figure 162 - Revised Diesel Power Package Exhaust Base Plate Drawing

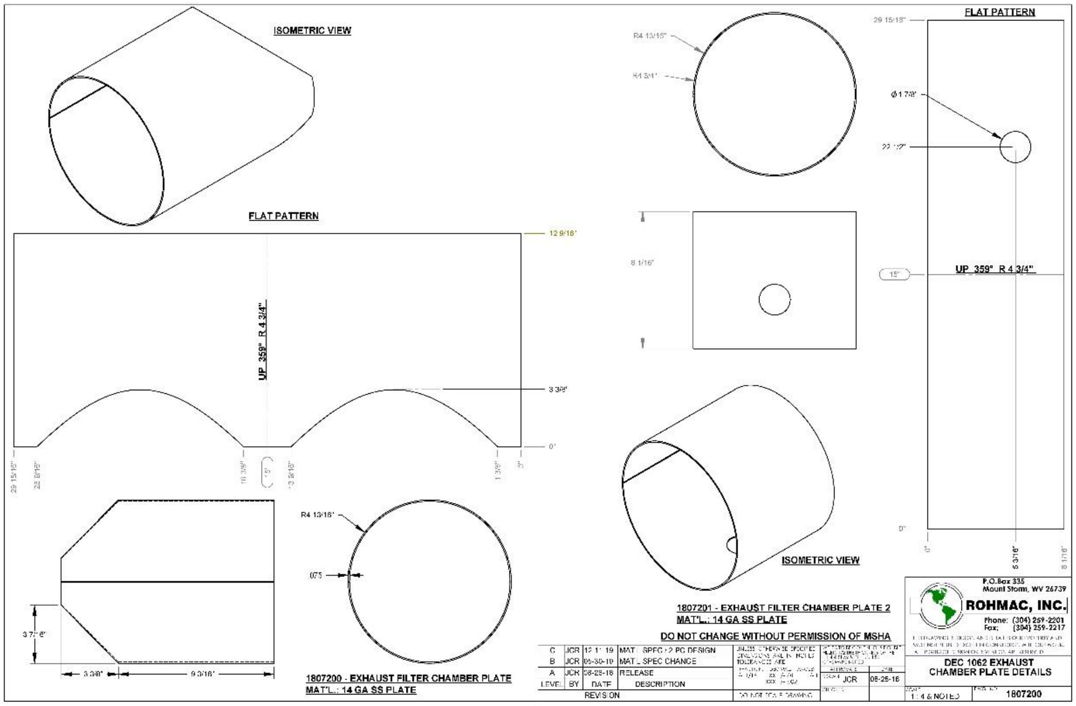


Figure 163 - Revised Diesel Power Package Exhaust Chamber Plate Detail Drawing

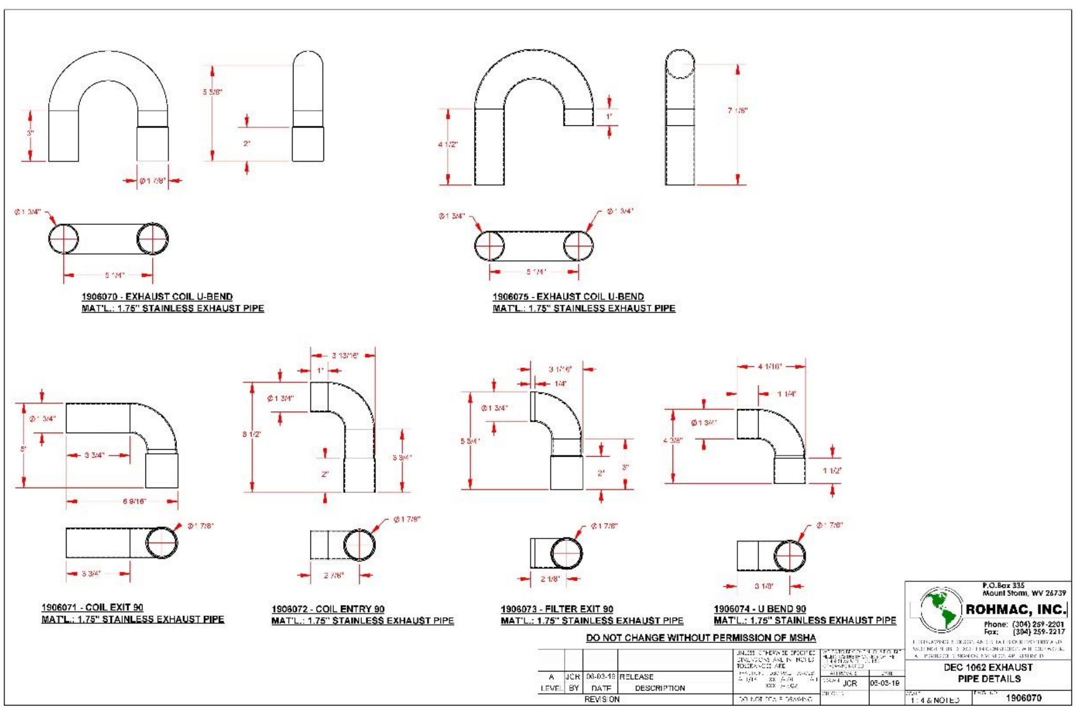


Figure 164 - Revised Diesel Power Package Exhaust Pipe Detail Drawing

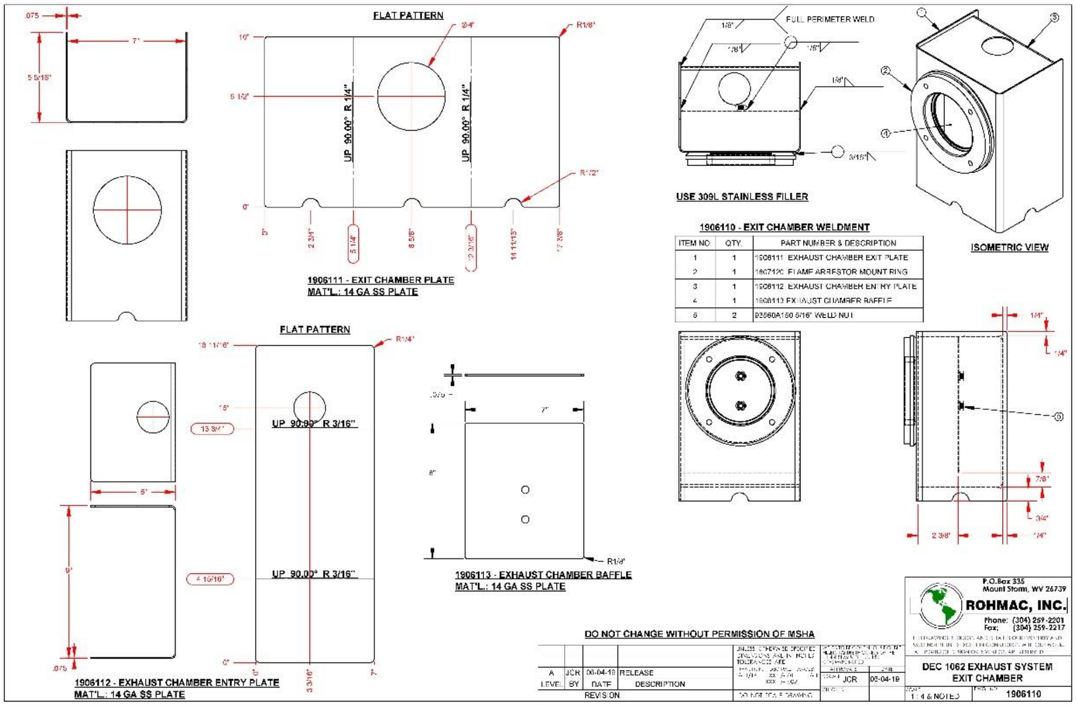


Figure 165- Revised Diesel Power Package Exhaust Exit Chamber Drawing

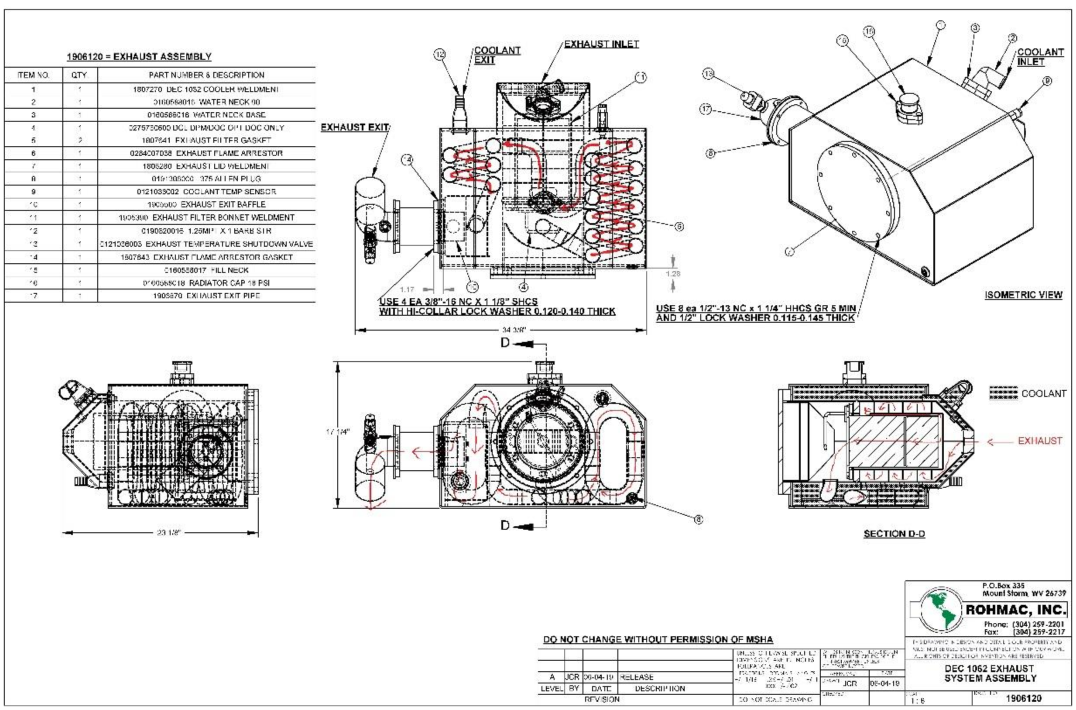


Figure 166 - Revised Diesel Power Package Exhaust Assembly Drawing

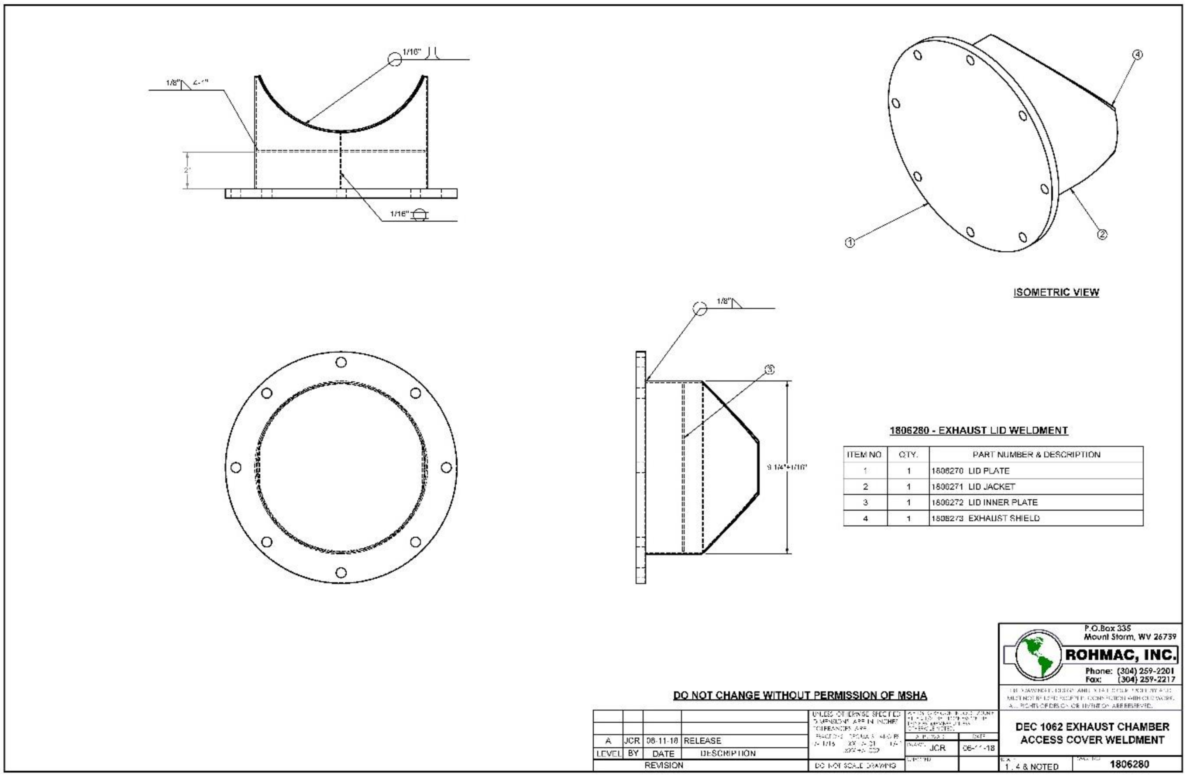


Figure 167 - Revised Diesel Power Package Exhaust Lid Drawing

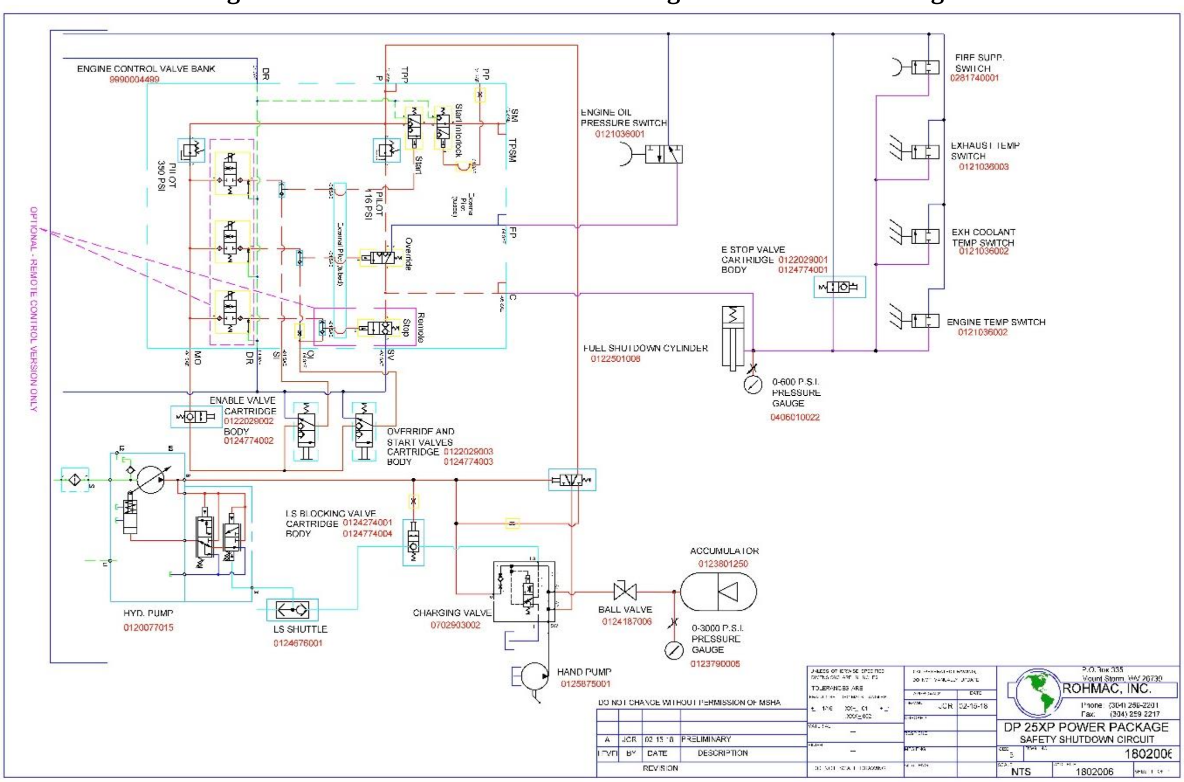


Figure 168 - Revised Diesel Power Package Safety Circuit Drawing

During a discussion later in May 2021 with MSHA representatives, it was learned that the diesel testing laboratory was experiencing issues with the gas analyzer bench, needed to perform the exhaust emissions measurements during the next phase of testing, whereby the ventilation rate of the engine was determined. Lab personnel were working to correct these issues, but it was uncertain as to when the problem would be corrected. MSHA indicated that they would initiate contact when they were ready to proceed with testing, and/or if additional action by the applicant was necessary. It was also mentioned during this discussion that it would be beneficial to build a model, to scale, of the diesel catalytic converter, and the combination converter and filter trap, to be installed in place of the catalyst / filter during the explosion testing. It was mentioned that this would prevent damage to these devices. The model pieces were built, and a spare handle was ordered from the filter manufacturer to complete the simulated devices.

On 12 August 2021, a call was received from a representative of MSHA A&CC. During this call, it was indicated that the issues that had prevented the use of the gas analyzer had been resolved, and that engine testing laboratory personnel would be starting the setup for testing the engine package for emissions and ventilation rate determination. It was discussed that Rohmac would like to have a representative present for the testing process, although it was indicated that this was not a requirement. At the end of the call it was indicated that testing should resume in the near future. On 24 September 2021, an e-mail was received from a representative of MSHA A&CC. The e-mail stated that the engine testing laboratory personnel were working on the setup of the emissions measurement system for possible testing of the engine package during the following week. It was stated that MSHA would provide a progress update in the near future.

In a later discussion with a MSHA representative, it was mentioned that the relatively low power rating of the engine presented a difficulty in performing an ISO 8178 emissions test, due to the windage loss of the dynamometer. Essentially, the dynamometer was sized for more powerful engines and the windage loss took up a significant amount of the engine's power curve, meaning that it might not be possible to test at the lower power settings used in the eight-mode test. It was mentioned to an MSHA representative that, by removing the engine driven fan, some power range might be restored to allow additional modes to be tested; which was not explored further. Once again, the timeline of the approval was discussed, and, it was mentioned that it MSHA hoped to have the necessary work to complete the approval nearly finished by the end of calendar year 2021. Discussion during follow-up calls in January and February 2022, indicated that the problem was still unresolved and causing issues, as well, other scheduling conflicts with high priority projects, were preventing staff from continuing the testing process for this application.

On 25 March 2022, an email was received from an MSHA representative stating that some preliminary operation of the diesel power package had been started, in preparation for the emissions and ventilation rate testing, and that a coolant leak had started along a weld seam on the exhaust cooling chamber. The email stated that the leak would need to be repaired before testing could continue. A picture of the leaking weld seam is shown in Figure 169. Upon investigation, it was determined that this was the same area that had previously exhibited a leak. It was believed that the fillet weld joint geometry was not ideal for this application, and that the proximity to a second weld seam could have created a heat affected zone, that may have embrittled the material and made it prone to cracking. A small design change was proposed to the plate work, to shorten the top and base plates, which would change this fillet joint to an open corner weld, while keeping the overall dimensions unchanged. The open corner weld would be a stronger weld seam, less prone to cracking, and also easier to repair in the field should a crack occur.

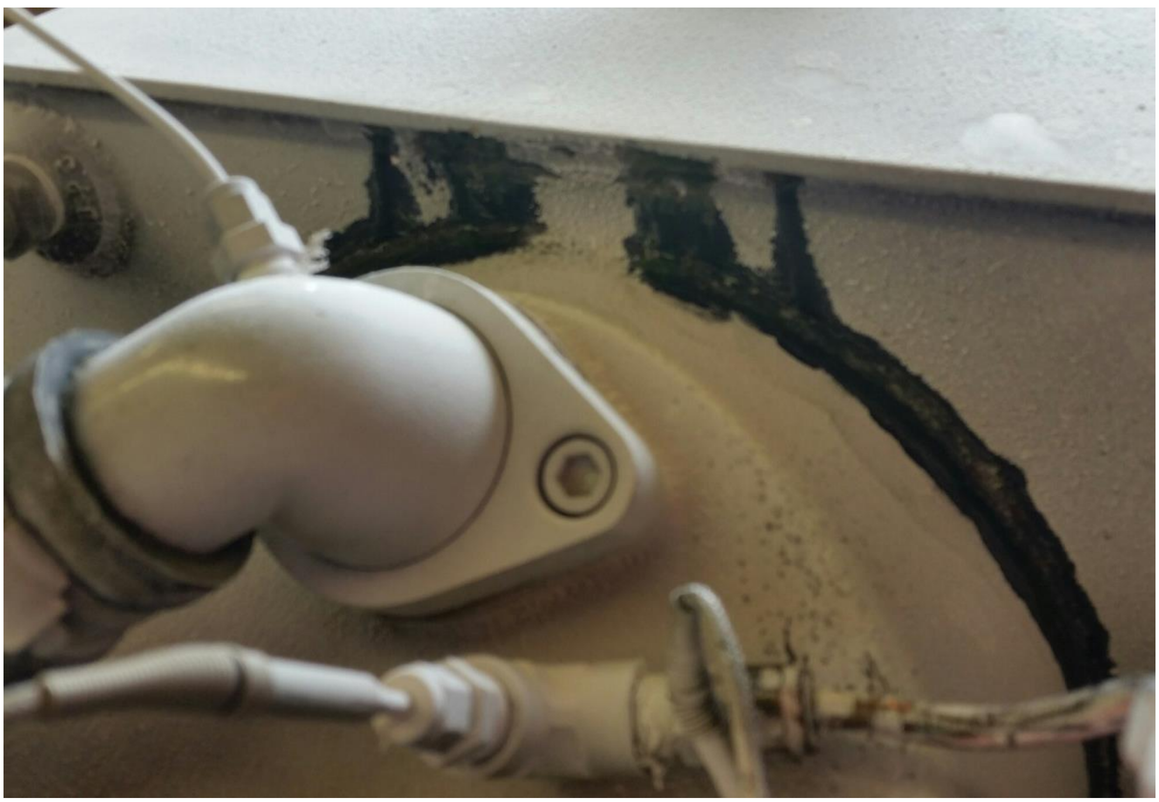


Figure 169 - Coolant Leak at Weld Seam

On 30 March 2022, a technician traveled to Triadelphia, WV, to repair the coolant leak. The weld joint and the proposed change was discussed with MSHA representatives who agreed that the change should improve the design without affecting the performance. To repair the seam, material was removed from the top plate, in the area of the leaks, to expose the top of the rear plate, creating the open corner joint with transition areas to the existing welds outside of the leak zone. A new weld was deposited, and the seal was checked by applying air pressure to the coolant chamber, while applying soap to the weld to identify leaks. After the repair was complete, MSHA laboratory personnel indicated that they would prepare the system and begin preliminary testing, to ensure all systems were functioning properly, and monitor the area for any leak development. It was mentioned that the emissions test may be performed in the following few weeks.

Following the repair of the exhaust cooling system, the drawings of the cooling enclosure were modified to change the outside corner joints. Updated drawings were sent to MSHA on 6 April 2022, and are shown below. Figure 170 shows the top and bottom housing plates with new dimensions, while Figure 171 shows the updated weldment with open corner welds, and Figure 172 shows the system assembly with the modification. After the drawings were sent, an MSHA representative mentioned that some preliminary operation of the diesel power package had been performed and that the repair weld on the exhaust cooler seemed to be working. The following day, however, we were informed of an issue with the driveshaft used on the dynamometer that required repair before testing could continue, and the timeframe to complete this repair was currently unknown.

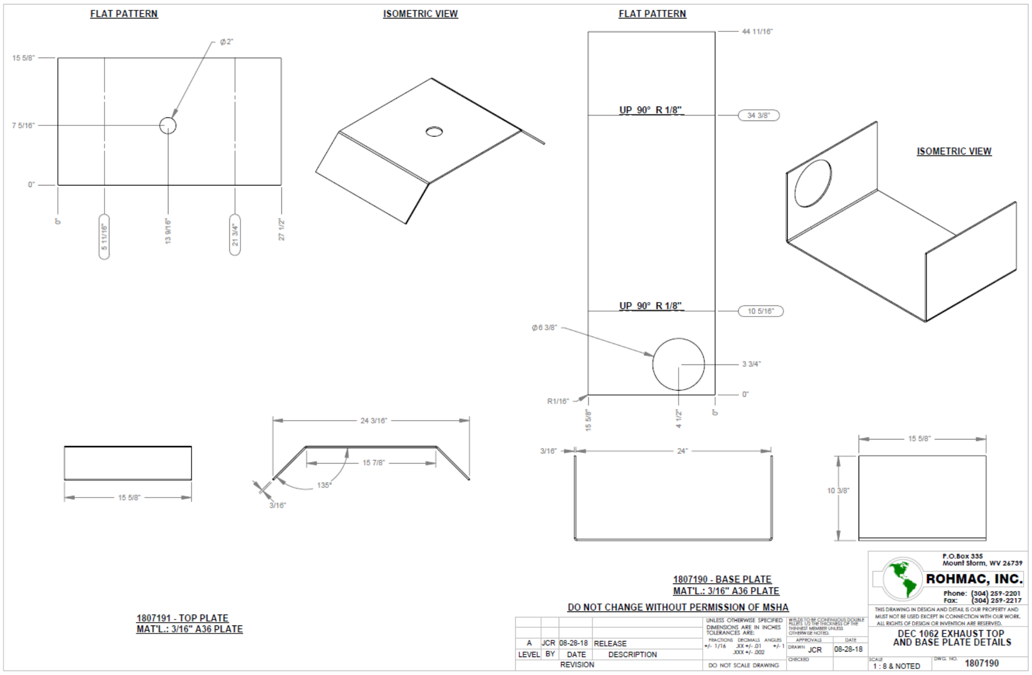


Figure 170 - Updated Exhaust Cooler Plate Dimension Drawing

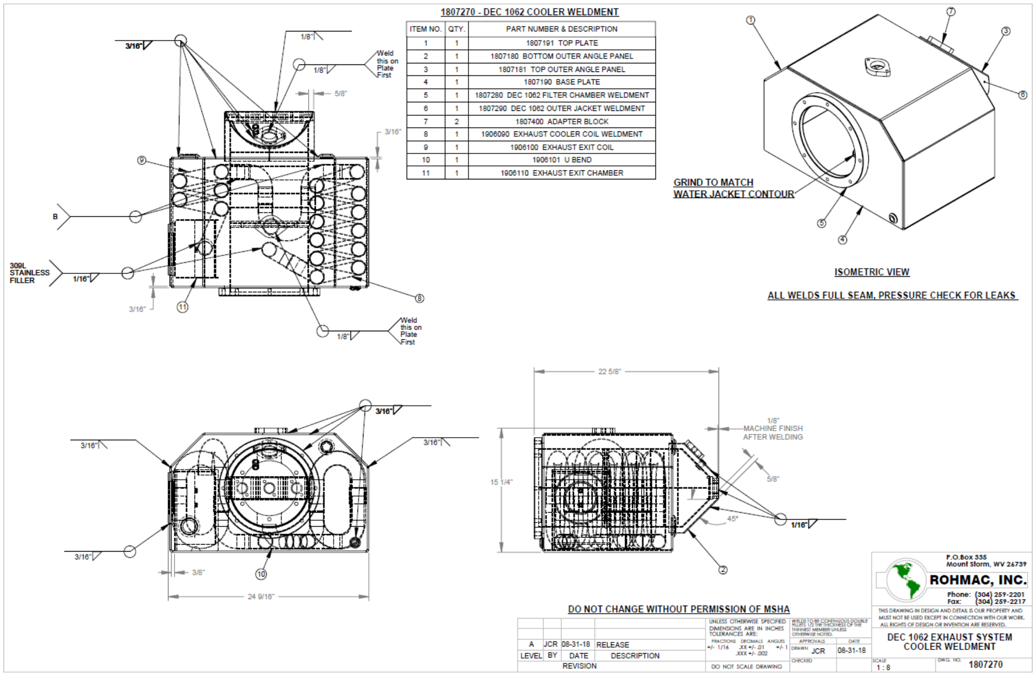


Figure 171 - Updated Exhaust Cooler Weldment Drawing

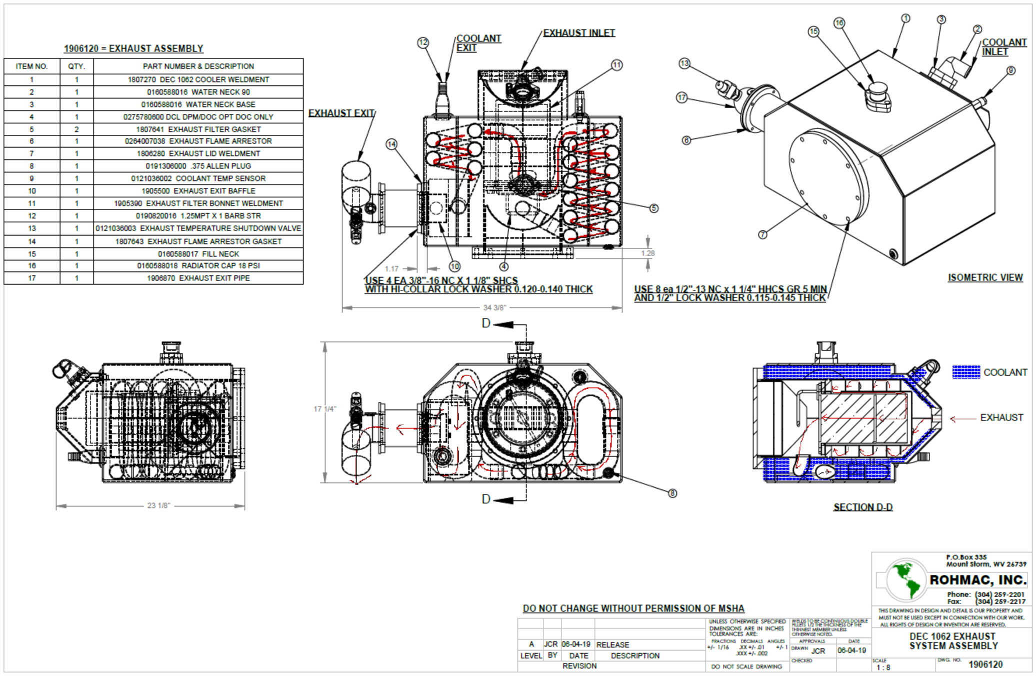


Figure 172 - Updated Exhaust System Assembly Drawing

As of the date of this report, no further communication was received regarding the progress of the diesel power package approval. With the approval evaluations for the explosion proof enclosure and the diesel engine and power package underway, and whereas the evaluation process timeline was uncertain, it was prudent to focus effort on the preparation and development of the applications for other necessary approvals, such as the diesel electric, and the Part 36 machine approval. Protocols for submitting an application, in which parts are used that are under evaluation and have not yet been approved, were discussed with MSHA It was mentioned that to submit the approval applications, they needed to reference the approval work underway and state that the subject application was contingent upon those approvals.

DIESEL ELECTRIC APPROVAL APPLICATION

A core theme of this project was that this machine was developed for, and using input from, mine rescue personnel. A teleconference was held on 16 November 2020 with representatives from MSHA MEO, CDC NIOSH, and Rohmac. As some time had passed since the beginning of the project, and some personnel changes had occurred, it was felt that the conversation with MEO about the project would be prudent. During the conference, a general update on the design revisions and progress was given. Particular attention was given to electrical control and data communication systems that may be used on the machine. In discussing communication protocols, and as change was constant in this technology, it was mentioned that the most prudent approach was to build capability into the prototype, that could be expanded at a later time to meet the needs of MEO; and that, in reference to data communication, the direction of industry at the time of this meeting seemed to be toward wireless mesh node networks. Using wireless data transmission on the machine for the video component was suggested for possible consideration. Another point that was discussed was to keep the machine simple and avoid complicated systems. It was noted that several personnel changes had occurred at MEO, and that the update on design and progress was beneficial to those with limited or no firsthand experience with the prototype machine.

The electrical system on the prototype machine was simplified from the original design not only to improve efficiency and reduce maintenance requirements, but also to simplify the approval process, and provide a basic framework that could later be expanded as necessary. Whereas the machine utilized a radio remote control system for operation, an on-board battery was necessary to power the control systems for initial machine startup, until the engine driven alternator became the electrical power source. The location, design, and use of the battery were of significant concern to MSHA. Batteries have been used in underground coal mines for many years, however, they require special consideration to prevent hazardous situations. For example, battery charging of lead-acid based batteries in underground coal mines is not permitted in permissible areas, because they can liberate hydrogen gas while being charged. Underground battery charging stations were located in fresh air areas and ventilated to returns to remove and dissipate this gas. Batteries on equipment, and inside of approved devices, must also be protected from physical damage; special battery enclosures were even specified in 30 CFR. During the project, there were several discussions involving the battery on the prototype machine.

A draft copy of the diesel electric approval application was sent to MSHA representatives on 28 October 2021, and a preliminary review was requested. The documents sent were as follows:

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

25 October 2021

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC is requesting approval for a new 12 volt diesel electric system for a MICROTRAXX model MTX, company code 190918.

The subject diesel electric consists of one 12 volt alternator, one 12 volt battery, four lights, one xp enclosure for switching and PLC control of the machine (currently being evaluated under PAR 0116463, this application is contingent upon the approval of this enclosure), one audible alarm device, seventeen 12 volt solenoid hydraulic valve actuators, and optional four cameras with emitters, along with one junction enclosure. An approved radio remote control device is also part of this system. The system is assembled according to layout drawing 1900014.

Since this is a new prototype diesel electric, it will be completely assembled and made available for inspection and testing at the MSHA Approval and Certification Center at a date and time to be coordinated.

Enclosed are all of the drawings, documents, and specifications pertinent to this application. If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremy Rohrbaugh, P.E.
Manager of Engineering
Rohmac, Inc.
792 Old Laurel Run Road
PO Box 335
Mt. Storm, WV 26739

Figure 173 - Diesel Electric Approval Application Draft Cover Letter

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

INVESTIGATION NO. DE-____________

DRAWING LIST

ROHMAC INC
MODEL MTX Diesel Electric, 12 volt, Direct Current
Built According to Drawing Number 1900014
Evaluation No. DE- -0

TITLE	DRAWING	REVISION
GENERAL LAYOUT DRAWING	1900014	A
ELECTRICAL DRAWING	1601004	A
BILL OF MATERIAL	190923JCR02	A
ELECT. PERM. CHECKLIST	190920JCR05	A
CAUTION STATEMENT	190918JCR02	A

Figure 174 - Diesel Electric Approval Application Draft Drawing List

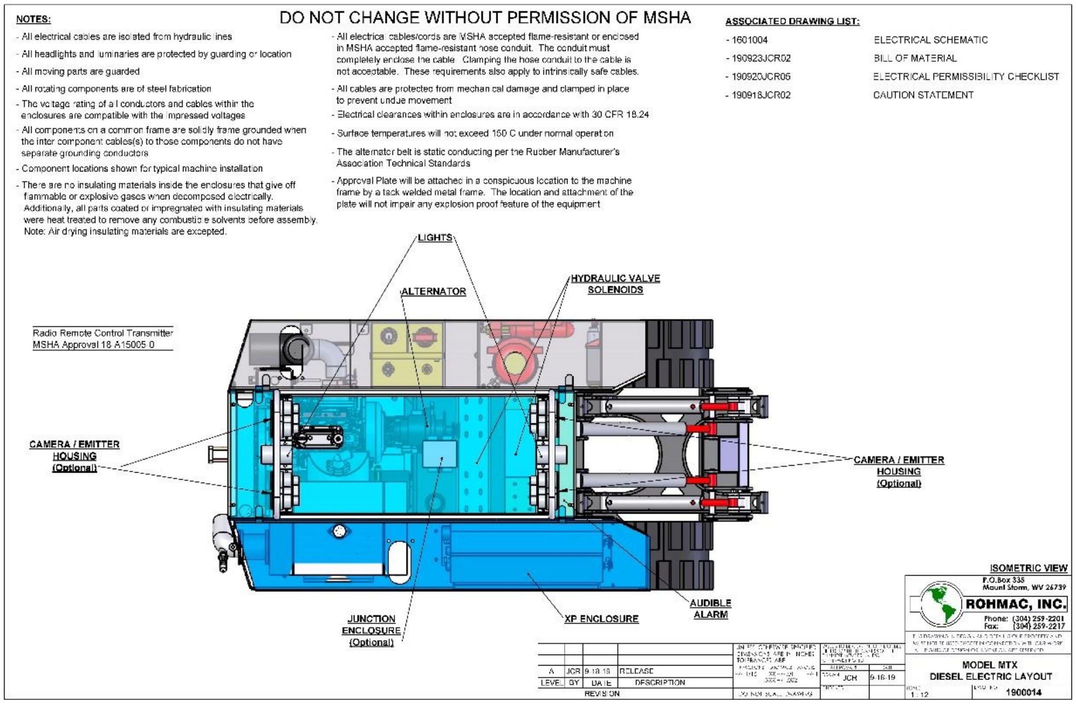


Figure 175 - Diesel Electric Approval Application Draft Layout Drawing

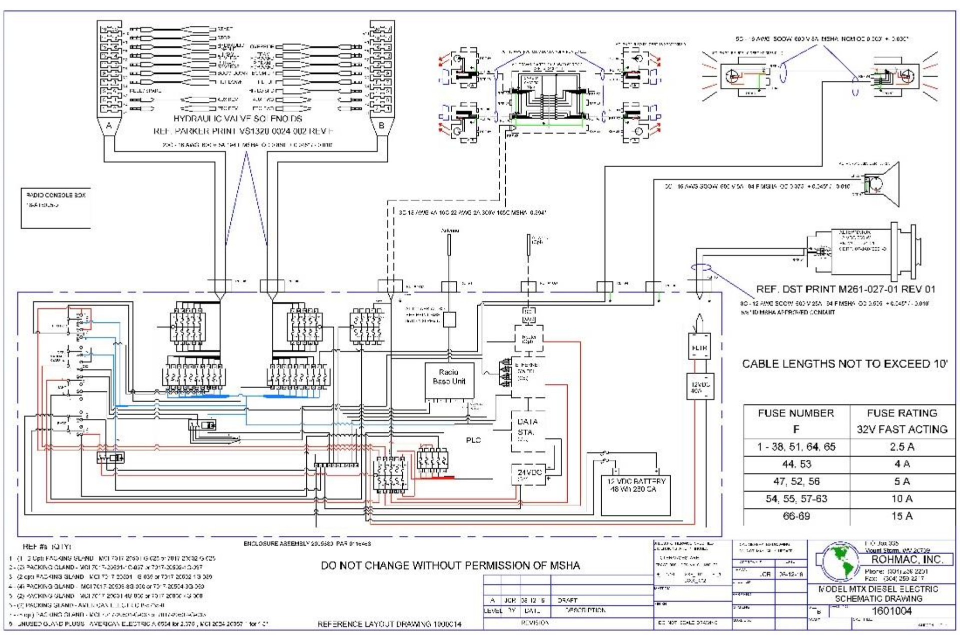


Figure 176 - Diesel Electric Approval Application Draft Schematic Drawing

DO NOT CHANGE WITHOUT APPROVAL OF MSHA

Office (304) 259-2201 • Fax (304) 259-2217 ROHMAC, INC. P.O. Box 335 • Mt. Storm, West Virginia 26739		BILL OF MATERIAL # 190923JCR02 REV A DIESEL ELECTRIC MODEL MTX				DATE	9/23/2019
		DRAWING NO.	1900014	REVISION	A	DATED	9/18/2019
ROHMAC PN	MFR(s)	MFR PN	INFO / ALT MFR PN	APPROVAL #	QTY	DESCRIPTION	
0160588014	DST	M500-521-01		07-JA040001-0	1	12 VDC ALTERNATOR	
N/A					2	15 A 32 VDC FAST ACTING FUSE	
	MCI	7017-20031-4G-060	7017-20036-4G-060		1	PACKING GLAND	
0102353022	MCI	7015-31678-15		XP 3938-0 & -1	2	50XP LED HEADLIGHT ASSY	
	MCI	7017-20503-3G-050	7017-20504-3G-050		3	PACKING GLAND	
	MCI	2024-20057-1			1	GLAND PLUG	
0109146001	MCI	7015-3603		3843-2	1	ALARM ASSY	
	MCI	7017-20501-1G-037	7017-20502-1G-037		1	PACKING GLAND	
	MCI	2024-20057-1			1	GLAND PLUG	
0125173004	Parker	VS1320-0024-002		4111-0	17	PULSAR SOLENOID	
0103747001	Hagemeyer	84F			2	JUNCTION CABLE	
	AEI	B-5765-8			2	PACKING GLAND	
2005880	ROHMAC	2005880		PAR 0116463	1	ENCLOSURE	
	ELECTROSWITCH	10102 LN 1530			4	SWITCH	
	TDK Lambda	RDEN-048050			1	FILTER	
	CUI Inc	VFK 400W-024-S12			1	12 VDC POWER SUPPLY	
	RHINO	PSP24-DC12-1			1 opt	24 VDC POWER SUPPLY	
	IFM				1	PLC	
	Power Sonic	PALP12HY			1	12 VDC Battery 48 Wh	
	Red Lion				1 opt	Data Station	
	Antaira				1 opt	Ethernet Switch	
N/A					41	2.5 A 32 VDC FAST ACTING FUSE	
N/A					2	4 A 32 VDC FAST ACTING FUSE	
N/A					3	5 A 32 VDC FAST ACTING FUSE	
N/A					9	10 A 32 VDC FAST ACTING FUSE	
N/A					2	15 A 32 VDC FAST ACTING FUSE	
	MCI	7017-20501-G-028	7017-20502-G-028		1-2opt	PACKING GLAND	
	MCI	7017-20501-1G-037	7017-20502-1G-037		1	PACKING GLAND	
	MCI	7017-20503-3G-050	7017-20504-3G-050		1	PACKING GLAND	
	MCI	7017-20031-4G-060	7017-20036-4G-060		1	PACKING GLAND	

792 Old Laurel Run Road Mt. Storm, WV 26739

Phone (304) 259-2201
Fax (304) 259-2210

Page 1 of 2

Figure 177 - Diesel Electric Approval Application Draft Bill of Material page 1

DO NOT CHANGE WITHOUT APPROVAL OF MSHA

ROHMAC, INC. Office (304) 259-2201 • Fax (304) 259-2217 P.O. Box 335 • Mt. Storm, West Virginia 26739		BILL OF MATERIAL # 190923JCR02 REV A DIESEL ELECTRIC MODEL MTX				DATE	9/23/2019
		DRAWING NO.	1900014	REVISION	A	DATED	9/18/2019
ROHMAC PN	MFR(s)	MFR PN	INFO / ALT MFR PN	APPROVAL #	QTY	DESCRIPTION	
	MCI	7017-20501-1G-039	7017-20502-1G-039		1 opt	PACKING GLAND	
	MCI / AEI	2024-20057	A-6583 or A-6584		AS REQ	GLAND PLUG	
0103002014	Cervis	WSMI-10208		18-A15005-0	1	REMOTE CONTROL	
		CB-9H07LV-10208		18-A15005-0	1	CONSOLE BOX	
		EBU-9H24XF-10208			1	BASE UNIT	
0107302001	Structured Mining Systems	AI-16704	Drawing 95109100 rev 5		1	AI-100 Aerial Isolator	
	MCI	7015-35400-610		XP-3844-1	1 opt	ENCLOSURE	
	MCI	7017-20501-1G-039	7017-20502-1G-039		1 opt	PACKING GLAND	
	MCI	7017-20501-G-033	7017-20502-G-033		4 opt	PACKING GLAND	
	MCI	2024-20057			3 opt	GLAND PLUG	
	MCI	7015-37400		18-XPA20003-0	4 opt	DUAL HEADLIGHT ENCLOSURE	
N/A					4 opt	CAMERA ASSY	
N/A					4 opt	EMITTER ASSY	
	MCI	7017-20501-G-033	7017-20502-G-033		4 opt	PACKING GLAND	
	MCI	2024-20057			12 opt	GLAND PLUG	

792 Old Laurel Run Road Mt. Storm, WV 26739

Phone (304) 259-2201
Fax (304) 259-2210

Page 2 of 2

Figure 178 - Diesel Electric Approval Application Draft Bill of Material page 2

Office (304) 259-2201 • Fax (304) 259-2217

ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

MTX DIESEL ELECTRIC PACKAGE

ELECTRICAL PERMISSIBILITY CHECKLIST

190920JCR05 REV A

MODEL MTX

MSHA CERTIFIED DIESEL ELECTRIC PACKAGE

MSHA DE-_______________

Page **1** of **5**

DO NOT CHANGE WITHOUT MSHA APPROVAL
REVISION A DATED SEPTEMBER 2019

Figure 179 - Diesel Electric Approval Application Draft Permissibility Checklist page 1

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

MTX ELECTRICAL PERMISSIBILITY CHECKLIST
190920JCR05 REV A

The component and function checks in this document that are identified as "weekly" must be performed during each weekly maintenance examination in accordance with 30 CFR, Section 75.1914. All checks must be performed in fresh air, in an area where permissible equipment is not required.

Machine Approval #______________ Serial #______________ Equipment # ______

Examination Date______________ Conducted by______________

[ ] (Weekly) All electrical enclosures have an MSHA plate attached that is clearly stamped with an MSHA certification number. The certification number must match the number listed in the table below.

ENCLOSURE	QTY	APPROVAL #
12 VDC ALTERNATOR	1	07-JA040001-0
HEADLIGHT	2	XP 3938-0 & -1
MAIN CONTROL / SWITCH ENCLOSURE	1	
JUNCTION BOX (Optional)	1	XP-3844-1
DUAL CAMERA / IR (Optional)	4	18-XPA200003-0
ALARM	1	3843-2

[ ] (Weekly) All electrical enclosures are securely mounted and all vulnerable electrical components are protected from physical damage.

[ ] (Weekly) All threaded covers are secured from loosening by a locking screw, wire, or other means.

[ ] (Weekly) Lock washers or equivalent devices are provided for all bolts, screws, or studs that secure parts of the explosion-proof enclosures. All fasteners and hardware are uniform in design, grade, and length. All bolts, screws, and studs are in place and tightened.

Page **2** of **5**

DO NOT CHANGE WITHOUT MSHA APPROVAL
REVISION A DATED SEPTEMBER 2019

Figure 180 - Diesel Electric Approval Application Draft Permissibility Checklist page 2

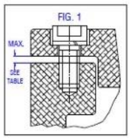
Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

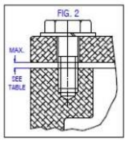
MTX ELECTRICAL PERMISSIBILITY CHECKLIST
190920JCR05 REV A

[ ] (Weekly) None of the fastenings used for joints on the explosion-proof enclosures are used for attaching non-essential parts or for making electrical connections.

[ ] (Weekly) Use feeler gages of the appropriate size to ensure that clearances in all accessible flame path joints, between the enclosures and corresponding covers, are not exceeded. **(See Table Below)**

COMPONENT	CLEARANCE (INCHES)
ALTERNATOR	0.006 (FIG. 1)
HEADLIGHT	N/A
SWITCH	0.002 (FIG. 2)
SWITCH SHAFT DIA.	0.006 (FIG. 3)
MAIN CONTROL ENCLOSURE	0.002 (FIG. 2)





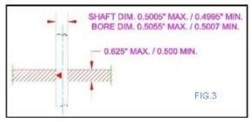
Page **3** of **5**

DO NOT CHANGE WITHOUT MSHA APPROVAL
REVISION A DATED SEPTEMBER 2019

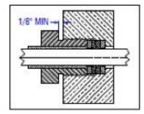
Figure 181 - Diesel Electric Approval Application Draft Permissibility Checklist page 3

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

MTX ELECTRICAL PERMISSIBILITY CHECKLIST
190920JCR05 REV A

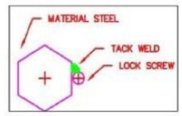


[ ] (Weekly) Electrical enclosures are intact, not cracked or broken, and the headlight and camera lenses are not loose. Selector switches are operable.



[ ] (Weekly) All lead entrances (packing glands) are assembled so that the cable jacket penetrates into the enclosure and when tightened, a 1/8" minimum clearance remains between the packing nut and stuffing box. **(See figure)**

[ ] (Weekly) All packing nuts and stuffing boxes are secured from loosening by a locking screw, wire, or other means



[ ] (Weekly) All unused lead entrances are closed with metal plugs which are secured in place by spot welding, brazing, or equivalent. **(See figure)**

[ ] (Weekly) Headlights are installed at each end of the machine.

[ ] (Weekly) Headlights are operable.

[ ] (Weekly) Headlight switches do not control or operate any electrical circuits other than the headlights.

[ ] Where required, electric cables outside of explosion proof enclosures are protected by flame resistant hose conduit. If hose conduit is used, it must be securely clamped at both ends and MSHA markings appear as "Flame-Resistant", US MSHA

[ ] Cables are clamped in place to prevent undue movement.

[ ] Damaged cables shall be replaced. Cable splices are not permitted unless the splice is made using an MSHA approved explosion proof junction box.

Page **4** of **5**

DO NOT CHANGE WITHOUT MSHA APPROVAL
REVISION A DATED SEPTEMBER 2019

Figure 182 - Diesel Electric Approval Application Draft Permissibility Checklist page 4

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

MTX ELECTRICAL PERMISSIBILITY CHECKLIST
190920JCR05 REV A

[ ] Cables are not subject to abrasion from sharp corners or edges.

[ ] Cables are protected from mechanical damage by position, flame-resistant hose conduit, metal tubing, or troughs. NOTE: Flexible or threaded rigid metal conduit is not acceptable.

[ ] Cables are isolated from hydraulic lines, hydraulic components, and fuel lines

[ ] Cables are flame resistant if not enclosed in hose conduit. This is indicated by "MSHA" markings on the cable.

[ ] 15 A 32 V fuses are installed inside the alternator housing for overload protection of each power conductor in the electrical system. The fuses are of the proper dimensions for the fuse holders.

[ ] 2.5 A , 4 A, 5 A, 10 A, and 15 A 32V fuses are installed inside the main control enclosure as specified on manufacturers drawing 1601004. The fuses are of the proper dimensions for the fuse holders and do not exceed the current rating listed.

[ ] Electrical connections inside the electrical enclosures are secure and insulated where space is limited. The ground conductors are not broken and are securely attached.

[ ] All joints forming flame arresting paths (flanges or covers) are smooth and free from rust, corrosion, and pitting.

[ ] Radio Remote Control Transmitter does not appear damaged or have damaged or missing parts

[ ] Radio Remote Control Batteries are both the same model and manufacturer and the pair are one of the following: Energizer E93 Standard, Energizer E93 Industrial, Eveready A93 LR4 Gold General Purpose, Duracell MN1400 Copper Top, Rayovac LR14 Al-C Ultra pro, Rayovac 4C/R14 Heavy Duty, or Panasonic LR14XWA Industrial

[ ] No damage is visible to the Flame Arrestor on the Audible Alarm housing, a 0.019" pin gauge does not pass through the arrestor

Page **5** of **5**

DO NOT CHANGE WITHOUT MSHA APPROVAL
REVISION A DATED SEPTEMBER 2019

Figure 183 - Diesel Electric Approval Application Draft Permissibility Checklist page 5

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

CAUTION STATEMENT

Drawing Number: 190919JCR01 REV: A Date: 9/19/2019

To retain "permissibility" of this equipment the following conditions shall be satisfied:

1. General Safety. Frequent inspection shall be made. All electrical parts, cable, and wiring shall be kept in a safe condition. Special efforts shall be made to maintain cable routing paths free from mud, rock, and other debris that could eventually cause cable damage. Cables shall be closely examined on a regular basis and damaged cables or protective hose conduits shall be replaced and the cause of the damage identified and corrected before the equipment is placed back into service. There shall be no openings into the casings of the electrical parts.

2. Servicing. Explosion-proof enclosures shall be restored to the state of original safety with respect to all flame arresting paths, lead entrances, etc., following disassembly for repair or rebuilding, whether by the owner or independent shop.

3. Fastenings. All bolts, nuts, screws, and other means of fastening, and also threaded covers, shall be in place, properly tightened and secured.

4. Renewals and Repairs. Inspections, repairs, or renewals of electrical parts shall not be made unless the diesel engine is shutoff and the machine locked and tagged out. Special care shall be taken in making renewals or repairs. Leave no parts off. Use replacement parts exactly like those furnished by the manufacturer. When any lead entrance is disturbed, the original leads or exact duplicates thereof shall be used and the stuffing boxes shall be repacked in the approved manner. When machine cables are replaced or otherwise disturbed from their normal position, they shall be routed in the same manner as they were when the machine was shipped from the manufacturer. In addition, any clamps, conduit, or guards that were in place to prevent cable damage shall be replaced.

DO NOT CHANGE WITHOUT APPROVAL OF MSHA

Figure 184 - Diesel Electric Approval Application Draft Caution Statement

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

18 September 2019

RE: Model MTX – Diesel Electrical System
Company Code No. 190918

To Whom it May Concern,

On behalf of ROHMAC INC, I hereby certify that ROHMAC INC will conduct an initial inspection of the subject diesel electric installation performed at our facility to insure that this product is made and assembled in strict accordance with the drawings and specifications approved by MSHA.

Sincerely,

Jeremiah Rohrbaugh, P.E.
Sales Engineer

Figure 185 - Diesel Electric Approval Application Draft Certified Statement

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

MTX Electrical Inspection Form # 190920JCR03 Rev A

Electrical Drawing # 1601004 Rev A Dated

Approval # ____________ Serial # ____________ Equipment # ____________

Date ____________ Inspected By ______________________________
print sign

Pass	Fail		Notes / Date Corrected
		The electrical system conforms to layout drawing 1900014	
		The electrical system conforms to Electrical Drawing 1601004	
		All Explosion Proof Enclosures have an MSHA plate attached	
		Lockwashers or Locknuts on all bolts securing flame path fits	
		None of the fastenings used for joints on explosion-proof enclosures are used for attaching non-essential parts or electrical connections	
		All joints forming flame arresting paths are smooth and free from rust corrosion and pitting	
		Clearances on all joints forming flame-arresting paths meet applicable regulations and manufacturer specifications (Check lids with feelers gage)	
		Lenses on lights and cameras are intact and not cracked or broken	
		Protective guards are installed for Lights and Cameras	
		All lead entrances are assembled so that the cable jacket is inside the enclosure and when tightened, a minimum 1/8" clearance remains between the packing nut and stuffing box.	
		Threaded covers on Lights and Cameras are tight and secured with set screws	
		All packing nuts and stuffing boxes are secured from loosening	
		All unused lead entrances are closed with plugs and secured by spot welding or equivalent	
		Electrical cables are secured in place to prevent undo movement	
		Electrical Cables are either flame resistant or enclosed in MSHA approved hose conduit.	

DO NOT CHANGE WITHOUT APPROVAL OF MSHA

Figure 186 - Diesel Electric Approval Application Draft Inspection Form

An email was received from MSHA representatives on 18 November 2021 with questions and comments about the draft Diesel Electric Application. It was mentioned that they would be available for a virtual conference meeting on 24 November 2021 if desired. A list of the comments included in this email follows:

1. It is preferred that Rohmac submit this DE application once other required component evaluations, such as the XP enclosure (PAR 116463) are at or very near completion.
2. What is the purpose of the battery? It was believed the last design iteration was a NiMH battery. If a lithium battery is used, additional concerns will need to be addressed.
3. Will the new Rohmac XP enclosure have a flame arrestor? Is it being considered how will battery gas be vented?
4. An MSHA certification number is not provided for the solenoid valves.
5. Certification numbers or evaluation numbers are not provided for the solenoid connectors and connection block.
6. Electrical ratings must be provided for the solenoids, solenoid connectors, and connection block. Some of these may require the inductance and energy to be provided for the solenoid coils to match with the connectors.
7. The I.S. evaluation number is not provided for the antenna barrier.

8. The transmit power of the radio probably needs to be specified to verify it is compatible with the barrier. It looks like a part number may be provided for the base unit, so we may be able to look it up.
9. The function of the switch “PTO FOR” needs identified.
10. Some of the wiring circled in blue on the snip below is not real clear. It looks like if the battery switch is on, it could be connected to the alternator through the fuse block circled on the right. The connections to the coil on the right look like they are connected together.
11. More details may need to be provided for the camera system. The function of the “emitter” needs to be identified. An MCI camera system is identified, which appears to be an Ethernet based camera because there isn’t a video monitor. Is the video fed back to the Ethernet switch and then transmitted wirelessly by the router?
12. The transmit power for the router needs to be provided. The barrier for the router and base unit antennas needs I.S. evaluation number on the drawing.

Note that the first comment was a request to delay submitting the application for this approval until the evaluation for the XP enclosure was nearly completed. Other comments focused on the use and selection of the battery housed in the enclosure. A response to this email was sent providing some additional information, and a brief explanation for a few of the questions, such as explaining the purpose of the battery for operating control systems at start-up, the manual PTO function whereby the machine could be used as a powerpack to operate tools such as a saw, drill, or pump; as well as agreeing to the virtual meeting. Information attached to the response included data sheets on a subject lithium based battery, and a certification statement on cells used by this manufacturer, the solenoid used to operate the hydraulic valves, the engineering drawings for the radio remote control system and the aerial isolator, and a picture of the junction blocks used for the valve coil wires.

On 24 November 2021 at 10 am, a virtual meeting was held with several representatives of the Electrical Division of MSHA A&CC, to discuss the subject diesel electric application. At the onset of the meeting, it was reiterated by MSHA personnel that formally submitting this application should be delayed until the evaluation for the XP enclosure was at or near completion. A brief discussion ensued about the basic design of the machine and the progress of the approval work, as well as the remaining approvals needed, including the diesel electric, which was identified as the next approval needed in the process toward a complete machine approval. Attention then moved to the on-board battery and the proposed Lithium Iron Phosphate battery pack. Several concerns and issues were mentioned about Lithium based battery packs. The primary concern was, that in the event of a thermal runaway of the lithium battery, that the gases released from the battery could generate significant pressures inside of the XP enclosure and compromise the explosion proof integrity. It was mentioned that in order to use a lithium battery inside the enclosure, that a flame arrestor would need to be installed on the enclosure to provide adequate ventilation ability and prevent such a pressure buildup. Further complicating the proposed use of this battery chemistry was the request to charge the battery while the machine was in operation, to reduce maintenance. While these batteries did not liberate hydrogen gas while charging, overcharging could cause internal damage to the battery cells, and compromise the integrity of the battery assembly. Discussion of the battery was a topic that was revisited several times during the meeting. A calculation of the free volume inside of the XP enclosure with all components installed was requested by MSHA, this was used to determine the ratio of volume compared to the battery cell volume and how much expansion volume was available should the battery release gases. Other applications using lithium batteries in mines, as well as applications where recharging of other battery chemistries occurred, were discussed. The subject LIFePO4 battery was discussed, and it was mentioned that the subject battery met the UN

38.3 standard for transportation, which subjected the battery to several tests for heat, vibration, shock, and damage, to show that it was safe for transport. It was also discussed that the battery had an on-board management system, as stated on the OEM technical data sheet. It was stated that more information on the subject battery was needed, such as the cell arrangement, vent sizing, and especially the battery management system, to see how it protects from thermal runaway. Additional control of the battery system inside of the enclosure was also mentioned, and possibilities of monitoring and protection systems that may also be required such as current draw, temperature, and internal short circuiting. As well, additional physical protection of the battery inside of the enclosure to protect from vibration, was mentioned as a possible requirement, and that it was necessary to locate the battery such that arcing could not compromise any flame path in the enclosure. It was mentioned that any information on the thermal runaway behavior of the battery cell would be beneficial. Batteries used in other applications were discussed as well as possible substitutes for the proposed Lithium battery; it was mentioned that Nickel based batteries would be preferable should a suitable candidate exist.

Apart from the focus on the battery, some other items were discussed. The list of questions and comments from the initial email were reviewed. It was mentioned that some more information was needed on the cameras and emitters used inside of the dual headlight enclosures, to determine any additional fusing requirements and/or suitability for use in the enclosures. Also, some information on approval numbers for certain components, such as the valve coils, needed to be added to the drawings. The junction blocks for the valve coil cables were mentioned. It was stated that, while these or similar components have been used on other approved machines such as miners and bolters, that the components were approved as part of these machines rather than separately, and that additional information might be necessary for use in this application. Also, after a brief description of the radio remote control system, and the transmission of video and possibly other data from the machine, it was mentioned that the barriers used on the communication system antennas must be rated for the frequency and transmit power used by the communications devices.

It was mentioned that work on the XP enclosure application should be paused until it could be determined if modification(s) would be necessary to include a flame arrestor or other battery related items. Also, the possibility of testing a thermal runaway of the battery proposed for use in the subject enclosure was raised; it was mentioned, however, that there may not be sufficient laboratory ability to perform such a test. A question was raised about the possibility of moving the battery into its own separate enclosure / battery box, but it was mentioned that any Lithium battery would need to be inside of an XP enclosure, and that a separate battery enclosure would also need to be approved. The meeting was concluded at approximately 12 pm, a follow up meeting was proposed for 2 December, which was later postponed to allow more time to gather information. At the end of the meeting, it was mentioned that MSHA had a list of particular issues and areas of concern for using lithium batteries in mines, and that they would email a copy of the list to us. The information contained in the email follows:

In regards to use of large format Li-ion batteries in **permissible** areas of the mine, 30 CFR Part 7 Subpart C regulations were written based on a lead acid battery cell chemistry. MSHA has not yet approved a battery assembly with cells using a chemistry other than lead acid. We would expect to evaluate your battery assembly under 30 CFR Part 7 Subpart C applying the provisions of 30 CFR 7.52. 30 CFR 7.52 states that:

> *MSHA may approve a battery assembly that incorporates technology for which the requirements of this subpart are not applicable, if the Agency determines that the battery assembly is as safe as those which meet the requirements of this subpart.*

This means that as part of the application process, the applicant must demonstrate to MSHA's satisfaction that this new technology is as safe as specifically required by the regulations.

To be approved under 30 CFR Part 7, a battery assembly must contain only battery cells. We understand that Li-ion battery cells must have a battery protection circuitry connected near the each cell. This circuitry must be housed in an MSHA certified explosion-proof enclosure or be required to be intrinsically safe and is not permitted in a 30 CFR Part 7 battery assembly box.

The applicant would be responsible for demonstrating not only the cells and circuitry are safe in a mining environment, but they must also demonstrate that it is safe placing Li-ion cells into an explosion-proof enclosure.
The applicant must demonstrate that any foreseeable failure of a component within the explosion-proof enclosure would not produce a hazardous condition nor reduce the effectiveness of the explosion-proof enclosure to contain a methane/air/coal dust explosion. The demonstration must be acceptable to MSHA and may be by analysis, test or compliance with similar standards. Examples of documentation and demonstration would require at least the following:

- Cell must be placed in MSHA certified explosion-proof enclosure.

- The manufacturer, chemistry, and model/type of the cell must be specified.

- The layout of the cells to form the large format battery must be specified and detailed. Information on how the cells are monitored must be documented.

- All failure modes of the cell must be specified. These failure modes must include how being inside an enclosure could also affect these failure modes. Test data may need to be submitted to support and document all possible failure modes.

- Any gas given off by the failure of a cell be specified and determine that this gas would not increase the force of a methane/air/coal dust explosion within the enclosure, cause any other hazardous condition, or create pressure in the enclosure. Test data may need to be submitted to support and document all possible failure modes.

- The failure of a cell not must not cause the failure of additional cells, unless the applicant demonstrates that the failure of the additional cells does not reduce the effectiveness of the enclosure to contain a methane/air/coal dust explosion or cause any other hazardous condition. Test data may need to be submitted to support and document all possible failure modes.

- The effect of moisture, vibration or other conditions common to the mining industry on the battery assembly be specified and test data may need to be submitted to support and document all possible failure modes.

- The failure modes of overcharging/reverse charging the battery assembly specified and test data may need to be submitted to support and document all possible failure modes.

- Information on your battery management system must be specified. Testing may be required.

Compliance with UL1642, IEC 62133, IEC 60079-0 & 60079-1 and IEC 61960 may aid you in demonstrating that this battery technology is as safe as required by the regulations

Above are general examples as to what would need to be tested and evaluated to prove the safety of proposed Li-ion battery systems. As MSHA learns more about your proposed assembly additional items, tests results, etc. would be required.

The topic of large format Li-Ion batteries located in explosion-proof enclosure has been around for several years. Throughout the years some critical discussion points have consistently been brought up. I have attached a word document to include some of these discussion points. This may give a little further insight to some critical design points which would be required to prove the validity and safety of entirety of large format Li-Ion battery. Please note, this is not an all-inclusive list.

An attached document to the email contained the following information:

Large format at Lithium-Ion Batteries

Below are some examples of concerns for housing lithium batteries inside of a sealed, explosion-Proof enclosure. This is **not an all-inclusive list** or specifically direct towards a specific design, but just some issues which have been discussed over the years when discussing large amount of lithium ion batteries/cells inside of an explosion-proof enclosure. These are worded in question format in order to get our thoughts and concerns across to applicants. We are not requesting a response to these points at this time, but listing them as discussion and thought provoking points to explain some of our current major concerns.

Explosion-Proof Enclosure Concerns and Scenarios

1. Is the enclosure designed to contain a thermal runaway or any other failures of Li-ion batteries assuming that the enclosure is in fresh air?

   A design pressure of 150 PSI has been established for methane-air mixtures to provide a safe structurally sound enclosure that can withstand a normal methane-air explosion and have known design characteristics to be able to contain a flame within the enclosure.

   - What would the design pressure (enclosure design – wall thicknesses fasterners size, etc.) and flamepath design (lengths, clearances, retaining method) need to be for an enclosure that is able to withstand a thermal runaway pressure build up and flame/fire of various types of Li-ion cell failure events?

2. Is the enclosure designed to contain thermal runaway or other failures of Li-ion batteries methane-air is present?

   What would be required of that same enclosure (design pressure and flamepath design) if it were to be used at the face where methane could be present and thermal runaway (or another Li-ion failure event) be the ignition source of methane or coal dust within the enclosure?

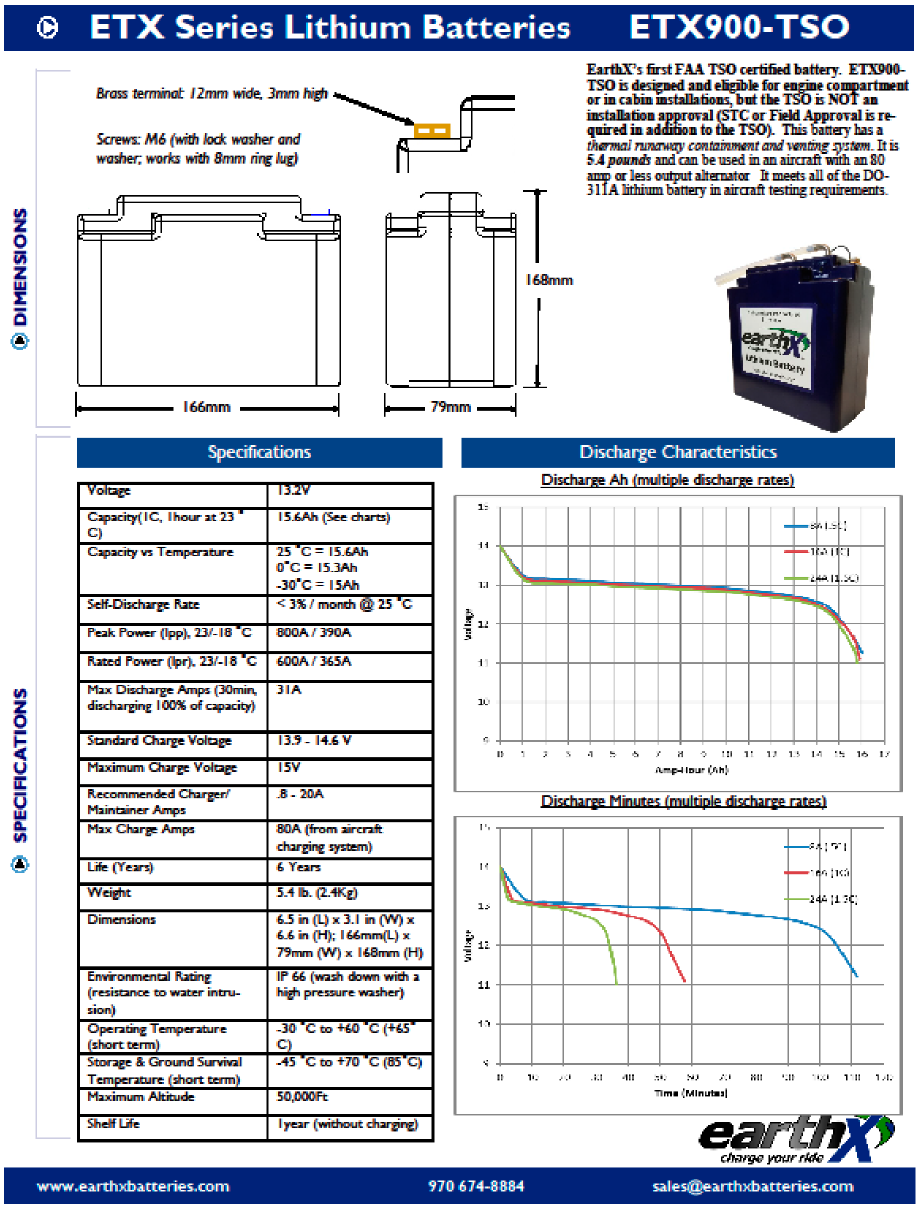
Following the meeting, designers began work to gather additional information on the proposed battery; also, with the additional requirements that were likely to be imposed, as well as the perceived resistance to the use of the Lithium battery, a search for alternative chemistry batteries was also started. A rough calculation of the free volume inside of the enclosure indicated that, depending on the size of the battery, there would be 2000-3000 cu in of free volume available.

While working to gather additional information on the camera and emitter devices, it was learned that they were no longer available, thus designers began looking for suitable alternative devices. Reputable manufacturers with approved camera systems were contacted to gather information on available technology for use on this machine. It was also discovered that there were thermal imaging cameras approved for mining outside of the USA, however, in discussions with MSHA, it was learned that these cameras used a germanium lens, which was brittle and could not withstand impact testing, and therefore no thermal imaging camera had been approved by MSHA. During January 2022, a camera vendor responded with a proposal for a new camera system. This camera was very similar to the original camera used on the prototype machine, with some added features. It could operate in color or black and white, and was not a thermal imaging camera, so an IR emitter would be used to improve visibility in low light, much like the original prototype setup. This camera did not, however, fit inside of the dual headlight enclosure previously used, and the vendor offered a slightly larger enclosure to house the camera. The IR emitter would need to be located in a separate enclosure, and the vendor was planning to do some testing of the setup to determine its low light capability. Figure 187 shows a picture of the proposed camera housing on a desk. The housing was approximately 6 inches tall and 7 inches wide, which was much taller than the original dual headlight housing. This size increase made the system somewhat undesirable.

Figure 187 - Prototype Camera Enclosure

As the cameras used in the initial prototype were no longer available, and an approved replacement system required more space and was also prohibitively expensive, it was recommended that the on-board camera system be tabled until a later time. It was believed that a simplified machine electrical system would give the best chance of producing a functional, approved machine design. Removing the video component also reduced power consumption, and could be added as an option later after the basic machine approval was done.

During research into alternative batteries, there was a focus on Nickel based batteries that could be used. A few candidate battery packs were identified, and additional information was requested from the manufacturers. A smart charger for Ni based batteries was found that used 12 vdc as a source voltage. Charging the battery on the machine would be highly desirable, but charging Ni based battery packs generally required chargers that were made to control the charging cycle, and connecting them directly to alternator sourced voltages was not considered ideal. One proposal to charge the battery would use a contactor to switch the battery out of circuit, and on to the smart charger once the alternator was producing voltage. In a discussion held with a representative of a Nickel battery pack manufacturer, this process was described and the question was asked as to how long the battery could tolerate charging from the alternator after startup before switching to the smart charger, and the representative was unable to provide an answer. While researching candidate batteries, it was observed that the trend of industry was moving away from Nickel based batteries and toward Lithium based batteries, and while the safety concerns with these batteries have been discussed, another battery selection concern was ensuring component availability once the mine rescue machine was approved for use. It was discovered that certain aviation batteries are NiCd, and additional research was conducted into aviation batteries. It was then discovered that a small lithium-based battery was evaluated by the FAA, and met their requirements for use in certified aircraft. This battery design had unique features that were of note, and it also seemed to meet many of the requirements mentioned by MSHA. As described in earlier reports, venting the enclosure through a flame arrestor was discussed as a possible requirement to use a Lithium based battery. Whereas mines tend to be damp, the possibility of condensation inside of a ventilated enclosure with sensitive electronic components was of concern. The newly discovered battery was built with vent lines that were made to relieve the fumes and gasses that could be generated by a thermal event in the battery cells. This design was shared with MSHA representatives, and it was mentioned that the vent lines could be plumbed to flame arrestor fittings, which could relieve the gas pressures that were of concern. A specification sheet on this battery is shown in Figure 188.



ETX Series Lithium Batteries ETX900-TSO

EarthX's first FAA TSO certified battery. ETX900-TSO is designed and eligible for engine compartment or in cabin installations, but the TSO is NOT an installation approval (STC or Field Approval is required in addition to the TSO). This battery has a *thermal runaway containment and venting system*. It is 5.4 *pounds* and can be used in an aircraft with an 80 amp or less output alternator It meets all of the DO-311A lithium battery in aircraft testing requirements.

Specifications

Voltage	13.2V
Capacity(1C, 1hour at 23 °C)	15.6Ah (See charts)
Capacity vs Temperature	25 °C = 15.6Ah 0°C = 15.3Ah -30°C = 15Ah
Self-Discharge Rate	< 3% / month @ 25 °C
Peak Power (Ipp), 23/-18 °C	800A / 390A
Rated Power (Ipr), 23/-18 °C	600A / 365A
Max Discharge Amps (30min, discharging 100% of capacity)	31A
Standard Charge Voltage	13.9 - 14.6 V
Maximum Charge Voltage	15V
Recommended Charger/ Maintainer Amps	.8 - 20A
Max Charge Amps	80A (from aircraft charging system)
Life (Years)	6 Years
Weight	5.4 lb. (2.4Kg)
Dimensions	6.5 in (L) x 3.1 in (W) x 6.6 in (H); 166mm(L) x 79mm (W) x 168mm (H)
Environmental Rating (resistance to water intrusion)	IP 66 (wash down with a high pressure washer)
Operating Temperature (short term)	-30 °C to +60 °C (+65° C)
Storage & Ground Survival Temperature (short term)	-45 °C to +70 °C (85°C)
Maximum Altitude	50,000Ft
Shelf Life	1year (without charging)

www.earthxbatteries.com 970 674-8884 sales@earthxbatteries.com

Figure 188 - Battery Specification Sheet

On 13 January 2022, a virtual discussion was held with a NIOSH representative that has studied Lithium based batteries, and possessed specialized knowledge on the devices. The specific safety concerns of implementing these batteries into underground mining were discussed, and the thermal runaway event was explained. It was noted that the pressure increase, due to gases released from a lithium cell during a thermal event, was substantial, and that the pressure could well exceed the design pressure for a MSHA approved XP enclosure. The venting of the pressure was discussed, and it was also mentioned that any flame arrestor used in this application would need to be designed for the vented gasses, and the possible temperatures generated during a thermal event. It was also mentioned, as it was of interest, that the thermal runaway temperature of a lithium battery cell had been observed to be below the autoignition temperature of methane air mixes. Additional discussion involved the lithium battery that was evaluated for certified aircraft and the vent lines used for escaping gasses. It was mentioned that this was an interesting design feature. After the discussion, information on the battery was sent to the NIOSH representative, who in turn provided additional research information on lithium battery thermal events for us to review.

Whereas the proposal to use a lithium-based battery on the machine was not received favorably, investigators felt that, in the interest of the project and attaining MSHA approval, a different battery alternative was likely be necessary. It was also unlikely that an alternative would hold the same power density as a lithium-based battery, due to the existing state of available battery technology. It was therefore determined that further simplifying the electrical system components and reducing power consumption would not only provide for longer battery run time, but also reduce some difficulty in attaining MSHA approval. After reviewing the electrical system, and meeting with the manufacturer of the approved radio remote control system on 24 March 2022, the system was discussed, and it was determined that the radio remote control base unit could perform the necessary functions to operate the machine, and that the PLC was essentially a redundant device that could be eliminated from the design. The radio system base unit was expandable, making it possible to add digital and analog input / outputs, and the J1939 CAN made it possible for a secondary control system input to operate the machine. Removing the additional component also reduced the total parts of the system, which improved reliability, with less components that could malfunction.

On 7 April 2022, a representative of MSHA's Electrical Division reached out to discuss the electrical system, enclosure approval, and the machine systems in general. It was noted that there had been several recent personnel changes within MSHA, and that there was some confusion relative to the machine design and approval applications. It was mentioned that review of the enclosure documentation was nearly complete, and that once the confusion surrounding the electrical approval and battery were addressed, that the evaluation could move forward. After some conversation, it was agreed to send additional information on the mine rescue machine prototype to the MSHA representative, to aid in the understanding of the project and machine design; and the representative indicated that they would assist as a point of contact for questions and information requests. The aforementioned simplification of the electrical system was also discussed at length. On 29 April 2022, a revised electrical schematic was sent to the MSHA representative for review, and a copy of this drawing is shown in Figure 189.

As shown in the figure, the electrical system was simplified substantially from the original prototype. The video camera and wired data communication system components, as well as the PLC were removed. The radio remote control base unit was shown as the controlling device for all outputs, and voltage dividers also allowed it to monitor battery and system voltages. The aforementioned battery charging suggestion was also shown, along with the base unit controlled relay, that switches the battery out of the power circuit and onto a smart charger.

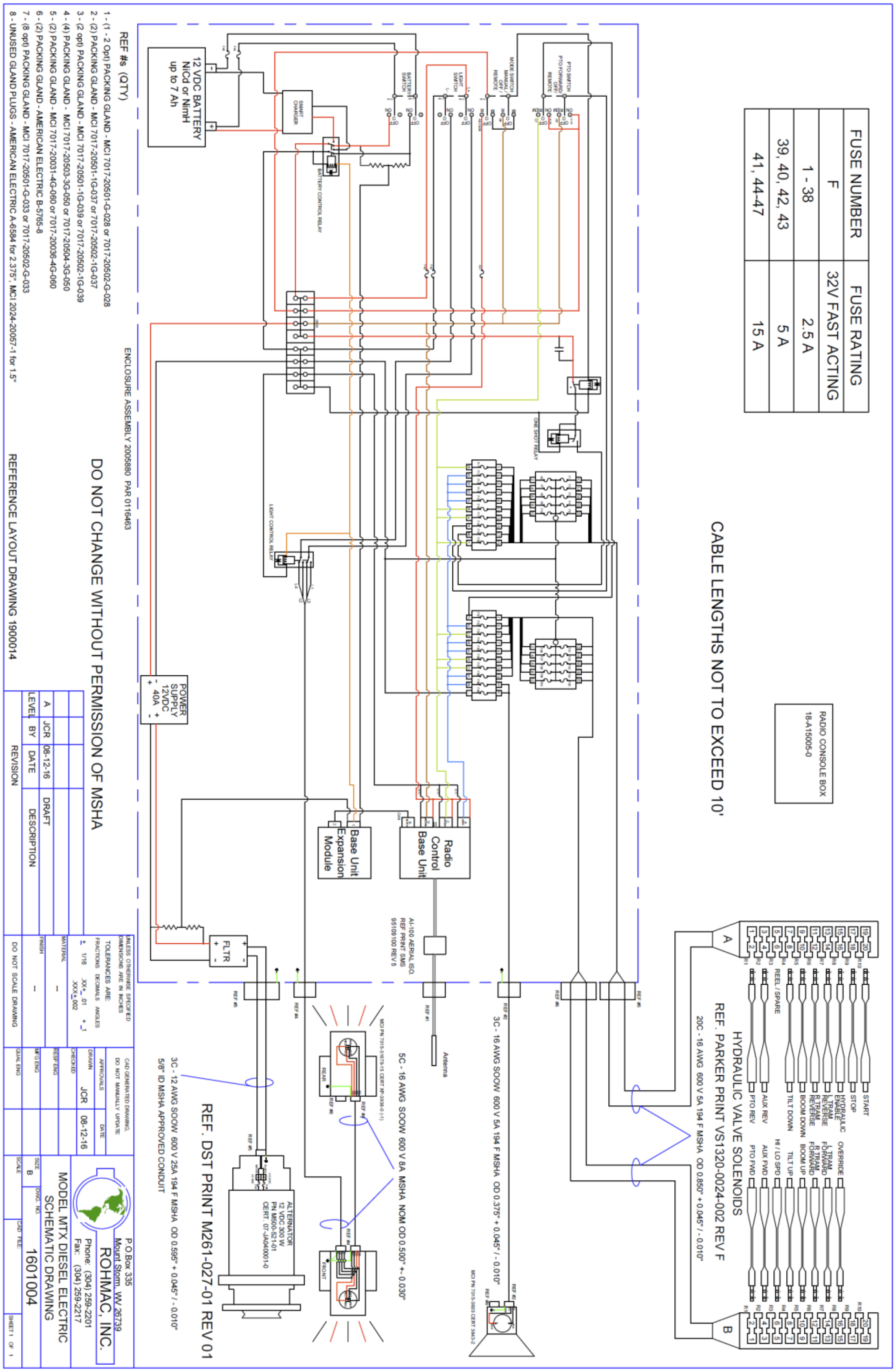
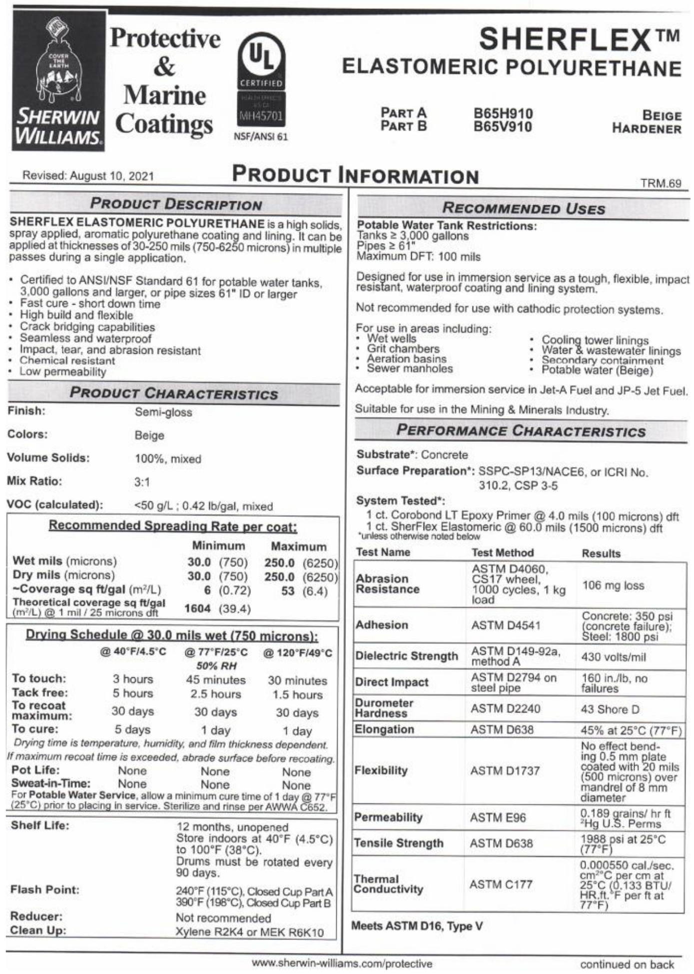


Figure 189 - Updated Electrical Drawing

On 18 May 2022, a call was received from representatives of MSHA's Electrical Division to discuss the proposed electrical system. It was explained that placing a battery of any kind inside of the explosion proof enclosure was undesirable. MSHA XP enclosures were designed to contain methane gas ignitions, and batteries posed a risk to the integrity of these enclosures; as well, in the case of alternate battery chemistries, the enclosure's ability to contain a battery thermal event was questionable. It was mentioned that MSHA intended to evaluate alternate battery chemistries for use in underground coal mines, but that this process would take a significant amount of time and study to arrive at proper safety protocols. It was therefore suggested that the subject diesel electric design be altered to remove the battery from the XP enclosure, and build a battery box as specified in 30 CFR part 7. The battery box design requirements were briefly discussed, as well the requirements for connection to the battery terminals. The function, power usage, and size of the battery were discussed, and it was mentioned that the battery would be very small as compared to typical mine batteries. Methods of battery change and charging were discussed, it was expected that the compact size of this battery enclosure assembly should be such that a person could carry the assembly through the mine and change it out on the machine as needed. Some minimum design features were discussed such as minimum plate thickness, and the requirement for a non-conductive, acid and flame resistant, approved coating to be applied to the inside surfaces of the battery enclosure. It was mentioned that approval of a part 7 battery enclosure was relatively simple so long as it met the minimum requirements. At the end of the discussion, the MSHA representatives agreed to send a list of approved coatings, as well as information on the battery box requirements. Further discussion on the battery enclosure and charging management were held during a follow up call on 25 May 2022. Following these calls, designers started investigating a battery box design. Information was sought on the approved coating needed for the inside of the battery enclosure, and a subject coating was found, Figure 190 shows a specification sheet for the coating.



Protective & Marine Coatings

SHERWIN WILLIAMS.

CERTIFIED MH45701 NSF/ANSI 61

SHERFLEX™
ELASTOMERIC POLYURETHANE

PART A	B65H910	BEIGE
PART B	B65V910	HARDENER

Revised: August 10, 2021

PRODUCT INFORMATION

TRM.69

PRODUCT DESCRIPTION

SHERFLEX ELASTOMERIC POLYURETHANE is a high solids, spray applied, aromatic polyurethane coating and lining. It can be applied at thicknesses of 30-250 mils (750-6250 microns) in multiple passes during a single application.

- Certified to ANSI/NSF Standard 61 for potable water tanks, 3,000 gallons and larger, or pipe sizes 61" ID or larger
- Fast cure - short down time
- High build and flexible
- Crack bridging capabilities
- Seamless and waterproof
- Impact, tear, and abrasion resistant
- Chemical resistant
- Low permeability

PRODUCT CHARACTERISTICS

Finish:	Semi-gloss
Colors:	Beige
Volume Solids:	100%, mixed
Mix Ratio:	3:1
VOC (calculated):	<50 g/L ; 0.42 lb/gal, mixed

Recommended Spreading Rate per coat:

	Minimum	Maximum
Wet mils (microns)	**30.0** (750)	**250.0** (6250)
Dry mils (microns)	**30.0** (750)	**250.0** (6250)
~Coverage sq ft/gal (m^2/L)	**6** (0.72)	**53** (6.4)
Theoretical coverage sq ft/gal (m^2/L) @ 1 mil / 25 microns dft	**1604** (39.4)	

Drying Schedule @ 30.0 mils wet (750 microns):

	@ 40°F/4.5°C	@ 77°F/25°C 50% RH	@ 120°F/49°C
To touch:	3 hours	45 minutes	30 minutes
Tack free:	5 hours	2.5 hours	1.5 hours
To recoat maximum:	30 days	30 days	30 days
To cure:	5 days	1 day	1 day

Drying time is temperature, humidity, and film thickness dependent.
If maximum recoat time is exceeded, abrade surface before recoating.

Pot Life:	None	None	None
Sweat-in-Time:	None	None	None

For **Potable Water Service**, allow a minimum cure time of 1 day @ 77°F (25°C) prior to placing in service. Sterilize and rinse per AWWA C652.

Shelf Life:	12 months, unopened. Store indoors at 40°F (4.5°C) to 100°F (38°C). Drums must be rotated every 90 days.
Flash Point:	240°F (115°C), Closed Cup Part A; 390°F (198°C), Closed Cup Part B
Reducer:	Not recommended
Clean Up:	Xylene R2K4 or MEK R6K10

RECOMMENDED USES

Potable Water Tank Restrictions:
Tanks ≥ 3,000 gallons
Pipes ≥ 61"
Maximum DFT: 100 mils

Designed for use in immersion service as a tough, flexible, impact resistant, waterproof coating and lining system.

Not recommended for use with cathodic protection systems.

For use in areas including:
- Wet wells
- Grit chambers
- Aeration basins
- Sewer manholes
- Cooling tower linings
- Water & wastewater linings
- Secondary containment
- Potable water (Beige)

Acceptable for immersion service in Jet-A Fuel and JP-5 Jet Fuel.

Suitable for use in the Mining & Minerals Industry.

PERFORMANCE CHARACTERISTICS

Substrate*: Concrete
Surface Preparation*: SSPC-SP13/NACE6, or ICRI No. 310.2, CSP 3-5

System Tested*:
1 ct. Corobond LT Epoxy Primer @ 4.0 mils (100 microns) dft
1 ct. SherFlex Elastomeric @ 60.0 mils (1500 microns) dft
*unless otherwise noted below

Test Name	Test Method	Results
Abrasion Resistance	ASTM D4060, CS17 wheel, 1000 cycles, 1 kg load	106 mg loss
Adhesion	ASTM D4541	Concrete: 350 psi (concrete failure); Steel: 1800 psi
Dielectric Strength	ASTM D149-92a, method A	430 volts/mil
Direct Impact	ASTM D2794 on steel pipe	160 in./lb, no failures
Durometer Hardness	ASTM D2240	43 Shore D
Elongation	ASTM D638	45% at 25°C (77°F)
Flexibility	ASTM D1737	No effect bending 0.5 mm plate coated with 20 mils (500 microns) over mandrel of 8 mm diameter
Permeability	ASTM E96	0.189 grains/ hr ft ²Hg U.S. Perms
Tensile Strength	ASTM D638	1988 psi at 25°C (77°F)
Thermal Conductivity	ASTM C177	0.000550 cal./sec. cm²°C per cm at 25°C (0.133 BTU/ HR.ft.°F per ft at 77°F)

Meets ASTM D16, Type V

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continued on back

Figure 190 - Specification Sheet for Example Battery Box Coating

Work also continued in the search for available nickel-based batteries. Discussion with a representative of a NiCd battery manufacturer yielded a compact battery that may be useful for the machine. It was mentioned that theses batteries had a history of use in industry and have proven to be reliable, and that as compared to other chemistries, they have good shelf life and little concern with over-discharge, but that overcharge can cause a limited amount of venting. The dimensions for a 12 Volt 24 Ah battery assembly would be approximately 6” x 10” by 10.6” tall with a weight of approximately 40 lb. Adding the necessary Part 7 protective enclosure would likely yield a 50 lb assembly, making it portable. Comparatively, there was a commercially available AGM lead based battery with a higher power rating (38 Ah), and would actually be lighter (26 lb) and more compact. However, the NiCd battery remained a viable alternative should a method to charge the battery from the alternator power source be approved; the slight increase in size would be offset by the reduction in maintenance of changing out batteries for recharging purposes. More discussion on the matter, and the control of possible hydrogen gas emissions, was necessary to determine what was possible.

On 23 June 2022, a call was received from representatives of MSHA’s Electrical Division to discuss the proposed electrical system. During the call, it was mentioned that there was still confusion about the proposed machine systems, mostly due to recent personnel changes. It was requested that MSHA be provided with a brief explanation of the machine system, as well as notes from former discussions relevant to the use of the battery on the machine. It was again stated that batteries inside of a XP enclosure were not desirable. Following the call, notes from previous meetings and discussions were reviewed, the electrical schematic was modified to show the battery outside of the XP enclosure, and information was sent to MSHA on 28 June 2022. Figure 191 shows the updated schematic, and the machine explanation that was sent to the MSHA representatives was as follows:

MICROTRAXX MTX 3648 description of power systems:

The MICROTRAXX model MTX 3648 is a compact radio remote controlled, diesel engine powered track loader design for which we are pursuing permissible approval. The diesel engine powers a variable displacement hydraulic pump, which powers machine functions and is controlled by hydraulic valves. The engine is started using a hydraulic motor-powered starter that is valve actuated; an on-board accumulator is charged by the main pump, and stores pressure to energize the starter. In the event that the accumulator is depleted, an on-board hand pump may be used to recharge the pressure. The hydraulic valves are actuated by pilot valves with permissible solenoid coils, there are also manual valves on the machine. Due to the nature of the machine and the tasks it performs, there is no operator compartment on-board the machine and normal operation is entirely through radio remote control. It is therefore necessary to actuate the engine start remotely.

The electrical system on the machine is 12 VDC. A belt driven permissible alternator provides the power source while the engine is running. This power goes through a filter and a dc-dc power supply to provide clean power to the electronic devices inside of the XP enclosure. When the engine is not running, a battery is necessary to power the radio control system base unit, and to actuate the override and engine start hydraulic valves during the engine start sequence. Once the engine has started, the alternator begins to supply power. At this point, A relay contact controlled by the base unit could separate the battery from the circuit, leave it in the circuit and allow it to charge, or separate it from the alternator circuit and connect to a smart or trickle charger, TBD. The power draw of the base unit in standby mode is rather small, and the actuation of the valve coils takes a couple of amps.

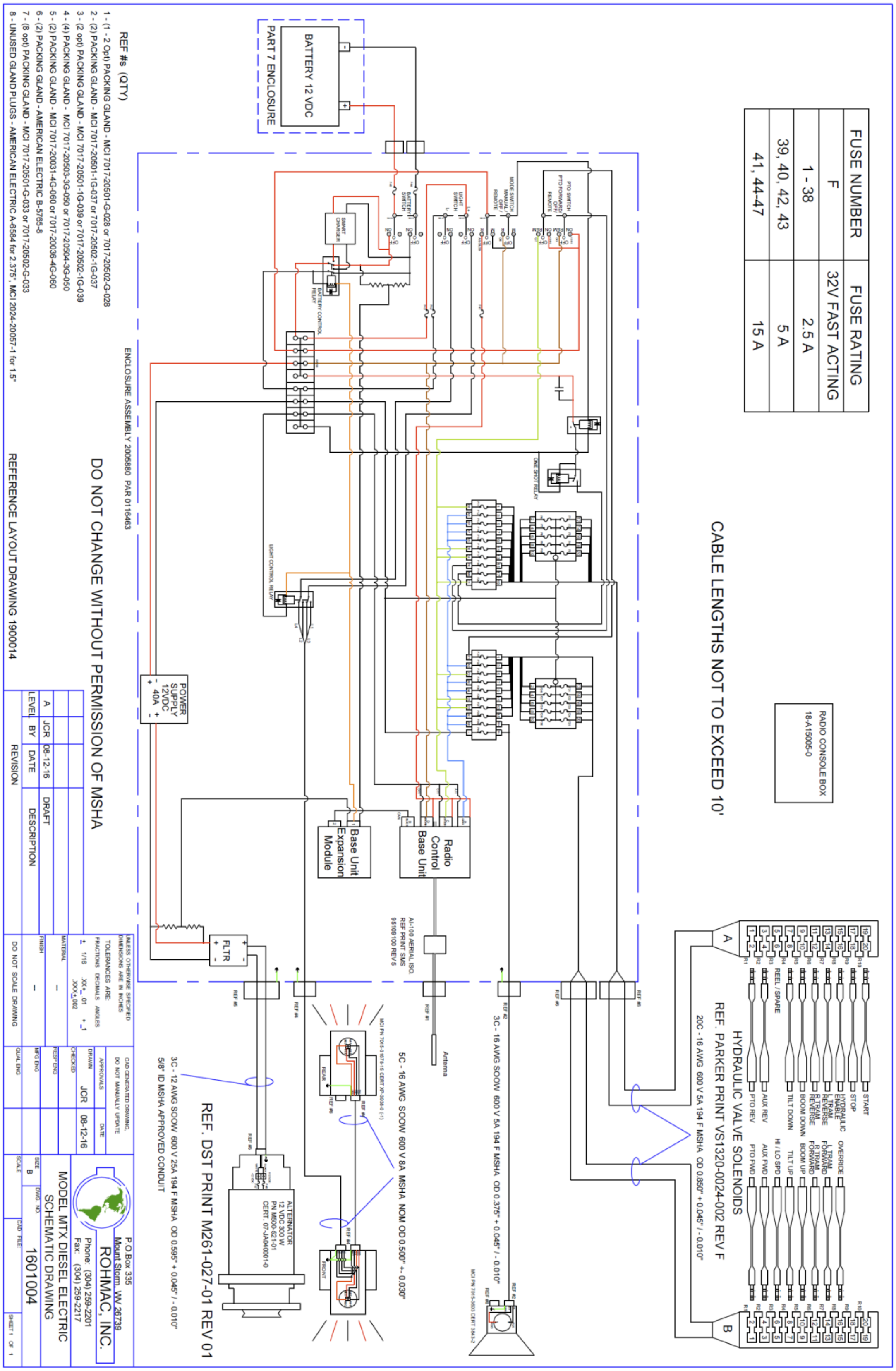

Figure 191 - Updated Electrical Drawing with Separate Battery Enclosure

As shown in Figure 191, the electrical system was substantially changed from the original prototype. In this drawing, the battery was shown in a separate external enclosure, and the radio remote control system base unit with expansion card, as well as the contact, mentioned in the machine description above, that can separate the battery from the alternator, are also drawn. During the previous calls with MSHA representatives, the separation of the battery and the alternator were mentioned, it was mentioned that a short transition period would be necessary to switch between battery power and alternator sourced power. During the transition period, the alternator would be providing power to the battery. The question was raised that, where necessary to separate the alternator from the battery, what would an acceptable time period be for the transition, it was mentioned that this process should take less than a minute to complete after startup, and guidance was sought on what MSHA may find acceptable.

At the time of this report, discussion on the subject diesel electric system was ongoing, it was believed that parties were moving closer to a resolution on the matter. Once the questions about the battery handling were answered, the process could move forward.

PART 36 MACHINE APPROVAL APPLICATION

A draft copy of the Part 36 machine approval application was developed and emailed to MSHA representatives for consultation on 1 November 2021. This approval was for the complete machine assembly and required that all other subsystem approvals were completed before it could be finished. It was mentioned by the MSHA representatives that no major issues were found after a brief review. This machine approval included and referenced all other approved equipment used on the machine.

Whereas there the design had changed since these documents were developed, there would be changes to them once other approvals and modifications were final. The draft application is shown in the following figures:

Office (304) 259-2201 • Fax (304) 259-2217

ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

29 October 2021

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC is requesting part 36 approval for a new MICROTRAXX model MTX 3648, company code 211029.

The subject machine consists of a model DP 25 XP diesel power package currently being evaluated under PAR 116579, and a model MTX diesel electric currently being evaluated under PAR, this application is contingent upon these approvals). The machine is a compact hydraulic driven track loader with adapter plate for loader attachments. The machine is controlled by an approved radio remote control device. The machine is assembled according to layout drawing 19xxx.

Since this is a new prototype machine, it will be completely assembled and made available for inspection and testing at the MSHA Approval and Certification Center at a date and time to be coordinated.

Enclosed are all of the drawings, documents, and specifications pertinent to this application. If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremy Rohrbaugh, P.E.
Manager of Engineering
Rohmac, Inc.
792 Old Laurel Run Road
PO Box 335
Mt. Storm, WV 26739

Figure 192 - Machine Approval Application Draft Cover Letter

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ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

29 October 2021

DRAWING LIST
Rohmac Inc MICROTRAXX Model MTX 3648

TITLE	Drawing / File No.	Rev
MTX 3648 General Arrangement	1800004	A
MTX 3648 Fuel System Layout	2100007	A
MTX 3648 Hydraulic Schematic	1802001	A
Approval Plate	2106120	A
MTX 3648 Permissibility Checklist	211101JCR01	A
MTX 3648 Factory Inspection Form	211101JCR02	A

Figure 193 - Machine Approval Application Draft Drawing List

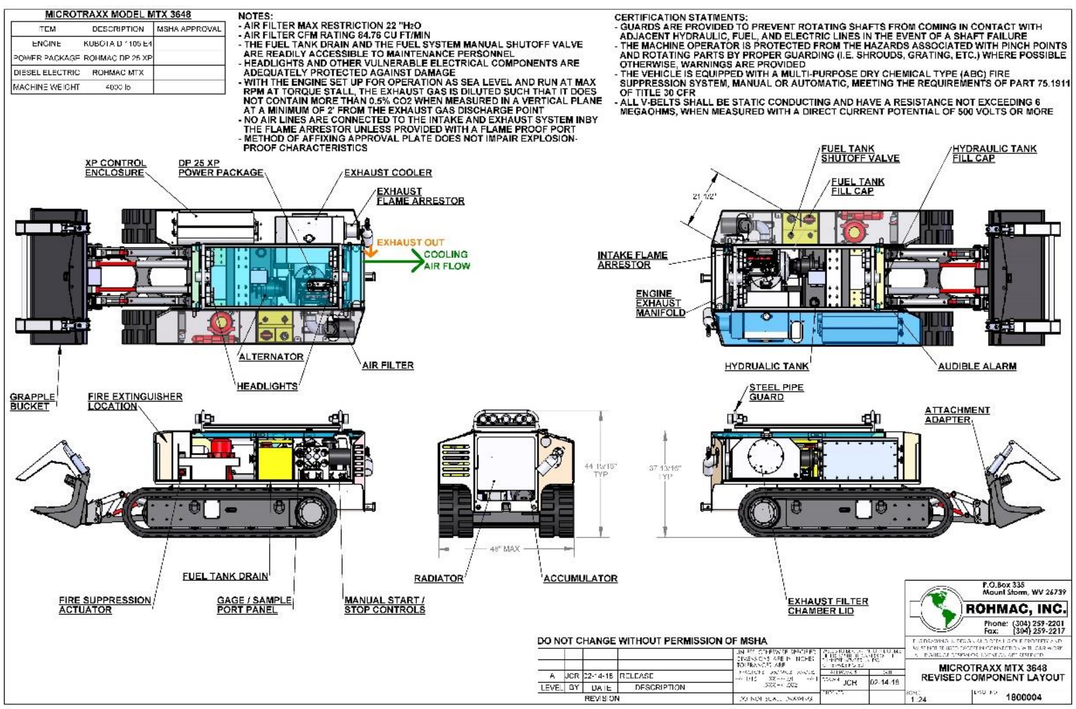

Figure 194 - Machine Approval Application Draft Layout Drawing

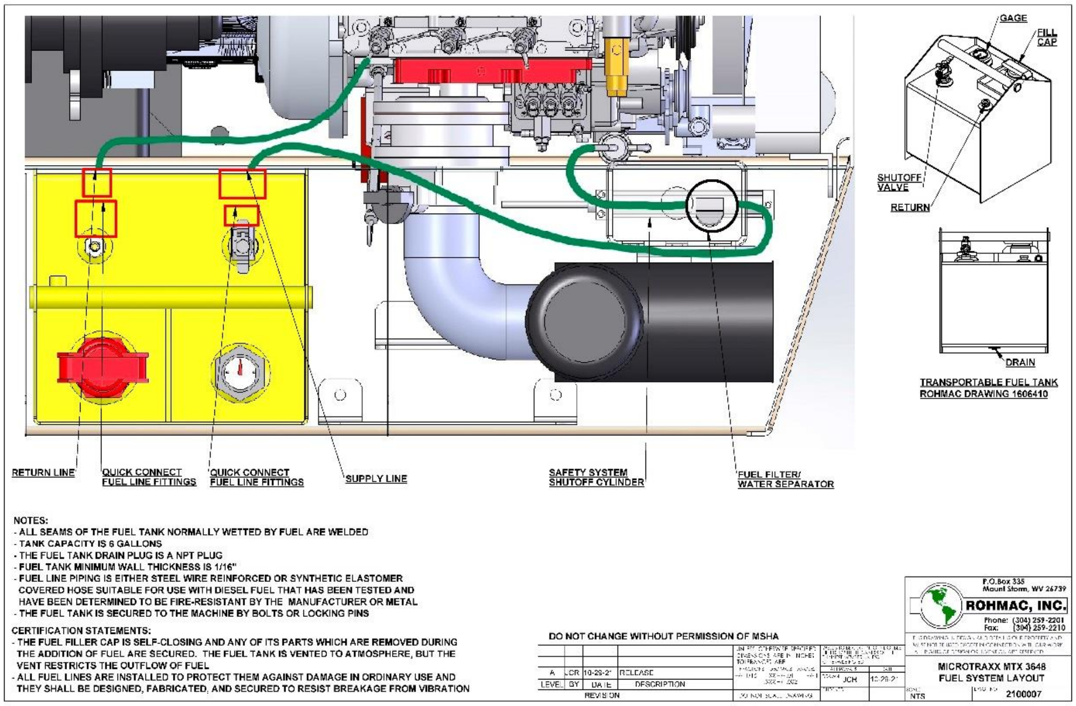

Figure 195 - Machine Approval Application Draft Fuel System Drawing

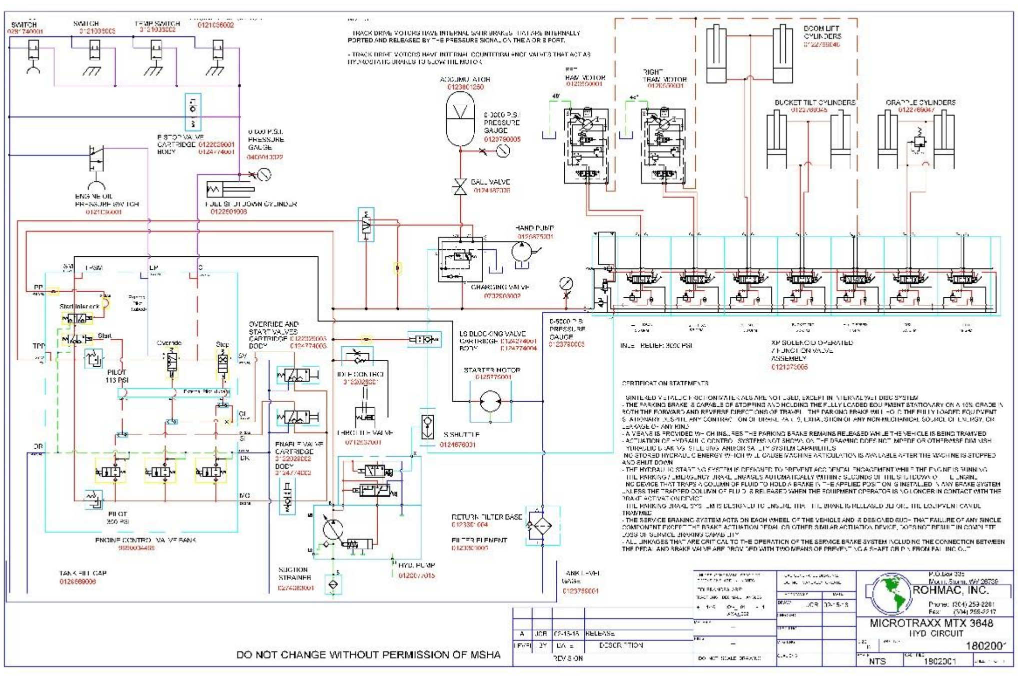

Figure 196 - Machine Approval Application Draft Hydraulic Schematic

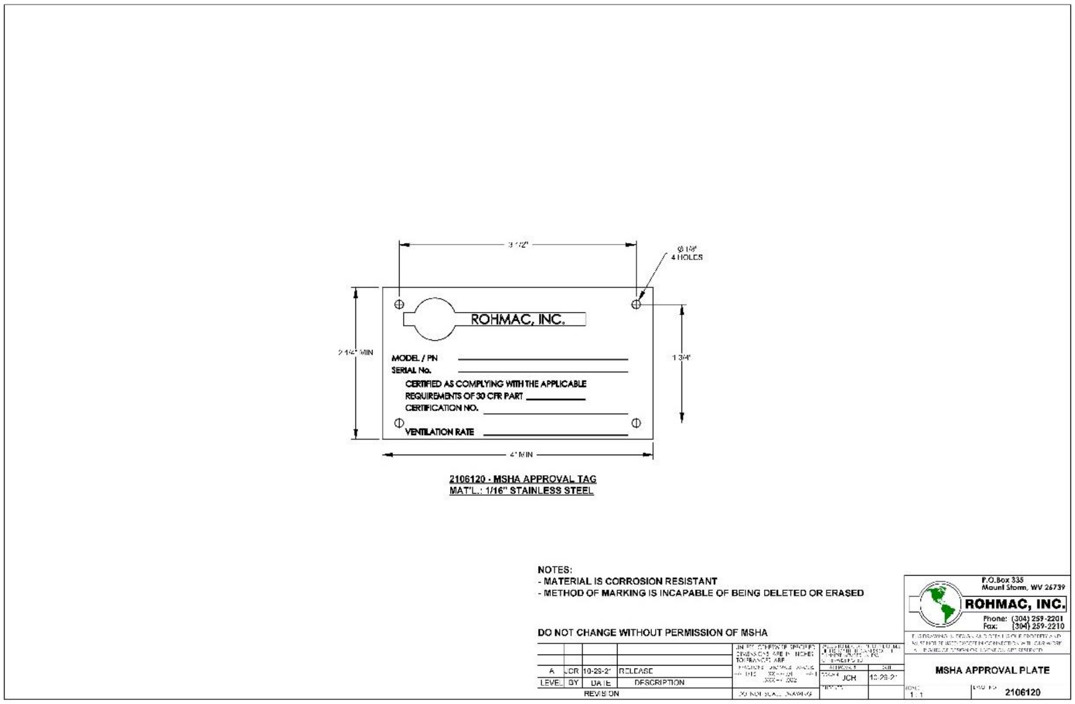

Figure 197 - Machine Approval Application Draft Approval Tag Drawing

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ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

ROHMAC INC

MICROTRAXX **MTX 3648**

MSHA Approval #

Machine Permissibility Checklist

Document # 211101JCR01

If a MSHA Part 36 approval plate has been attached to this machine, it must meet the requirements of Part 36, Title 30, Code of Federal Regulations. It is the responsibility of the mine operator to ensure that this machine is maintained in permissible condition in accordance with this checklist.

This checklist must be used in conjunction with a Diesel Power Package Permissibility Checklist 190905JCR01, and a Diesel Electric Permissibility Checklist 190920JCR05, for a complete equipment permissibility evaluation.

The component and function checks designated as "weekly" in this checklist shall be performed as part of each weekly maintenance examination in accordance with Code of Federal Regulations, Title 30, Section 75.1914.

Source Power: Rohmac DP 25XP Diesel Power Package Approval #

Engine : Kubota D 1105 MSHA Approval #'s 07-ENA140006 and 07-EPA21000

Machine Serial or Property No. ________________

Date of Examination ________________

Indicated Hours on Machine ________________

Examination Conducted by ________________

Page **1** of **3**

Drawing # 211101JCR01 Rev A
1 November 2021

Figure 198 - Machine Approval Application Draft Permissibility Checklist page 1

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1. It has been determined that the area, in which tests are to be performed, is in FRESH AIR, in an area where permissible machines are not required.
2. The approval plate specifies a ventilation rate of cubic feet per minute
3. The maximum grade on which this machine may be operated shall not exceed 25%

Fuel System:

I. ____(Weekly) There are no fuel leaks
II. ____(Weekly) The fuel filler cap is vented and the vent is not plugged
III. ____(Weekly) The fuel filler cap is self-closing and is attached to the tank in a manner that will prevent loss while refueling
IV. ____(Weekly) Auxiliary fuel tank capacity has not been added to the machine
V. ____(Weekly) The fuel filter is properly installed and not damaged
VI. ____(Weekly) The fuel shutoff valve in the supply line is operable
VII. ____(Weekly) The fuel tank drain plug is tight and secured
VIII. ____(Weekly) Fuel lines are either steel wire reinforced, fire-resistant synthetic elastomer-covered hose suitable for use with diesel fuel, or metal
IX. ____(Weekly) Fuel lines are not routed near or connected to hot exhaust components and are protected from external damage
X. ____(Weekly) Fuel lines are secured from excess movement
XI. ____(Weekly) Fuel line disconnect fittings function properly or have been replaced with permanent fittings
XII. ____(Weekly) Fuel tank is secured to the machine with locking pins or bolts and will not move

Braking System:

WARNING: Brake tests are to be conducted on a relatively level surface away from traffic areas where other machines or persons may be moving about. Ensure all persons are clear of the area while performing test. **ALWAYS** stand clear of the machine in a safe position while performing the test.
Note: These tests must insure service and parking brake capability equal to or greater than the maximum specified gradeability of the machine

To perform the test, use of a scoop or other mechanism with a winch capable of dragging the machine while stationary is recommended. **CAUTION:** While pulling tension on winch cable ensure that no person is positioned between the machines, or where failure of the cable or tow

Page **2** of **3**

Drawing # 211101JCR01 Rev A
1 November 2021

Figure 199 - Machine Approval Application Draft Permissibility Checklist page 2

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ROHMAC, INC.

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link could cause them harm. Attach a tow link to the hitch receiver on the machine and securely connect the winch cable to the link.

I. ____(Weekly) Hydrostatic / Service Brake Test
   a. Start the machine and enable hydraulics and tram, activate each track in each direction separately and then release control, the control lever should return to center and the track will stop rotating immediately
   b. With the engine running pull the winch, the tracks should skid without rotating the sprockets
II. ____(Weekly) Park Brake Test
   a. With the engine shut down, pull the winch, the tracks should skid without rotating the sprockets

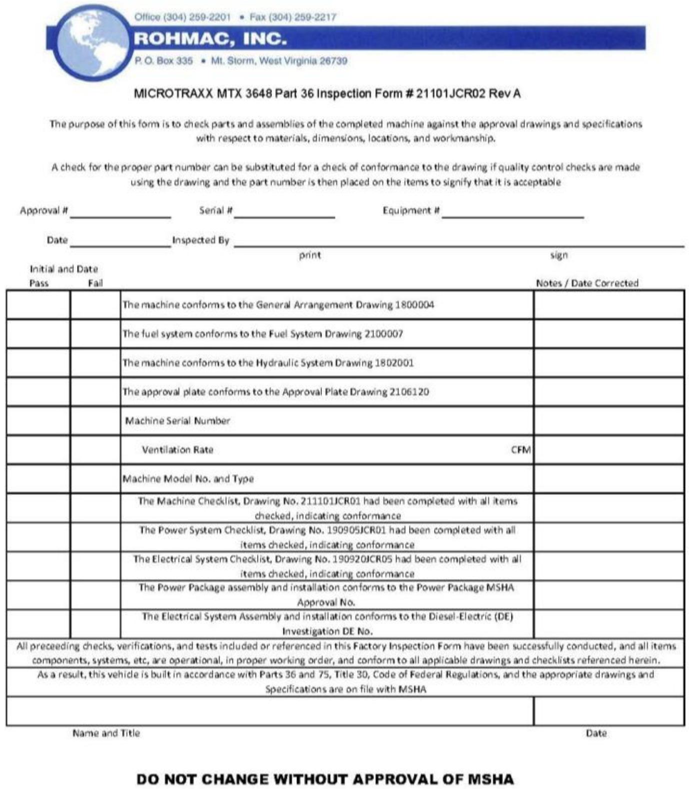
Miscellaneous Checks

I. ____(Weekly) The machine is equipped with one dry chemical fire extinguisher with a minimum of a 10A:60B:C NFPA rating, that is fully charged
II. ____(Weekly) The fire suppression system is tested and maintained in accordance with it's manufacturer's recommended maintenance and inspection program
III. ____(Weekly) The fire suppression system is operable as determined by the following:
   a. System components exhibit no visual indications of physical damage or corrosion
   b. Check hose fittings and nozzles for signs of physical damage or cuts
   c. Nozzles are protected against the entry of foreign materials such as mud, coal dust, or rockdust. Check nozzle openings, slot on nozzles should be closed with a plastic blow off cap
   d. The lead or wire seals are installed on all manual actuators. (If missing refer to fire suppression system manufacturer's inspection manual for inspecting actuator gas cartridges.)
IV. ____(Weekly) The machine has a legible Part 36 approval tag attached to it in a conspicuous location
V. ____(Weekly) The neutral start and tram control features on the machine are functioning properly. The radio system will not link up unless all switches and function operators are in the neutral of off position. There is no tendency for the tracks to move during engine start, or until both the hydraulic enable AND Tram enable features are active, the tram enable times out in 5 seconds if no input is detected from the levers. The hydraulic function outputs will not operate unless the hydraulic enable is activated.
VI. ____(Weekly) With the machine tramming, pressing the red M-Stop Switch on the radio transmitter immediately stops the active function, followed by machine shutdown
VII. ____(Weekly) The radio inactivity timeout function will shutdown the machine when no function levers are activated for a period of 5 minutes

Page **3** of **3**

Drawing # 211101JCR01 Rev A
1 November 2021

Figure 200 - Machine Approval Application Draft Permissibility Checklist page 3



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ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

MICROTRAXX MTX 3648 Part 36 Inspection Form # 21101JCR02 Rev A

The purpose of this form is to check parts and assemblies of the completed machine against the approval drawings and specifications with respect to materials, dimensions, locations, and workmanship.

A check for the proper part number can be substituted for a check of conformance to the drawing if quality control checks are made using the drawing and the part number is then placed on the items to signify that it is acceptable

Approval # ____________ Serial # ____________ Equipment # ____________

Date ____________ Inspected By ____________________ (print) ____________________ (sign)

Initial and Date Pass	Fail		Notes / Date Corrected
		The machine conforms to the General Arrangement Drawing 1800004	
		The fuel system conforms to the Fuel System Drawing 2100007	
		The machine conforms to the Hydraulic System Drawing 1802001	
		The approval plate conforms to the Approval Plate Drawing 2106120	
		Machine Serial Number	
		Ventilation Rate CFM	
		Machine Model No. and Type	
		The Machine Checklist, Drawing No. 211101JCR01 had been completed with all items checked, indicating conformance	
		The Power System Checklist, Drawing No. 190905JCR01 had been completed with all items checked, indicating conformance	
		The Electrical System Checklist, Drawing No. 190920JCR05 had been completed with all items checked, indicating conformance	
		The Power Package assembly and installation conforms to the Power Package MSHA Approval No.	
		The Electrical System Assembly and installation conforms to the Diesel-Electric (DE) Investigation DE No.	

All preceeding checks, verifications, and tests included or referenced in this Factory Inspection Form have been successfully conducted, and all items components, systems, etc, are operational, in proper working order, and conform to all applicable drawings and checklists referenced herein.

As a result, this vehicle is built in accordance with Parts 36 and 75, Title 30, Code of Federal Regulations, and the appropriate drawings and Specifications are on file with MSHA

Name and Title ____________________ Date ____________

DO NOT CHANGE WITHOUT APPROVAL OF MSHA

Figure 201 - Machine Approval Application Draft Factory Inspection Form

Figure 192 and Figure 193 show the request letter and a drawing list, respectively. These were similar to those used in the other approval applications performed under the project. Figure 194 shows a layout overview drawing of the mine rescue machine along with callout labels of component positions, overall dimensions, specifications, and certification statements required by MSHA. Figure 195 shows the layout of the diesel fuel system, with callouts for hoses and fittings, as well, the transportable fuel tank was shown, and additional required notes and certifications statements were located at the bottom of the drawing. A schematic drawing of the machine hydraulic system is shown in Figure 196, and a drawing of the approval tag, that would be used upon completion of all approvals, is shown in Figure 197. A permissibility checklist for the machine safety requirements starts with Figure 198, and a factory inspection checklist is shown in Figure 201.

It was anticipated that there would be necessary revisions to these documents, based on alterations necessary for other approvals, prior to submitting them for approval, and that a consultation review of the documents would also be performed prior to submitting them to MSHA.

RESULTS

This project resulted in the significant redesign of several operating systems on the prototype mine rescue machine. Noteworthy changes included the redesign of the exhaust treatment system, and moving from the water mixing exhaust cooler to a dry-type exhaust system that cooled the exhaust gases without using consumable water, the alteration of the engine start and control system from pneumatic to hydraulic powered, space saving measures involving the engine intake and the fire suppression systems, and modification of the electrical system to utilize a MSHA approved, self-exciting alternator. In addition to the redesigned features, an explosion proof enclosure was developed for use on the machine.

Changing the start system to a hydraulic rather than pneumatic design presented some unexpected challenges due to the nature of hydraulic systems as compared to pneumatics, such as difference in the components' pressure capacities, fluid usage and leakage, and actuation mechanisms. Overall though, the modification addressed one of the primary concerns voiced by operators, in that now the fluid reservoir used to start the engine gets recharged while the engine operates, thus improving engine start capacity; also, the addition of a hand pump provided for a means to manually recharge the reservoir without the need of other equipment. Replacing the pneumatic system with the hydraulic control system contributed to the most significant space savings improvement attained during this project.

Modifications to the design of the exhaust treatment system were some of the most involved and time-consuming efforts undertaken. Redesign, development, and testing of a fundamentally different system than used on the original prototype resulted in a significant gain of function to the machine, by maximizing the grade on which the machine could operate, and also eliminating a shutdown sensor (low water level). A deciding factor in undertaking the redesign was space savings, after it was learned that additional volume would be necessary to continue with the original system. Concerns relating to low ambient temperatures causing the water in the mixing chamber to freeze were also eliminated. The exhaust and cooling system design was proven effective by certification testing of the device. The approval of the diesel power package was delayed by the requirement for a separate approval for the subject engine, and further by technical difficulties with test equipment. The expectation at this point in time, was that this approval would be completed without modification of the existing power package design.

Given the small footprint of the machine, and the need for effective use of volume for the possibility of adding future electronic capacity, it was necessary to design and build an explosion proof enclosure to house the electrical control and communications systems used on the machine. Some time was used in an attempt to find an existing approved device before undertaking this effort, as the design and approval process added significant time and cost to the overall project. The custom design enclosure was reviewed and an approval application was submitted. A level of corrections was also performed to the documentation. At the time of this report, the enclosure assembly design was undergoing evaluation by MSHA for permissible approval.

The machine electrical system was also redesigned under this project. Due to a variety of factors, it was necessary to simplify the design and set aside excess features, such that a functional base level machine could be approved. This simplification, while removing some components that were redundant, or had become obsolete, left provision for addition of features at a later time. The machine mounted battery used to start the machine via remote control became a focal point of concern, and was cause for confusion and delay while factors surrounding the appropriate specifications, position, and use of the battery were debated and discussed. Ultimately, several iterations of design were performed in consideration of this component, and as of the writing of this report, had yet to be completely resolved. The most current status was that a separately approved battery enclosure would be used to house the battery on the machine.

Documentation for the machine approval was also developed, and preliminary reviews were done. The documentation framework will simplify the approval application process as it will only require revisions to update any changes to subassemblies, once they are approved.

CONCLUSION

The original goal of the project was to develop and submit the necessary approval applications for the prototype mine rescue machine. The applications were developed, and the contractor worked with MSHA extensively during the application review, and approval evaluation process of the submitted approvals. It was also requested that submitting remaining applications be held until the subparts currently under review were completed, and therefore not all approval applications had been submitted as of the date of this report. This report would also be remiss without acknowledging the effects due to the COVID-19 pandemic, which caused direct and substantial delays to the project.

As there are active approval evaluations underway, it is the intent of the contractor to continue these processes to completion; as well, to the degree possible, to continue work on the necessary approvals that have yet to be submitted. It is the desire to see that a machine approval is completed.

APPENDIX A – Explosion Proof Enclosure Approval Application

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

31 December 2020

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC (TIN: 52-1813657-001) is requesting approval for a new XP Enclosure Assembly Part Number 2005880 company code 200911.

The subject enclosure consists of a steel enclosure weldment with switch operator assemblies and / or gland entrances for cables as specified in the attached drawings. An Aluminum bolt on cover is used on the enclosure assembly.

Since this is a new prototype enclosure, it will be completely assembled and available for inspection and testing upon request.

Enclosed are all of the drawings, documents, and specifications pertinent to this application. If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremiah Rohrbaugh, P.E.
Manager of Engineering
Rohmac, Inc.
PO Box 335
Mt. Storm, WV 26739

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

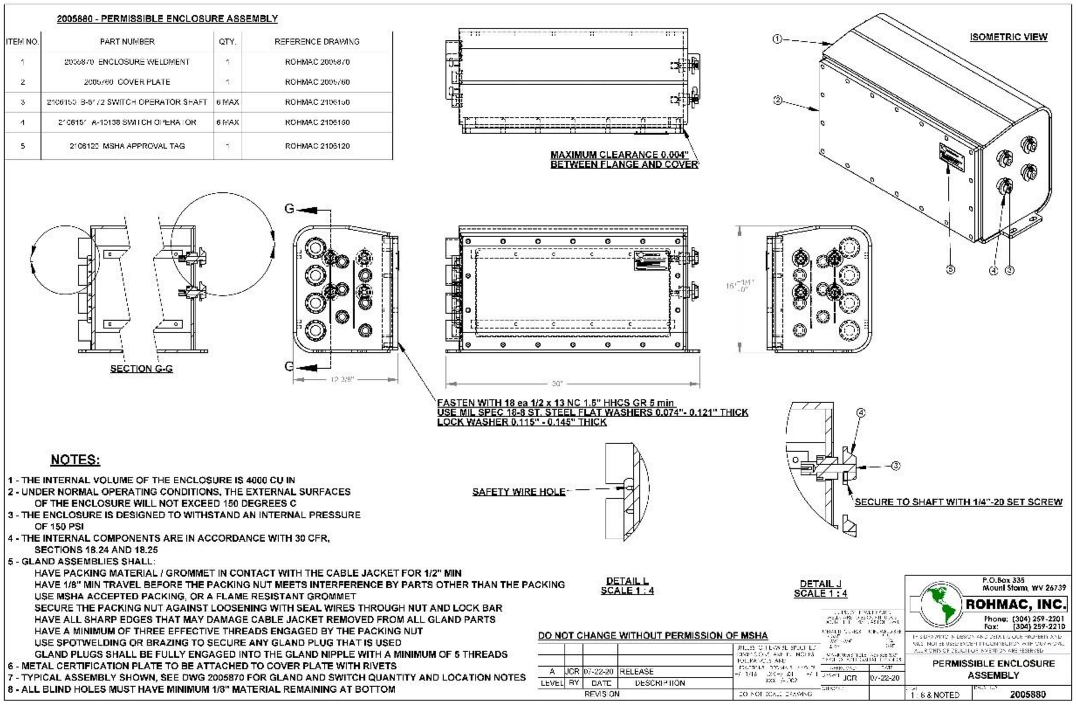
INVESTIGATION NO. MR-

DRAWING LIST

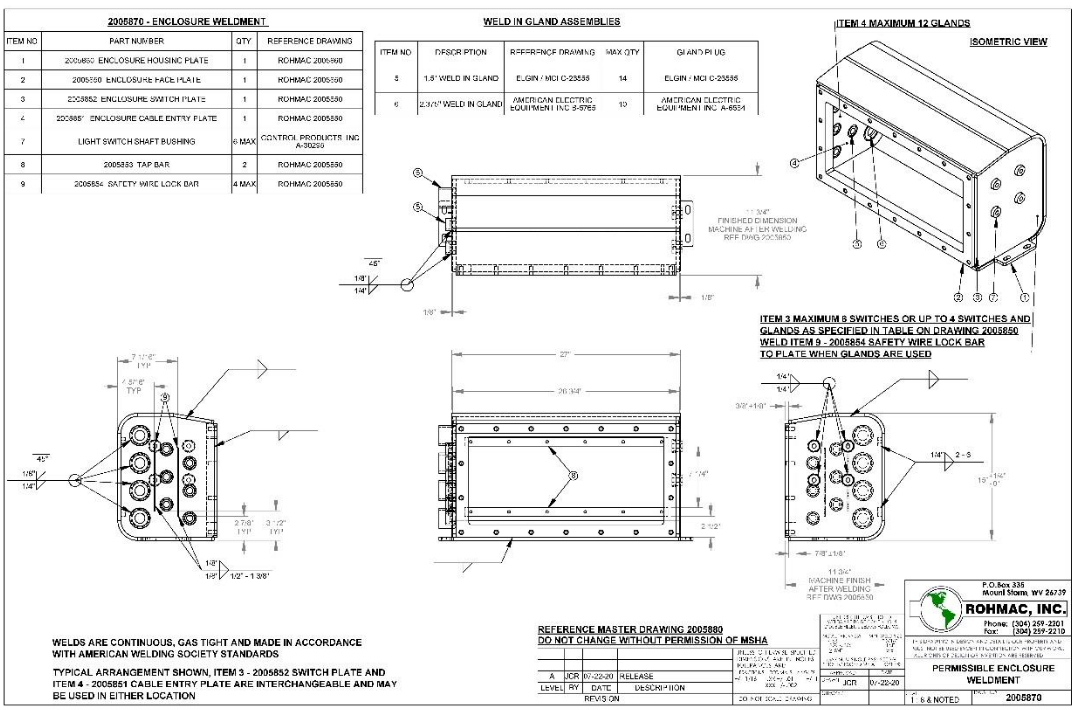
ROHMAC INC
Explosion Proof Enclosure Assembly PN 2005880
Built According to Drawing Number 2005880
Certification No. X/P-

TITLE	DRAWING	REVISION
ENCLOSURE ASSEMBLY	2005880	A
ENCLOSURE WELDMENT	2005870	A
HOUSING PLATE	2005860	A
ENCLOSURE PLATE DETAILS	2005850	A
COVER PLATE	2005760	A
ROTARY SWITCH OPERATOR	2106150	A
MSHA APPROVAL PLATE	2106120	A

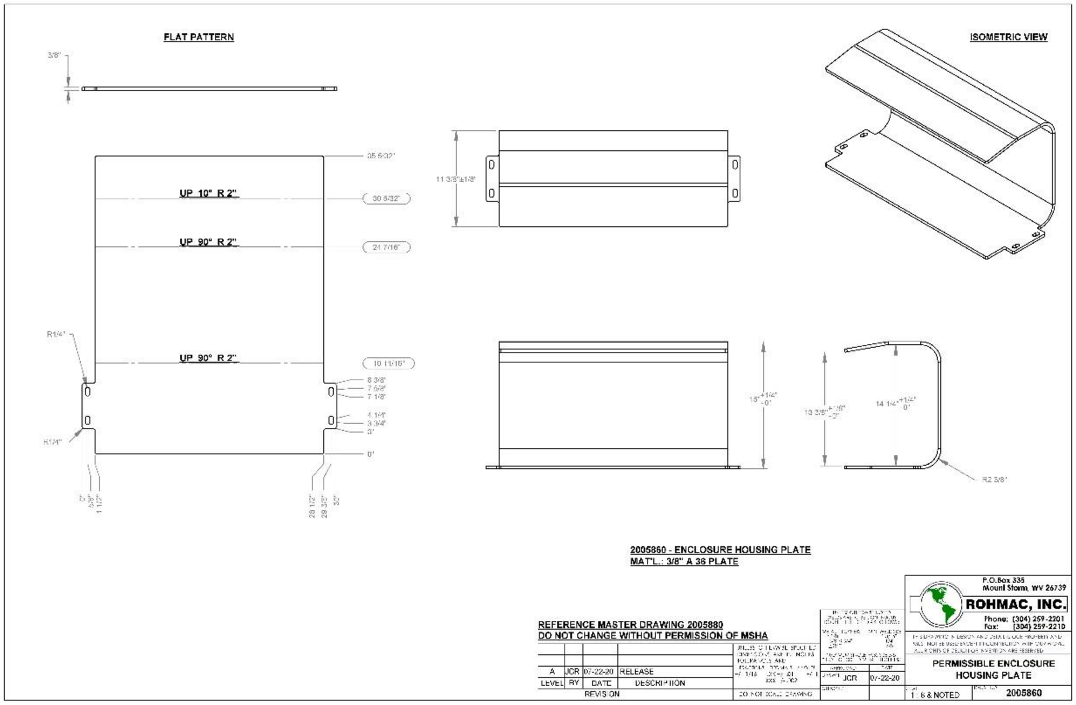
CERTIFIED STATEMENT DATED 11 SEPTEMBER 2020

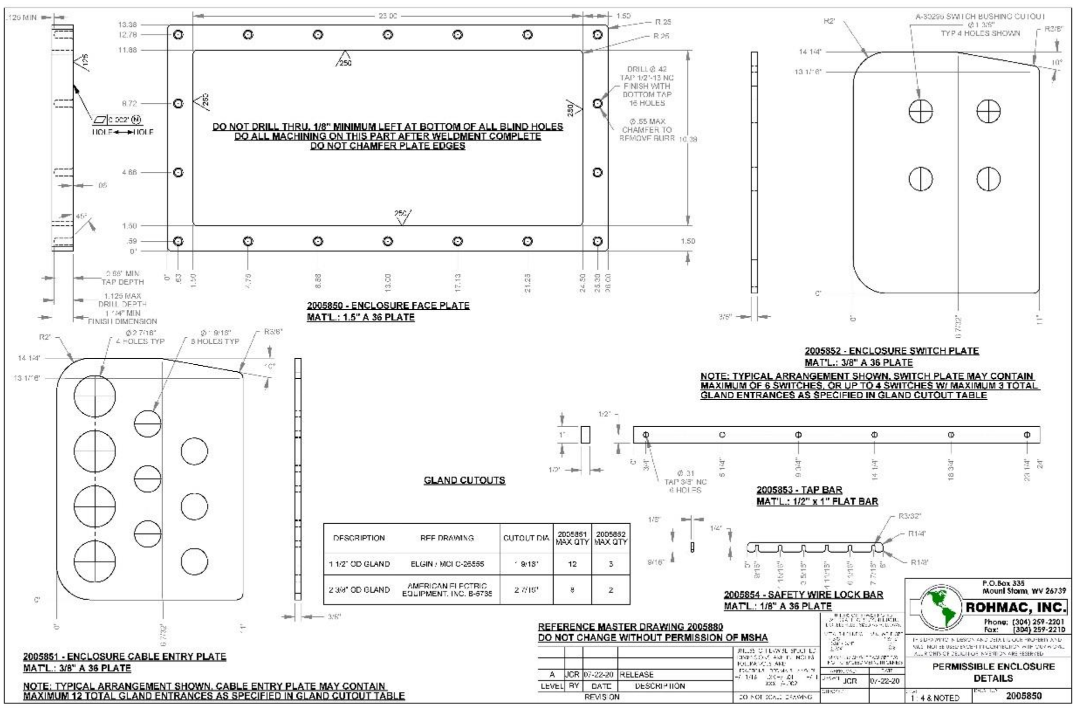


2005880 - PERMISSIBLE ENCLOSURE ASSEMBLY
ITEM NO. | PART NUMBER | QTY. | REFERENCE DRAWING
1 | 2005870 ENCLOSURE WELDMENT | 1 | ROHMAC 2005870
2 | 2005760 COVER PLATE | 1 | ROHMAC 2005760
3 | 2106150 B-5172 SWITCH OPERATOR SHAFT | 6 MAX | ROHMAC 2106150
4 | 2106151 A-10138 SWITCH OPERATOR | 6 MAX | ROHMAC 2106150
5 | 2106120 MSHA APPROVAL TAG | 1 | ROHMAC 2106120
ISOMETRIC VIEW
MAXIMUM CLEARANCE 0.004" BETWEEN FLANGE AND COVER
SECTION G-G
FASTEN WITH 18 ea 1/2 x 13 NC 1.5" HHCS GR 5 min
USE MIL SPEC 18-8 ST. STEEL FLAT WASHERS 0.074"- 0.121" THICK
LOCK WASHER 0.115" - 0.145" THICK
SAFETY WIRE HOLE
SECURE TO SHAFT WITH 1/4"-20 SET SCREW
DETAIL L SCALE 1 : 4
DETAIL J SCALE 1 : 4
NOTES:
1 - THE INTERNAL VOLUME OF THE ENCLOSURE IS 4000 CU IN
2 - UNDER NORMAL OPERATING CONDITIONS, THE EXTERNAL SURFACES OF THE ENCLOSURE WILL NOT EXCEED 150 DEGREES C
3 - THE ENCLOSURE IS DESIGNED TO WITHSTAND AN INTERNAL PRESSURE OF 150 PSI
4 - THE INTERNAL COMPONENTS ARE IN ACCORDANCE WITH 30 CFR, SECTIONS 18.24 AND 18.25
5 - GLAND ASSEMBLIES SHALL:
HAVE PACKING MATERIAL / GROMMET IN CONTACT WITH THE CABLE JACKET FOR 1/2" MIN
HAVE 1/8" MIN TRAVEL BEFORE THE PACKING NUT MEETS INTERFERENCE BY PARTS OTHER THAN THE PACKING
USE MSHA ACCEPTED PACKING, OR A FLAME RESISTANT GROMMET
SECURE THE PACKING NUT AGAINST LOOSENING WITH SEAL WIRES THROUGH NUT AND LOCK BAR
HAVE ALL SHARP EDGES THAT MAY DAMAGE CABLE JACKET REMOVED FROM ALL GLAND PARTS
HAVE A MINIMUM OF THREE EFFECTIVE THREADS ENGAGED BY THE PACKING NUT
USE SPOTWELDING OR BRAZING TO SECURE ANY GLAND PLUG THAT IS USED
GLAND PLUGS SHALL BE FULLY ENGAGED INTO THE GLAND NIPPLE WITH A MINIMUM OF 5 THREADS
6 - METAL CERTIFICATION PLATE TO BE ATTACHED TO COVER PLATE WITH RIVETS
7 - TYPICAL ASSEMBLY SHOWN, SEE DWG 2005870 FOR GLAND AND SWITCH QUANTITY AND LOCATION NOTES
8 - ALL BLIND HOLES MUST HAVE MINIMUM 1/8" MATERIAL REMAINING AT BOTTOM
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A | JCR | 07-22-20 | RELEASE
LEVEL | BY | DATE | DESCRIPTION
REVISION
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2210
PERMISSIBLE ENCLOSURE ASSEMBLY
1:6 & NOTED
2005880

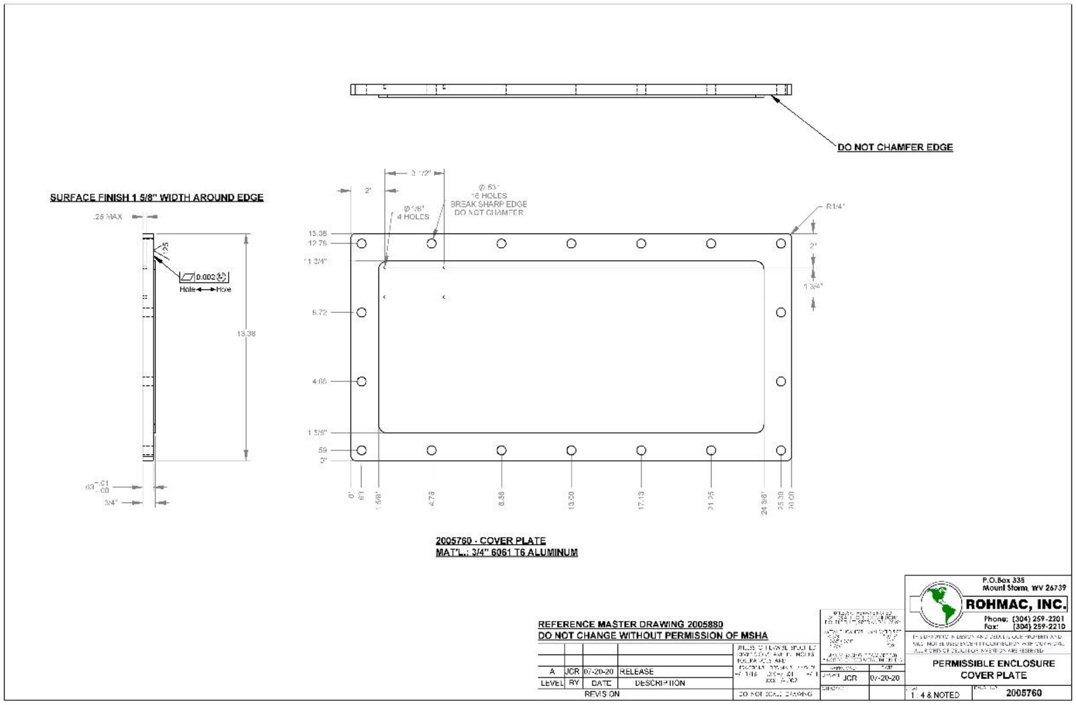


2005870 - ENCLOSURE WELDMENT
ITEM NO | PART NUMBER | QTY | REFERENCE DRAWING
1 | 2005860 ENCLOSURE HOUSING PLATE | 1 | ROHMAC 2005860
2 | 2005850 ENCLOSURE FACE PLATE | 1 | ROHMAC 2005850
3 | 2005852 ENCLOSURE SWITCH PLATE | 1 | ROHMAC 2005850
4 | 2005851 ENCLOSURE CABLE ENTRY PLATE | 1 | ROHMAC 2005850
7 | LIGHT SWITCH SHAFT BUSHING | 6 MAX | CONTROL PRODUCTS INC A-30295
8 | 2005853 TAP BAR | 2 | ROHMAC 2005850
9 | 2005854 SAFETY WIRE LOCK BAR | 4 MAX | ROHMAC 2005850
WELD IN GLAND ASSEMBLIES
ITEM NO | DESCRIPTION | REFERENCE DRAWING | MAX QTY | GLAND PLUG
5 | 1.5" WELD IN GLAND | ELGIN / MCI C-23555 | 14 | ELGIN / MCI C-23555
6 | 2.375" WELD IN GLAND | AMERICAN ELECTRIC EQUIPMENT INC B-5765 | 10 | AMERICAN ELECTRIC EQUIPMENT INC A-6554
ITEM 4 MAXIMUM 12 GLANDS
ISOMETRIC VIEW
11 3/4" FINISHED DIMENSION MACHINE AFTER WELDING REF DWG 2005850
ITEM 3 MAXIMUM 8 SWITCHES OR UP TO 4 SWITCHES AND GLANDS AS SPECIFIED IN TABLE ON DRAWING 2005850
WELD ITEM 9 - 2005854 SAFETY WIRE LOCK BAR TO PLATE WHEN GLANDS ARE USED
11 3/4" MACHINE FINISH AFTER WELDING REF DWG 2005850
WELDS ARE CONTINUOUS, GAS TIGHT AND MADE IN ACCORDANCE WITH AMERICAN WELDING SOCIETY STANDARDS
TYPICAL ARRANGEMENT SHOWN, ITEM 3 - 2005852 SWITCH PLATE AND ITEM 4 - 2005851 CABLE ENTRY PLATE ARE INTERCHANGEABLE AND MAY BE USED IN EITHER LOCATION
REFERENCE MASTER DRAWING 2005880
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A | JCR | 07-22-20 | RELEASE
LEVEL | BY | DATE | DESCRIPTION
REVISION
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2210
PERMISSIBLE ENCLOSURE WELDMENT
1:6 & NOTED
2005870

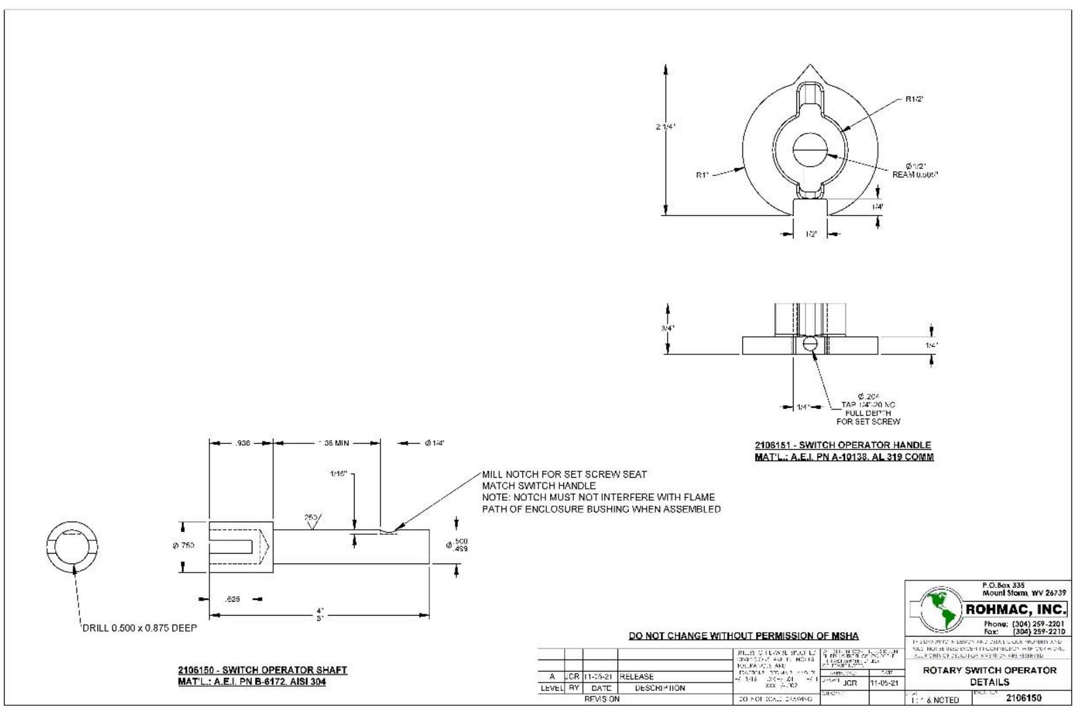




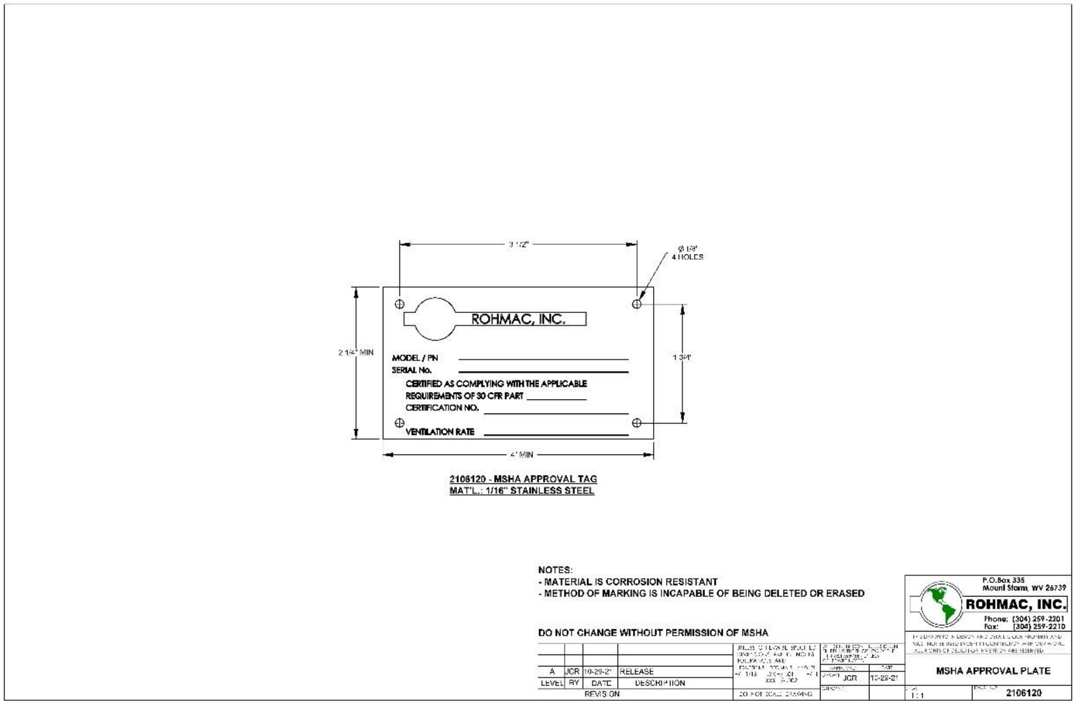
DESCRIPTION	REF DRAWING	CUTOUT DIA	2005851 MAX QTY	2005852 MAX QTY
1 1/2" OD GLAND	ELGIN / MCI C-25555	1 9/16"	12	3
2 3/8" OD GLAND	AMERICAN ELECTRIC EQUIPMENT, INC. B-5735	2 7/16"	8	2



DO NOT CHAMFER EDGE
SURFACE FINISH 1 5/8" WIDTH AROUND EDGE
.25 MAX
0.002
Hole ↔ Hole
13.38
2"
3 1/2"
Ø .531
16 HOLES
BREAK SHARP EDGE
DO NOT CHAMFER
Ø 1/8"
4 HOLES
R1/4"
15.38
12.76
1 3/4"
8.72
4.66
1 5/8"
.59
0"
0"
.61
1.58"
4.73
8.88
13.00
17.13
21.25
24 3/8"
25.38
26.00
3/4"
2005760 - COVER PLATE
MAT'L.: 3/4" 6061 T6 ALUMINUM
REFERENCE MASTER DRAWING 2005880
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A
JCR
07-20-20
RELEASE
LEVEL
BY
DATE
DESCRIPTION
REVISION
DO NOT SCALE DRAWING
JCR
07-20-20
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2210
PERMISSIBLE ENCLOSURE
COVER PLATE
1 : 4 & NOTED
2005760



2 1/4"
R1/2"
R1"
Ø 1/2"
1/4"
1/2"
3/4"
1/4"
1/4"
Ø .204
FULL DEPTH
FOR SET SCREW
2106151 - SWITCH OPERATOR HANDLE
MAT'L.: A.E.I. PN A-10138, AL 319 COMM
.938
1.36 MIN
Ø 1/4"
1/16"
MILL NOTCH FOR SET SCREW SEAT
MATCH SWITCH HANDLE
NOTE: NOTCH MUST NOT INTERFERE WITH FLAME
PATH OF ENCLOSURE BUSHING WHEN ASSEMBLED
250
Ø .750
.500
.499
.625
DRILL 0.500 x 0.875 DEEP
2106150 - SWITCH OPERATOR SHAFT
MAT'L.: A.E.I. PN B-6172, AISI 304
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A
JCR
11-05-21
RELEASE
LEVEL
BY
DATE
DESCRIPTION
REVISION
DO NOT SCALE DRAWING
JCR
11-05-21
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2210
ROTARY SWITCH OPERATOR
DETAILS
& NOTED
2106150



Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

11 September 2020

RE: Explosion Proof Enclosure Assembly PN 2005880
Company Code No. 200911

To Whom it May Concern,

I hereby certify that ROHMAC INC will conduct regular inspections of the subject enclosure to ensure that this product is made and assembled in strict accordance with the drawings and specifications accepted by MSHA.

Sincerely,

Jeremiah Rohrbaugh, P.E.
Manager of Engineering

APPENDIX B – Diesel Power Package Approval Application

Office (304) 259-2201 • Fax (304) 259-2217

ROHMAC, INC.

P. O. Box 335 • Mt. Storm, West Virginia 26739

3 March 2021

Chief, Approval and Certification Center
RR #1, Box 251, Industrial Park Road
Triadelphia, West Virginia 26059

Gentlemen:

ROHMAC INC (TIN: 52-1813657-001) is requesting a part 7F approval for a model DP 25XP Diesel Power Package, company code 190830.

The subject power package, shown on Rohmac drawing number 1906850, uses a Kubota D1105-E4 engine rated at 24.8 hp @ 3000 rpm. The power package includes an exhaust aftertreatment device that controls surface and exhaust gas temperatures, as well as exhaust emissions.

Since this is a new prototype diesel power package, it will be completely assembled and delivered to MSHA A&CC, for inspection and testing, date and time to be coordinated.

Enclosed are all of the drawings, documents, and specifications pertinent to this application. If there are any questions, please contact me by phone at (304) 259-2201 x-233 or (301) 616-7351 mobile, by fax at (304) 259-2210, or by email at jeremyrohrbaugh@rohmacinc.com.

Sincerely,

Jeremy Rohrbaugh, P.E.
Manager of Engineering
Rohmac, Inc.
PO Box 335
Mt. Storm, WV 26739

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

3 March 2021

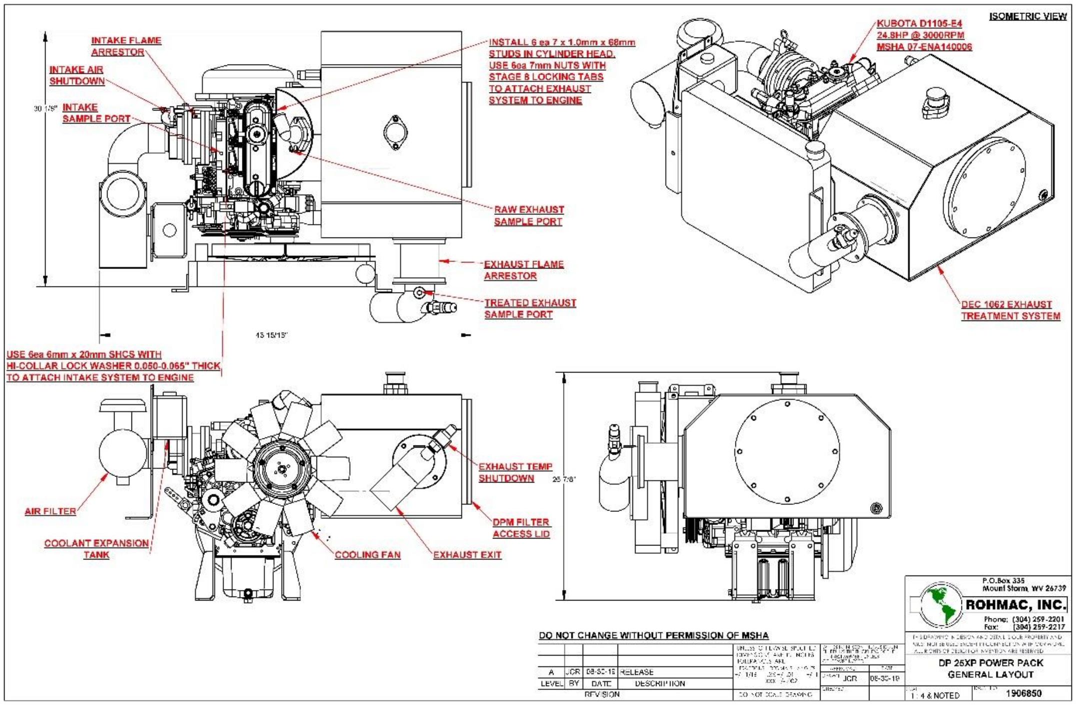
DRAWING LIST
Rohmac Inc Diesel Power Package Model DP 25XP

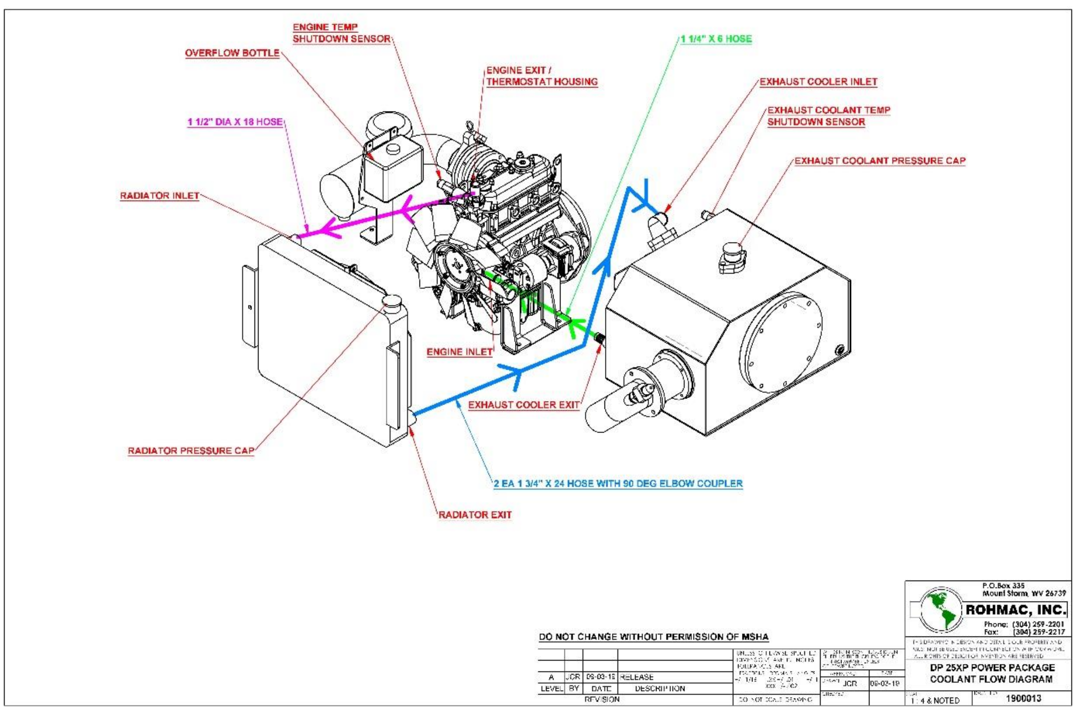
TITLE	Drawing / File No.	Rev
General Layout	1906850	A
Cooling System Flow Diagram	1900013	A
Cooling System Elevation	1900012	A
Cooling System Fill Procedure	190830JCR01	A
Radiator Cooling Fan Specifications	20180209	
Intake Flame Arrestor	M386-500-01	2
Intake Manifold Details	1807620	A
Intake Manifold Weldment	1807630	A
Intake and Exhaust Gaskets	1807640	A
Intake Shutoff Device	DS-RB3A-1214	2
Air Filter Specification	1661611014-SOS-0	4
Intake Assembly	1906880	A
Exhaust Cooler Details		
Manifold Plate	1805460	A
Exhaust Chamber Flange	1806080	B
Exhaust Exit Flange	1807120	A
Exhaust Chamber Lid Details	1806270	A
Outer Plate Details	1807140	A
Front and Back Plate Details	1807180	B
Top and Bottom Plate Details	1807190	A
Exhaust Chamber Plate	1807200	C
Exhaust Chamber Baffle	1807400	A
Exhaust Tubing Details	1906070	A

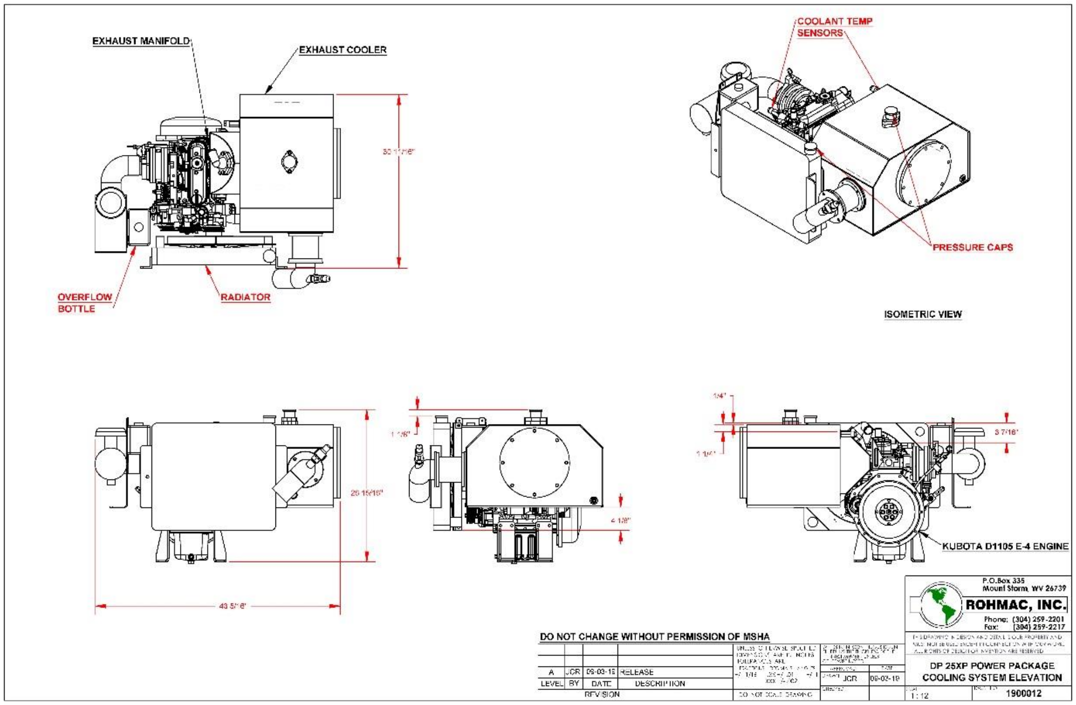
Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

DRAWING LIST
Rohmac Inc Diesel Power Package Model DP 25XP

TITLE	Drawing / File No.	Rev
Exhaust Cooler Weldment	1807270	A
Exhaust Chamber Subweldment	1807280	A
Outer Jacket Subweldment	1807290	A
Exhaust Cooling Coil Weldment	1906090	A
Exhaust Exit Coil Weldment	1906100	A
Exhaust Exit Chamber Weldment	1906110	A
Exhaust Cooler Assembly	1906120	A
Exhaust Chamber Lid Weldment	1806280	A
Exhaust Filter Bonnet	1905390	A
Exhaust Exit Baffle	1905500	B
Exhaust Flame Arrestor	M386-501-01	1
Safety Shutdown System Schematic	1802006	A
Safety Shutdown System Description	190830JCR02	A
Safety System Component Specifications		
Coolant Temperature Sensor		
	Datasheet_2230_4430_2-way_sensing_valve_0614	1
Exhaust Gas Temperature Sensor		
	Datasheet_4075_4475_High_Temperature_ Valve_Feb18	4
Oil Pressure Sensor		
Spec Sheet	1201076	006
Starter	M10-DWZ46	0
Start / Safety Manifold Valve Block	SGM361493	0
E-Stop Valve	1202981	09
Permissibility Checklist	191905JCR01	A


ISOMETRIC VIEW
INTAKE FLAME ARRESTOR
INTAKE AIR SHUTDOWN
INTAKE SAMPLE PORT
INSTALL 6 ea 7 x 1.0mm x 68mm STUDS IN CYLINDER HEAD. USE 6ea 7mm NUTS WITH STAGE 8 LOCKING TABS TO ATTACH EXHAUST SYSTEM TO ENGINE
KUBOTA D1105-E4 24.8HP @ 3000RPM MSHA 07-ENA140006
RAW EXHAUST SAMPLE PORT
EXHAUST FLAME ARRESTOR
TREATED EXHAUST SAMPLE PORT
DEC 1062 EXHAUST TREATMENT SYSTEM
43 15/13"
USE 6ea 6mm x 20mm SHCS WITH HI-COLLAR LOCK WASHER 0.050-0.065" THICK TO ATTACH INTAKE SYSTEM TO ENGINE
EXHAUST TEMP SHUTDOWN
AIR FILTER
DPM FILTER ACCESS LID
COOLANT EXPANSION TANK
COOLING FAN
EXHAUST EXIT
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A JCR 08-30-19 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
DO NOT SCALE DRAWING
JCR 08-30-19
DP 25XP POWER PACK
GENERAL LAYOUT
1:4 & NOTED
1906850


ENGINE TEMP SHUTDOWN SENSOR
OVERFLOW BOTTLE
1 1/4" X 6 HOSE
ENGINE EXIT / THERMOSTAT HOUSING
EXHAUST COOLER INLET
1 1/2" DIA X 18 HOSE
EXHAUST COOLANT TEMP SHUTDOWN SENSOR
EXHAUST COOLANT PRESSURE CAP
RADIATOR INLET
ENGINE INLET
EXHAUST COOLER EXIT
RADIATOR PRESSURE CAP
2 EA 1 3/4" X 24 HOSE WITH 90 DEG ELBOW COUPLER
RADIATOR EXIT
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A JCR 09-03-19 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
DO NOT SCALE DRAWING
JCR 09-03-19
DP 25XP POWER PACKAGE
COOLANT FLOW DIAGRAM
1:4 & NOTED
1900013


EXHAUST MANIFOLD
EXHAUST COOLER
OVERFLOW BOTTLE
RADIATOR
COOLANT TEMP SENSORS
PRESSURE CAPS
ISOMETRIC VIEW
KUBOTA D1105 E-4 ENGINE
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A JCR 09-03-19 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
DO NOT SCALE DRAWING
JCR 09-03-19
DP 25XP POWER PACKAGE
COOLING SYSTEM ELEVATION
1 : 12
1900012

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

30 August 2019

Doc ID 190830JCR01

DP 25XP Power Package Coolant Filling procedure

This procedure describes the recommended practice for filling the cooling system on the Rohmac model DP 25XP diesel power package:

First Fill

- With the power package cold and level, open the pressure caps on the radiator and exhaust cooling chamber
- Fill with 50/50 mix antifreeze / water until water level reaches the water neck under both caps, replace pressure caps
- Start and warm the engine to operating temperature, it is recommended that the engine be placed under load to ensure that all coolant has reached operating temperature. Shutdown the engine
- Immediately after shutdown, fill the expansion reservoir with coolant.

Check / Fill

- Check the coolant level in the expansion reservoir while at operating temperature and add coolant to the expansion reservoir as needed
- NOTE: When the engine is cold, the coolant level will appear low in the reservoir, adding coolant when cold may allow coolant to push out of the reservoir when the engine is at operating temperature.
- DO NOT Open the pressure caps once the initial fill procedure has been performed unless there is evidence that a leak has caused loss of fluid

Do Not change without permission of MSHA

Attestation of Conformity for components - ATEX

We hereby certify that the following component

Material type: Aluminium

is designed in accordance with the following EC-directives & standards:

Standards: EN 14986:2017 - Design of fans working in potentially explosive atmospheres
ATEX Directive 2014/34/EU

As required per *EN 14986:2007, §4.8.2, table 1, footnote c*, the aluminium alloy used by Multi-Wing International A/S has a silicon content of approximately 12% (between 10.5 and 13.5%) and is therefore appropriate from an anti-sparking and corrosion viewpoint.

The choice of the 2[nd] material of the material pairing is the responsibility of the fan manufacturer and must be a pairing listed in table 1 in order to satisfy EN 14986.
Multi-Wing International A/S has no responsibility in the choice of the second material of the pairing and therefore in the suitability of the pairing with regards to EN 14986.

Also according to EN 14986, §4.15, the fan manufacturer has to respect a minimum clearance between the rotating and fixed parts. This shall be at least 1% of the relevant contact diameters and no less than 2mm in axial or radial directions.
This is not a complete definition of the standard; Multi-Wing International A/S cannot be held responsible for the construction of the final assembly. Please consult EN 14986 for complete details.

The component can be used for gas explosion groups IIA, IIB and IIC, following EN14986.

Name: Lisbeth Tonsberg Dahl

Position: Managing Director

Date: 02/09/2018

Multi-Wing International a·s
Denmark

Staktoften 16
DK-2950 Vedbæk

info@multi-wing.com
www.multi-wing.com

+45 / 45 89 01 33 Phone
+45 / 45 89 31 33 Telefax

ISO 9001 certified

MULTI-WING

Attestation of Conformity for components - ATEX

We hereby certify that the following component

Material type: PAGAS

is designed in accordance with the following EC-directives & standards:

ATEX Directive 2014/34/EU
Standards: EN 1127-1:2011, EN ISO 80079-36:2016, EN ISO 80079-38:2016, EN 14986:2017

The material has been tested in accordance with EN ISO 80079-36:2016 §6.7.4 a) and §6.7.5 a) by an independant laboratory and is below the maximum authorized level of surface resistance of 1 GΩ @ (23 ± 2)°C and (50 ± 5)% relative humidity.

* The test results cover also the requirements in EN 60079:2012 §7.4.2 a)

The component can be used for category M2 in Group I and categories 2 & 3 in Group II and can work in areas with potentially explosive atmospheres.

The general characteristics of the impellers designed and manufactured for use in potentially explosive atmospheres and how these impellers have to be incorporated into equipment or protective systems are described in the technical documentation supplied with this document.

Name: Lisbeth Tonsberg Dahl

Position: Managing Director

Date: 02/09/2018

Multi-Wing International a·s
Denmark

Staktoften 16
DK-2950 Vedbæk

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ISO 9001 certified

MULTI-WING

ATEX – TECHNICAL DOCUMENTATION		VALID FROM: 2.9.2018	PAGE: 1 / 15
PREPARED BY: David Svoboda	APPROVED BY: Lisbeth T. Dahl	FILE NAME: W:\Instruktioner\ATEX\ATEX Annex 8_Technical documentation_20180209.docx	
CIRCULATION:			

1. General Description of the Equipment

Axial flow impeller for use in potentially explosive atmospheres, composed primarily of a central hub in aluminium and individual blades in aluminium or polymer material of designation "PAGAS".
The impeller is intended to move air for the purpose of ventilation or cooling of mechanical equipment.

Aluminium

Designation: EN AC-47100 - Al Si12Cu1(Fe)

Manufacturing process: high pressure die casting

Mechanical properties (as cast):

- Tensile strength R_m MPa : 240
- Yield strength $R_{p0,2}$ MPa : 140
- Elongation A_{50mm} % : 1
- Brinell hardness HBW : 70

Chemical compositions: can be found in EN 1706.

Flammability: Not flammable in the solid component state; only flammable in powder form.

Electrical conductivity: 15 – 20 MS/m

Surface temperature: Not self-heating; same temperature as the surroundings of the impeller itself.

Operational limits:
Tip speed: see tip speed limit provided by Multi-Wing Optimiser software.
This limit is valid within standard operating conditions, which are:

- Airflow: Evenly distributed and undisturbed
- Temperature: min. temp. –60 °C max. temp. +245 °C

Polymer

Special grade polyamide 6 designed for electrical conductivity properties.
Designation: PAGAS

Manufacturing process: injection moulding. Multi-Wing International a·s uses several moulds with different surface finishes, either smooth polish or micro-blasted to impart a rough texture (approx. Charmilles 36 roughness grade).

Mechanical properties (conditioned):

- Tensile strength (MPa) : 70
- Tensile modulus (MPa) : 4400
- Strain at break (%) : 6

Chemical compositions: Based on PA6, glass fibre reinforced.

Flammability: HB rating at 3mm (based on ISO 1210)

<u>Surface resistance</u>: tested to be below 1 GΩ at 23 °C 50% Rh, for both the smooth mould surface and micro-blasted mould surface.

<u>Surface temperature</u>: Not self-heating; same temperature as the surroundings of the impeller itself.

<u>Operational limits</u>:
Tip speed: see tip speed limit provided by Multi-Wing Optimiser software.
This limit is valid within standard operating conditions, which are:

- Airflow: Evenly distributed and undisturbed
- Temperature: min. temp. –40 °C max. temp. +110 °C

2. Conceptual design drawings

See representative drawings of typical impellers in Appendix I.

3. Procedures and recommendations

General balancing procedure

If our customers require nothing else, impellers are balanced according to G6.3 at 950 RPM. As standard the following types of impellers are balanced:

- 12 and 14 bladed type H
- All type Z
- All type W
- All type G
- All impellers with Al-blades

Risk assessment

The main causes for failures in operation we have experienced are due to:

- Foreign objects
- Fatigue due to dynamic load

To reduce the dynamic load the following should be observed:

- Do not run the fan in stalled condition!
- Avoid objects disturbing the airflow (shadow effects)
- Ensure an even flow distribution

Installation

<u>Tip clearance</u>: The minimum clearance between rotating components such as the impeller and fixed components e.g. the fan casing shall be at least 1 % of the relevant contact diameter (diameter of a rotating part at the point where it can contact a stationary part) of the finish component, but shall not be less than 2 mm in the axial or radial directions nor be more than 20 mm (EN 14986:2017).

On applications fitted with anti-vibration mounts, consideration to increased tip clearance should be given to allow for movement and vibration.

Mounting of impeller: The axial distance between impeller and protection guard as well as the density of the protection guard should as a minimum conform to any regulations set by local authorities or industrial organizations.

Earthing conducting parts; the requirements of EN ISO 80079-36:2016 shall apply. Note: **it is normally sufficient to ground the static parts of the fan**. If there is a voltage build-up in the rotating parts, this is sufficiently grounded through metallic antifriction bearings to prevent ignition by electric spark […]. (EN 14986:2017, 4.11).

Impeller-shaft attachment; […] shall be designed in a way that (even in the event of expected malfunction) no drift can occur and that the joint is secured against loosening (EN 14986:2017, 4.21).

If possible, avoid the use of hammers. If unavoidable, use a mallet or strike with a wooden mandrel. Alternatively aluminium hubs may be heated to ease mounting.

4. Applicable standards

List of standards applied in the design of the impellers in compliance with Directive 2014/34/EU:
EN 1127-1:2011
EN ISO 80079-36:2016
EN 14986:2017

5. Design calculations

According to EN 14986:2017 chapter 4.7, *"Impellers shall be of a rigid design and shall be able to withstand a test run at a minimum of 1.15 times the maximum operational rotating speed for at least 60 s without causing an ignition risk, i.e. the impeller shall not contact the casing."*

This design criteria is therefore satisfied if the design tip clearance of min. 1% is never closed due to blade deflection/elongation under 1.15 times the maximum operational speed.
Multi-Wing has developed a software to compute blade deflection/elongation (radial deflection = blade elongation; axial deflection = deflection on impeller's rotation axis) under load based on FEM (Finite Elements Method) analyses. The FEM analyses were done using the tensile properties described in Figure 2 in the next chapter.
The program will output the deflections in mm and these can be compared to the min. 1% tip clearance.

As an example, for a Ø650 mm, 5 blades, 2Z impeller, running at a maximum operating speed of 1500 RPM at 60 °C, we have the deflections given in Figure 1. The deflection is therefore calculated for
1500 RPM x 1.15 = 1725 RPM

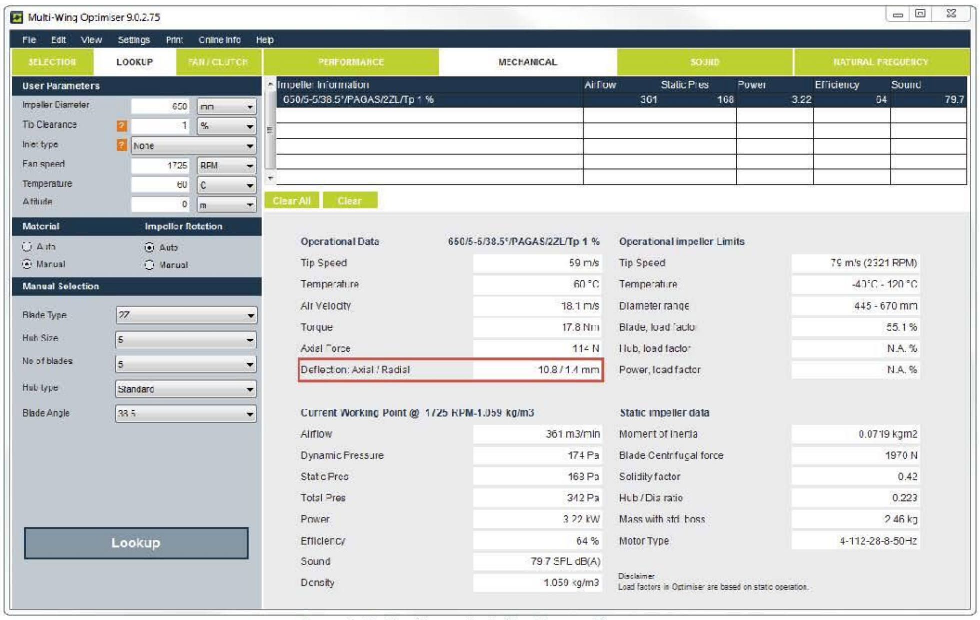
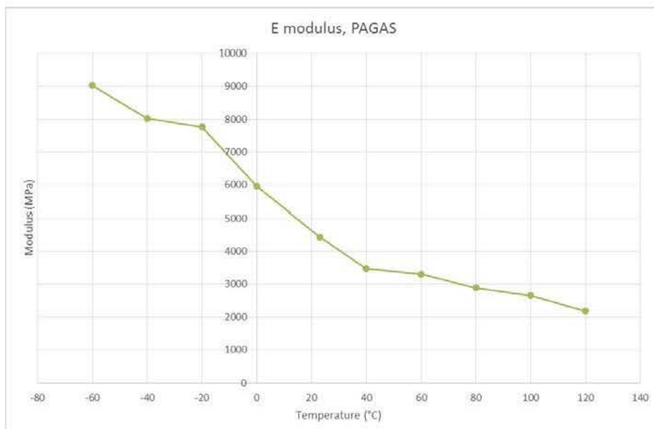


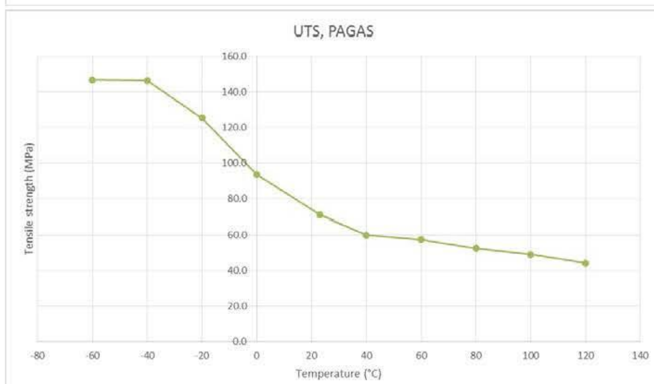
Figure 1: Deflection calculation from software

6. Examinations carried out

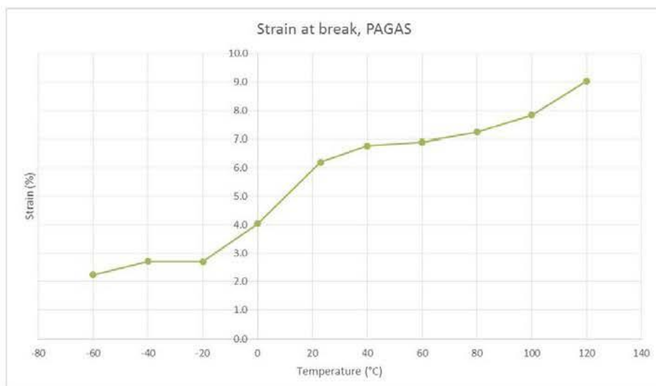
Tensile testing



a)



b)



c)

Figure 2 a, b and c): Tensile testing results over temperature range

Spin test & stress

Based on actual spin to burst tests, the maximum allowable blade centrifugal force is determined. As a matter of safety, the maximum allowable centrifugal force is 1/4 of the calculated blade centrifugal force at break. This translates to a maximum allowable speed of 50% of the failure speed.

Short term exposure to flame

Flammability test according to chapter 4.23 of EN14986 has been carried out by the supplier of PAGAS on moulded blades. The blades selected (1H, 4Z, 6W) range from the smallest and thinnest one moulded in PAGAS (1H) to a “medium large blade”, i.e. Multi-Wing International moulds blades in PAGAS larger than the largest one tested but it was deemed that if these satisfy the requirements, so will even larger blades. The flame has been applied on various locations and the time to extinction was recorded. In all tests, the flames – if there were flames – extinguished within 200 seconds, leaving the blade only partly damaged.

Figure 3: 1H blade with times to extinction

Figure 4: 4Z blade with times to extinction

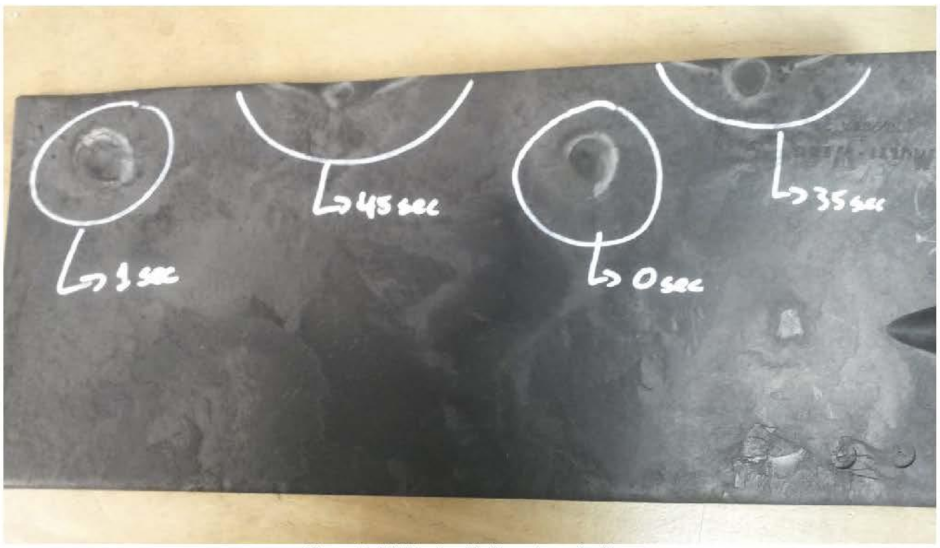


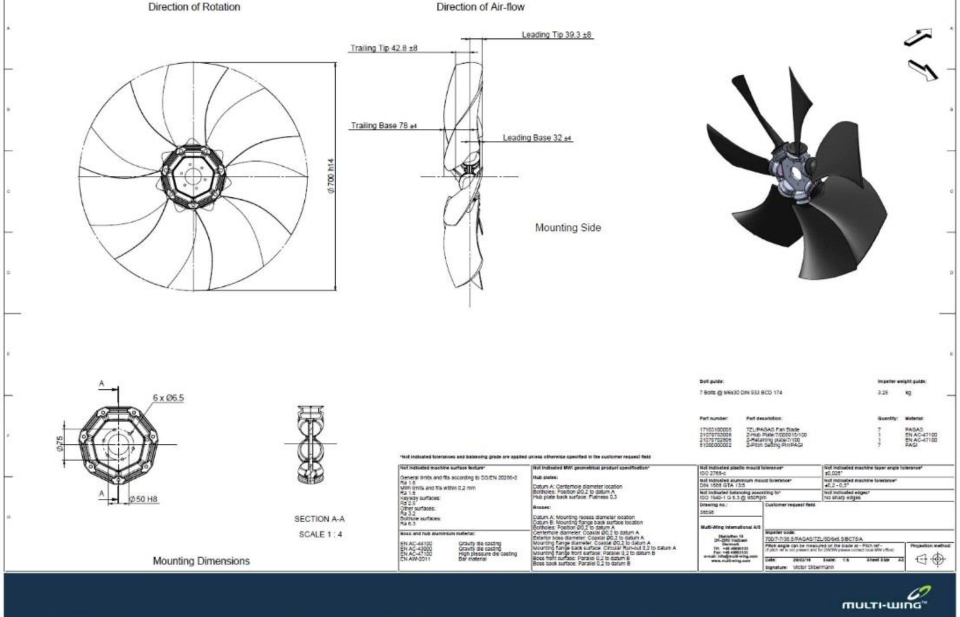
Figure 5: 6W blade with times to extinction

7. Test reports

Surface resistance test report according to EN 13463-1:2009 in Appendix II. Test conditions are the same as EN ISO 80079-36:2016.
As mentioned in Chapter 1, Multi-Wing International a·s uses several moulds with different surface finishes, either smooth polish or micro-blasted to impart a rough texture (approx. Charmilles 36 roughness grade). Therefore both types of surface textures have been tested in order to validate the compliance to EN 13463-1:2009. EN ISO 80079-36:2016.

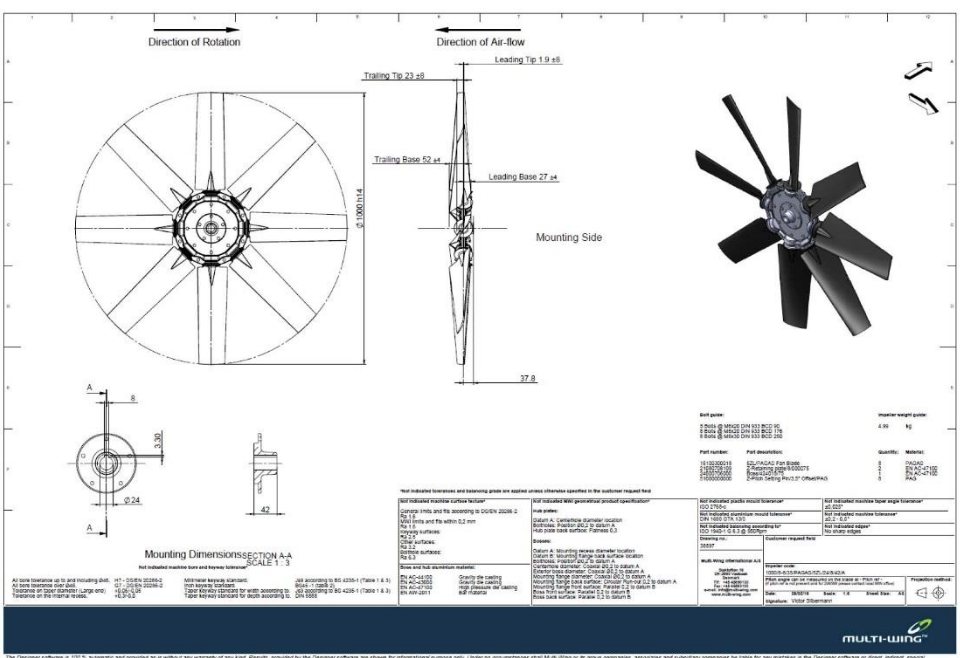
Appendix I

Appendix II



MULTI-WING

ATEX – TECHNICAL DOCUMENTATION | VALID FROM: 20.04.2016 | PAGE: 11 / 15 | PREPARED BY: Victor Silbermann | APPROVED BY: Lisbeth T. Dahl | FILE NAME: W:\Instruktioner\ATEX\ATEX Annex 8_Technical documentation_20180209.docx



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DANISH TECHNOLOGICAL INSTITUTE

Product Description

The test concerns two types of black cast plastic fan blades made of PAGAS based on PA6, glass and reinforced conductive polyamide specified by document no: TDS-PAGAS, Revision date: 2012-02-14.
The test samples are delivered in two different surface roughness:

Marking of EUT	4Z	1W
Surface	Smooth	Micro-blasted
Mould number	104507	110313

Danish Technological Institute are requested to make test on samples of different surface roughness in order to find potential ignition sources in the shape of static electricity in accordance with the requirements of the ATEX directive 94/9/EC, EN 60079:2012 §7.4.2 a) ref. Testing to clause 26.13. or IEC 60079:2011 clause 7.4.2 a) ref. Testing in clause 26.13.

The test results covers fan blades marked as listed above.

Test Principle

The purpose of this test is to determine whether a non-metallic material as plastic can be charged and thereby become an ignition source for explosive atmospheres. In CLC/TR 50404:2003 this is define as electrostatic dissipative.

The requirement can be accomplished by having a material composed by appropriate material to ensure that the electrical insulation resistance on the surface does not exceed 1GΩ at 23° C (± 2 °C) and 50 % relative humidity (± 5 %) measured in accordance with EN 60079-0:2012, § 26.13.

Treatment

Preparation of test samples: The samples have been cleaned and treated in a climate chamber. According to standard EN/IEC 60079-0, paragraph 26.13, the specimens shall be treated/ conditioned for at least 24 hours at a temperature of 23 °C ± 2° C and at a relative humidity, that does not exceed 50 % ± 5 %.

The testing are done under the same conditions. The samples were placed in a climate chamber the 8th of February 2016 at 10:30 a.m. The test was carried out the 11th of February 2016 at 9:30 a.m.

Test Procedure

The test is carried out on the same conditions that the samples were treated under, 23 °C ± 2° C, and a relative humidity that does not exceed 50 % ± 5 %.

Two parallel electrodes are painted on the delivered samples with dimensions as shown in figure 1.

DANISH TECHNOLOGICAL INSTITUTE
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DK-2630 Taastrup
Phone 72 20 10 00
info@teknologisk.dk
www.teknologisk.dk

TECHNICAL REPORT

Test of plastic blades for fans made of PAGAS based on PA6, reinforced, conductive mould.
Document no: TDS-PAGAS, Revision date: 2012-02-14
-
– Surface Insulation Resistance

Carried out for:
Multi-Wing International A/S
Attn.: Victor Silbermann
Staktoften 16
DK 2950 Vedbaek

Date:
11th February 2016

Carried out by:
Jakob Nittegaard

Our project no.: 683320

DANISH TECHNOLOGICAL INSTITUTE

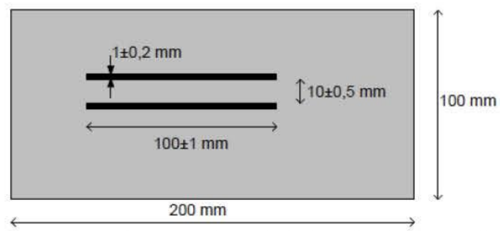


Figure 1: Dimensions for conductive electrodes painted on the samples

A direct voltage of 500 V ±10 V is applied between the electrodes for 65 seconds +/- 5 seconds. Thereafter the power is measured, and the resistance is calculated.

For resistance below 0,5 K Ω is an ordinary ohm-meter can be used.

Conclusion

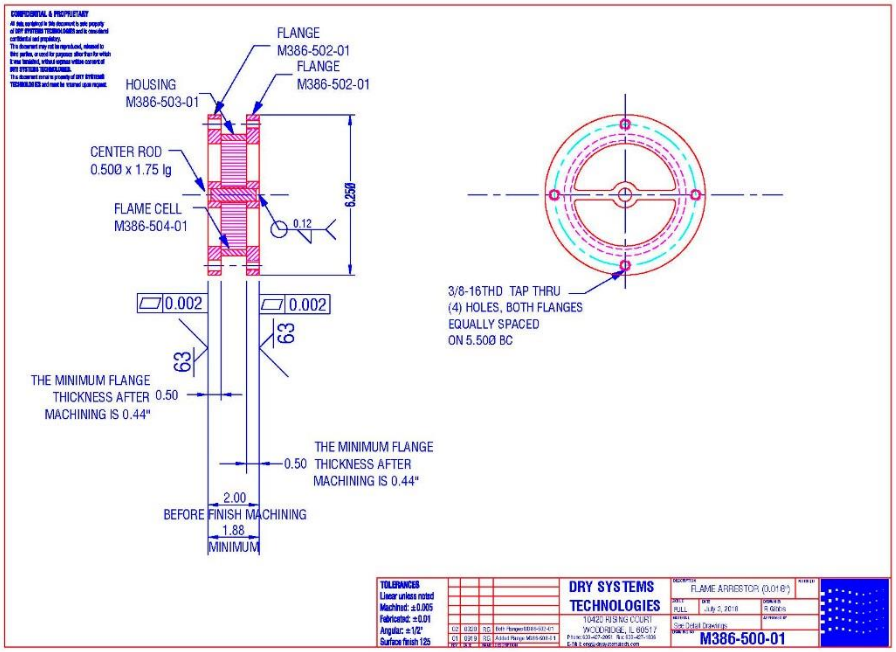
The measurement was done on two samples with different surface roughness (mould 104507 and 110313) and it was confirmed that both samples meets the requirements of having an insulation resistance below 1 GΩ as stated in the standard.

Even though the material can be characterised as antistatic, it should – in the shape of ventilator blades – be earthed and equipotentially bonded for what concerns the rest of the installation.

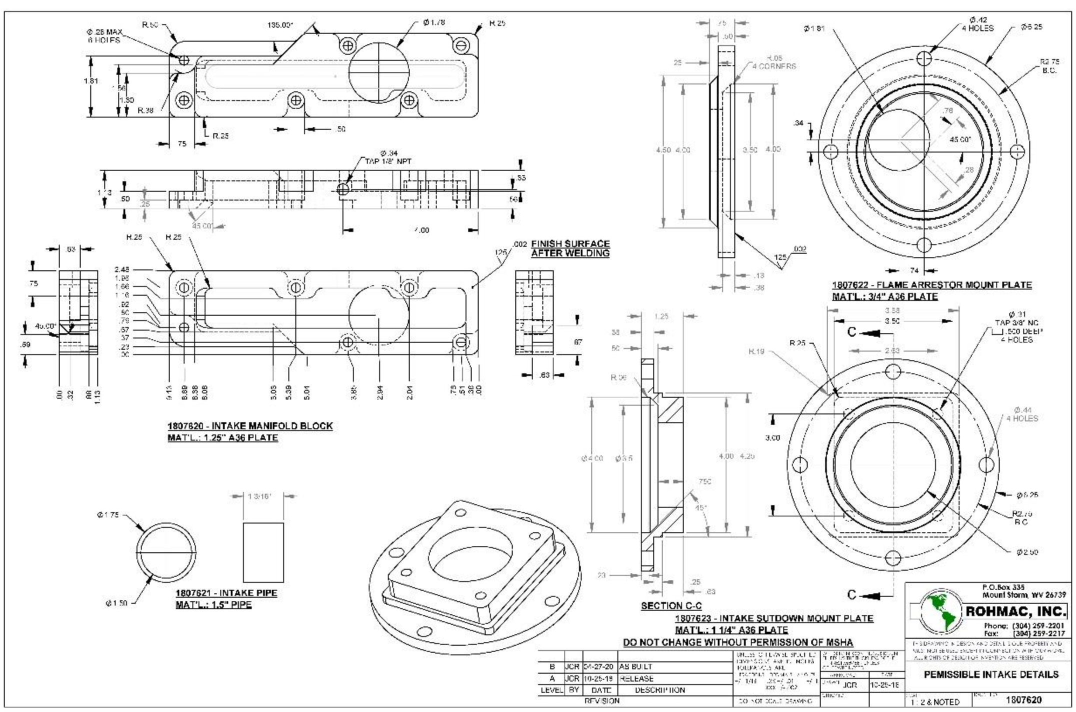
Taastrup, 11th February 2016

Danish Technological Institute
Certification & Inspection

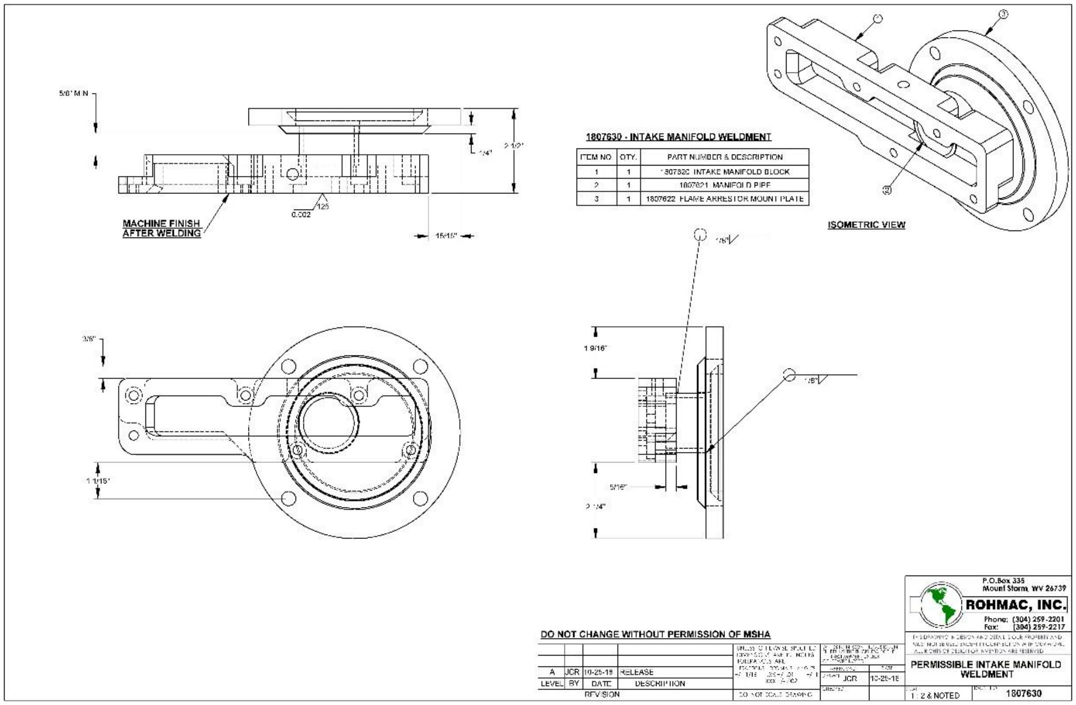
Jakob Nittegaard
ATEX Certification & Inspection
www.atexdirektivet.dk
ATEX Senior Consultant
Mobile +45 72 20 34 66
jnit@teknologisk.dk

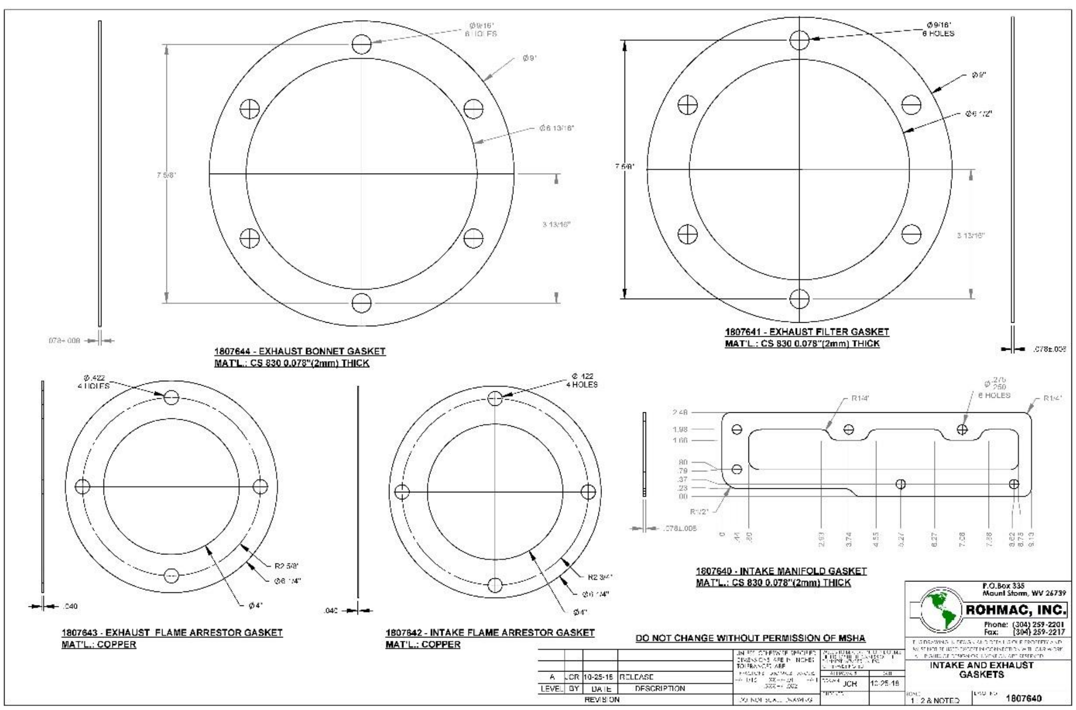


FLANGE
M386-502-01
FLANGE
M386-502-01
HOUSING
M386-503-01
CENTER ROD
0.500Ø x 1.75 lg
FLAME CELL
M386-504-01
6.25Ø
0.002
0.002
3/8-16THD TAP THRU
(4) HOLES, BOTH FLANGES
EQUALLY SPACED
ON 5.500Ø BC
THE MINIMUM FLANGE
THICKNESS AFTER 0.50
MACHINING IS 0.44"
THE MINIMUM FLANGE
0.50 THICKNESS AFTER
MACHINING IS 0.44"
2.00
BEFORE FINISH MACHINING
1.88
MINIMUM
DRY SYSTEMS
TECHNOLOGIES
M386-500-01



1807620 - INTAKE MANIFOLD BLOCK
MAT'L.: 1.25" A36 PLATE
1807621 - INTAKE PIPE
MAT'L.: 1.5" PIPE
1807622 - FLAME ARRESTOR MOUNT PLATE
MAT'L.: 3/4" A36 PLATE
SECTION C-C
1807623 - INTAKE SUTDOWN MOUNT PLATE
MAT'L.: 1 1/4" A36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
FINISH SURFACE
AFTER WELDING
ROHMAC, INC.
PEMISSIBLE INTAKE DETAILS
1807620


1807630 - INTAKE MANIFOLD WELDMENT
ITEM NO. | QTY. | PART NUMBER & DESCRIPTION
1 | 1 | 1807620 INTAKE MANIFOLD BLOCK
2 | 1 | 1807621 MANIFOLD PIPE
3 | 1 | 1807622 FLAME ARRESTOR MOUNT PLATE
MACHINE FINISH AFTER WELDING
ISOMETRIC VIEW
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
PERMISSIBLE INTAKE MANIFOLD WELDMENT
A JCR 10-25-18 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
1807630


1807644 - EXHAUST BONNET GASKET
MAT'L.: CS 830 0.078"(2mm) THICK
1807641 - EXHAUST FILTER GASKET
MAT'L.: CS 830 0.078"(2mm) THICK
1807643 - EXHAUST FLAME ARRESTOR GASKET
MAT'L.: COPPER
1807642 - INTAKE FLAME ARRESTOR GASKET
MAT'L.: COPPER
1807640 - INTAKE MANIFOLD GASKET
MAT'L.: CS 830 0.078"(2mm) THICK
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
INTAKE AND EXHAUST GASKETS
A JCR 10-25-18 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
1807640

RODA DEACO

Air Intake Shutoff Valve

Model RB3A Compact Butterfly Valve

Overview

The Roda Deaco RB3A range is a compact butterfly design air intake shutoff valve available with electrical or mechanical actuation. Actuation of the RB3A solenoid rapidly closes the valve's sealing element which shuts off intake air flow into the engine.

The RB3A can be used in fully automatic or manual shutdown systems. When incorporating into an automatic overspeed shutdown system, this valve is compatible with the Revguard 2 Speed Switch.

We offer custom configurations to fit your specific applications. Our valves are tested to strict OEM standards for shock, corrosion, vibration and life cycle.

The compact butterfly design is also available in 2" and 4". Additionally, we offer custom configurations to fit your specific applications, with a variety of different types of valves ranging in size from 1" to 14".

Please contact our customer service department to discuss your requirements.

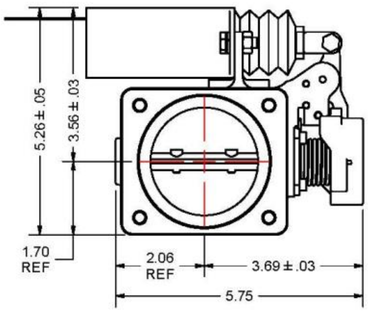
Trusted Industry Experts

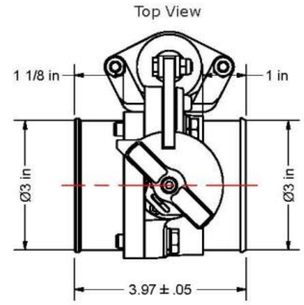
We are the leading provider of air intake shutoff valves and systems with manufacturing facilities in Canada, England and the United States to serve our global markets. Our success is driven by our people and their commitment to exceed customer expectations. We will help you find the right protection system for your diesel engine application.

Features and Benefits

- Compatible for modern low emission diesel engines
- Lightweight, compact design
- Easy to install and maintain
- Can be mounted post-intercooler on turbocharged engines
- Corrosion resistant aluminum construction
- Heavy duty stainless steel linkage
- High strength sealing disc
- Multiple actuation available
- Size range: 2 3/4" to 3 1/2"

Dimensions





Specifications

Standard materials	Valve body	Aluminum
	Sealing element	Brass
	Seals	Nitrile/Silicon
	Solenoid housing	Plated steel
Net weights	Manual actuated	2.5 lbs (1.5 kg)
(including actuator)	Standard solenoid actuated	4.5 lbs (2 kg)
Intake air temp range	Standard valve	-40°F to 257°F (-40°C to 125°C)
Ambient air temp range	Standard valve	-40°F to 257°F (-40°C to 125°C)
Electric solenoid actuation	Nominal 12 VDC power requirement	48 amp pull in
(standard solenoid)	Cycle rate	4 activations per minute
	Nominal 24 VDC power requirement	25 amp pull in
	Cycle rate	6 activations per minute
Manual actuation	Mechanical pull to release	15 lbs (67 Newton)

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info@rodadeaco.com

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info@amot.com

AMOT - Germany
Tel +49 (0) 40 8537 1298
Fax +49 (0) 40 8537 1331
germany@amot.com

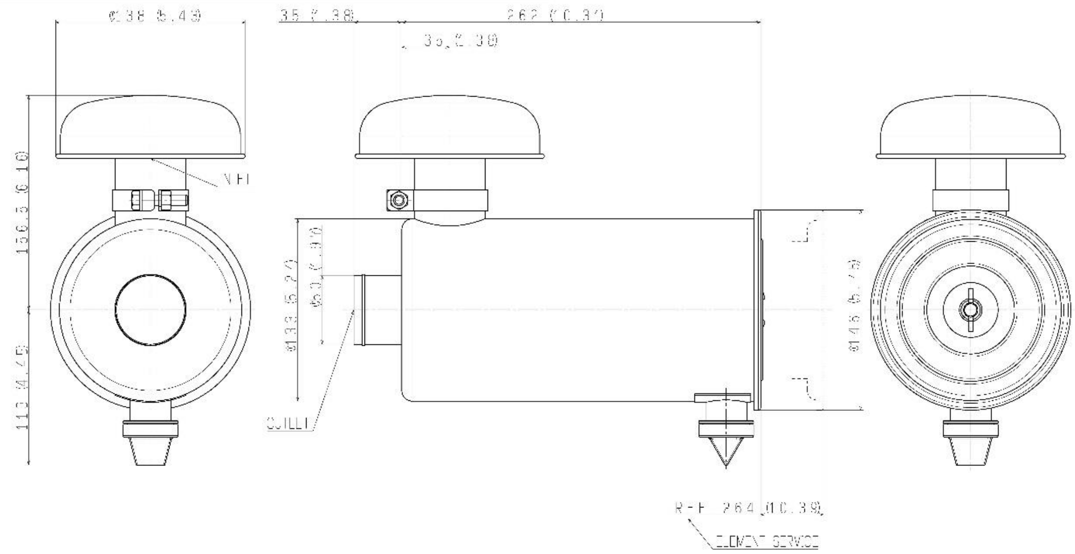
www.rodadeaco.com

Creation:2017/09/21 4_Updated:2019/08/02

PART NO.
16616-1101-4

COMPONENT PARTS		
NAME	PART No.	REMARK
ELEMENT	15741-1108A	FILTRATION AREA 0.88m² (9.47 ft²)

(Unit: mm(INCH)) for 05 series WG1605



NOTE:SPECIFICATIONS ARE SUBJECTED TO CHANGE WITHOUT PRIOR NOTICE.

KUBOTA 1661611014_SOS-0A1

b AIR CLEANER

★:Standerd
●:Optional

	Engine Model / Part NO	D905-B	D1005-B	D1105-B	D1105-T	V1205-B	V1305-B	V1505-B	V1505-T
b-1	16286-11013	●	●	●		●	●	●	
b-2	16616-11013	●	●	●		●	●	●	
b-3	15312-11012						●	●	
b-4	15372-11016	●							
b-5	68311-42202	●	●	●	●				
b-6	68391-42202	●	●	●		●	●	●	
b-7	16296-11013				●				●
b-8	16266-11011	●	●	●					

b-1

PART NO.

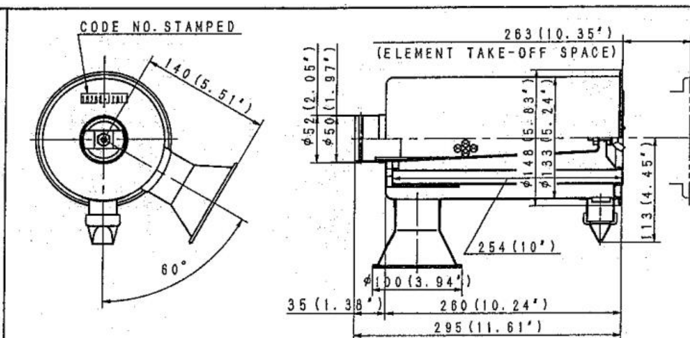
16286-11013

KIT SERIAL NO.

205(for 3cyl)
206(for 4cyl)

KIT NO.

16286-11002(for 3cyl)
16286-11002(for 4cyl)



- Applicable inlet pipe is of code NO. 16286-11621, 16266-11621
- FILTRATION AREA: 0.88m² (9.47ft²)
- RATED (MAX.) AIR FLOW RATE: 2.4m³/minute (84.76ft³/minute)
- AIR FLOW RESISTANCE: LESS THAN 230mm Aq (9.06 inch Aq)
- WEIGH: APPROX. 1.7kg (3.75lbs)

b-2

PART NO.

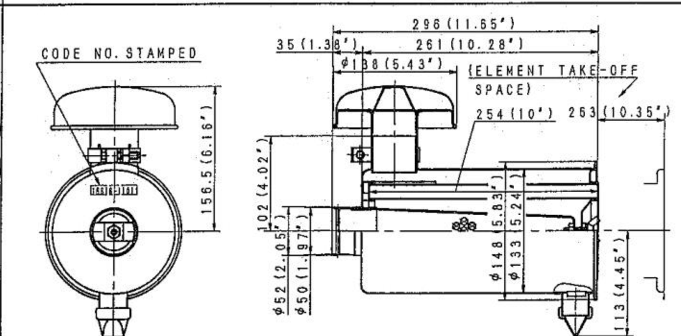
16616-11013

KIT SERIAL NO.

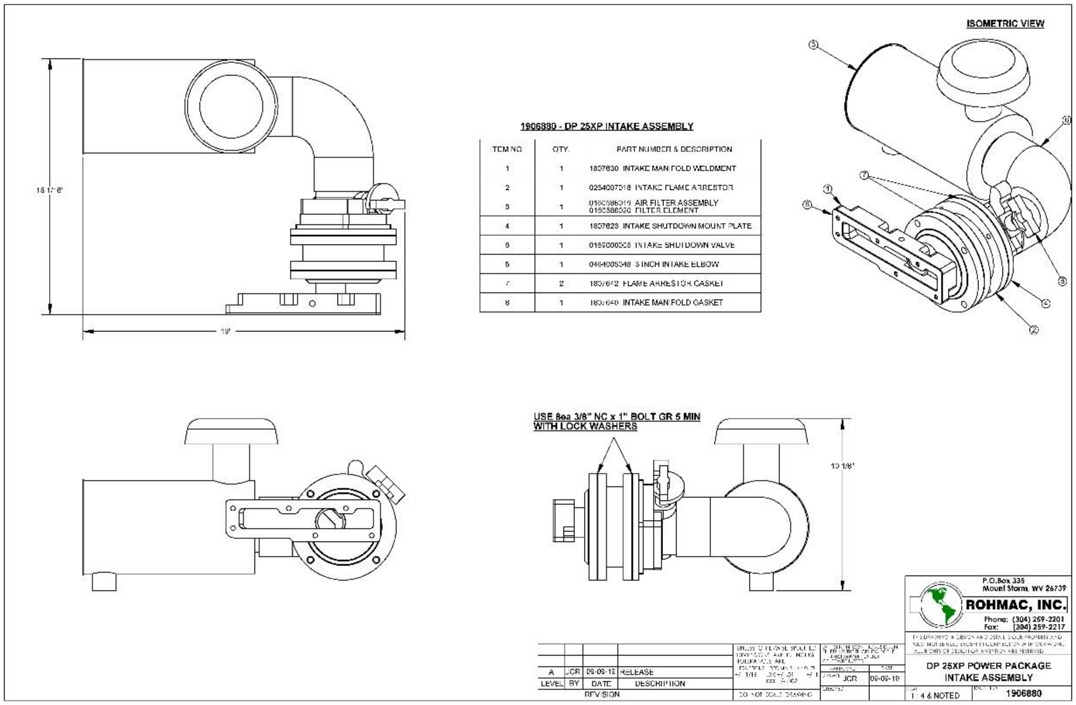
180 (B51) (3Cyl, BBS Spec)
181 (B52) (4Cyl, BBS Spec)
198 (B54) (3, 4Cyl, KTC Spec)

KIT NO.

16613-11002 (3Cyl, BBS Spec)
16616-11002 (4Cyl, BBS Spec)
16615-11002 (3, 4Cyl, KTC Spec)

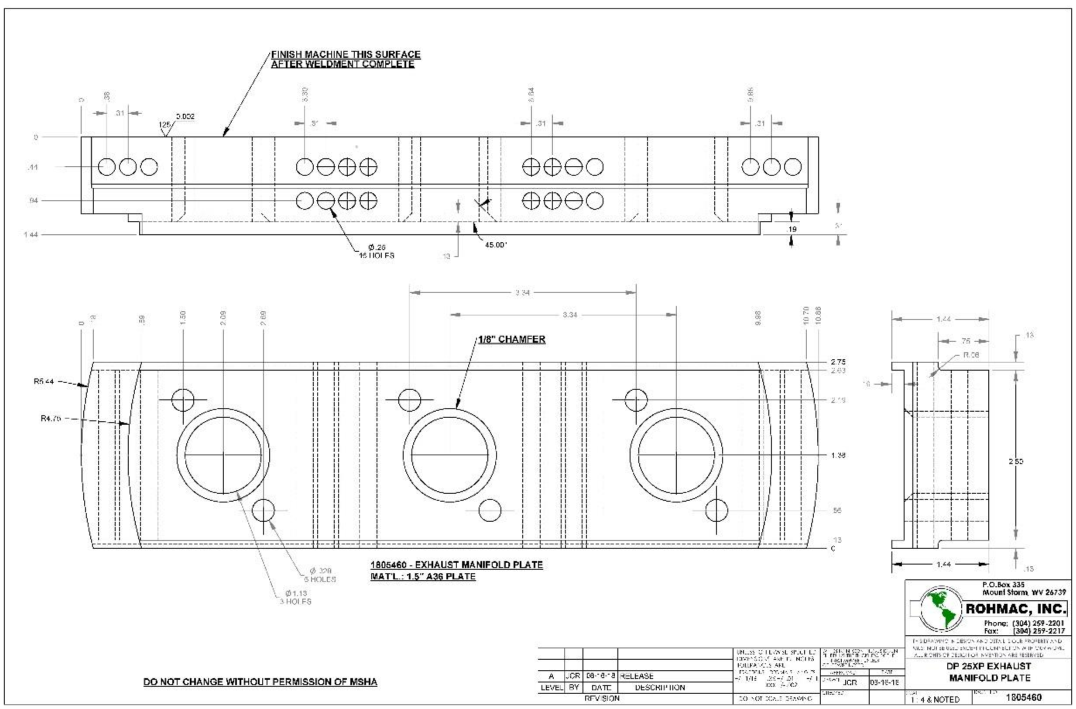


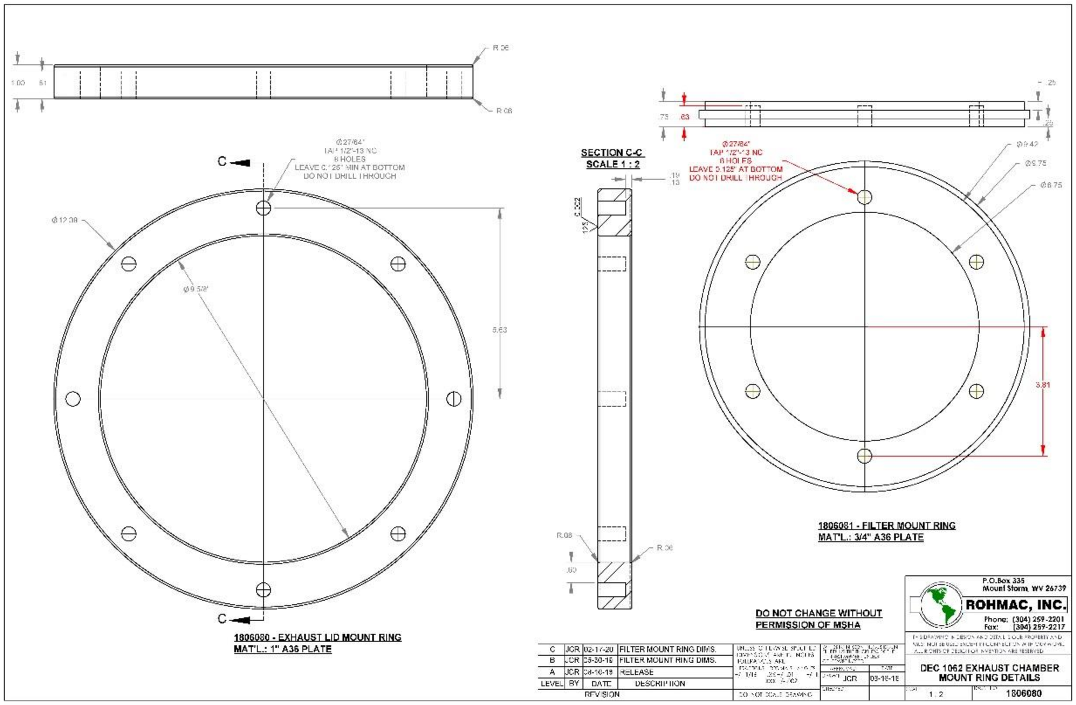
- Applicable inlet pipe is of code NO. 16616-11621
- FILTRATION AREA: 0.88m² (9.47ft²)
- RATED (MAX.) AIR FLOW RATE: 2.4m³/minute (84.76ft³/minute)
- AIR FLOW RESISTANCE: LESS THAN 280mm Aq (11.02 inch Aq)
- WEIGHT: APPROX. 1.7kg (3.75lbs)

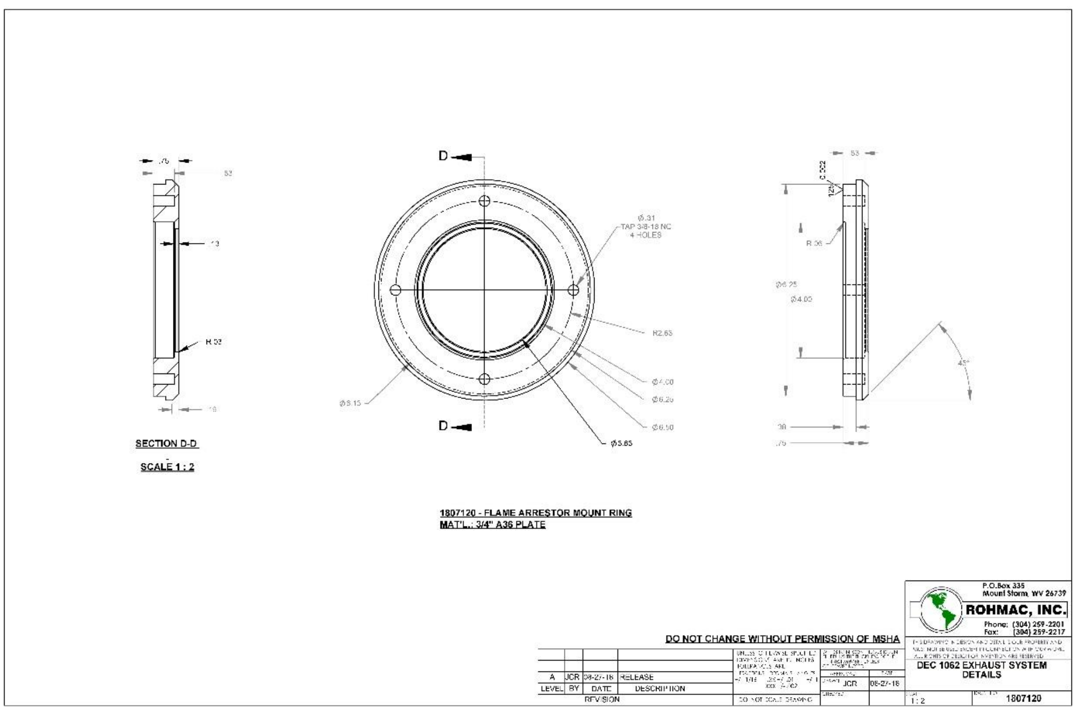


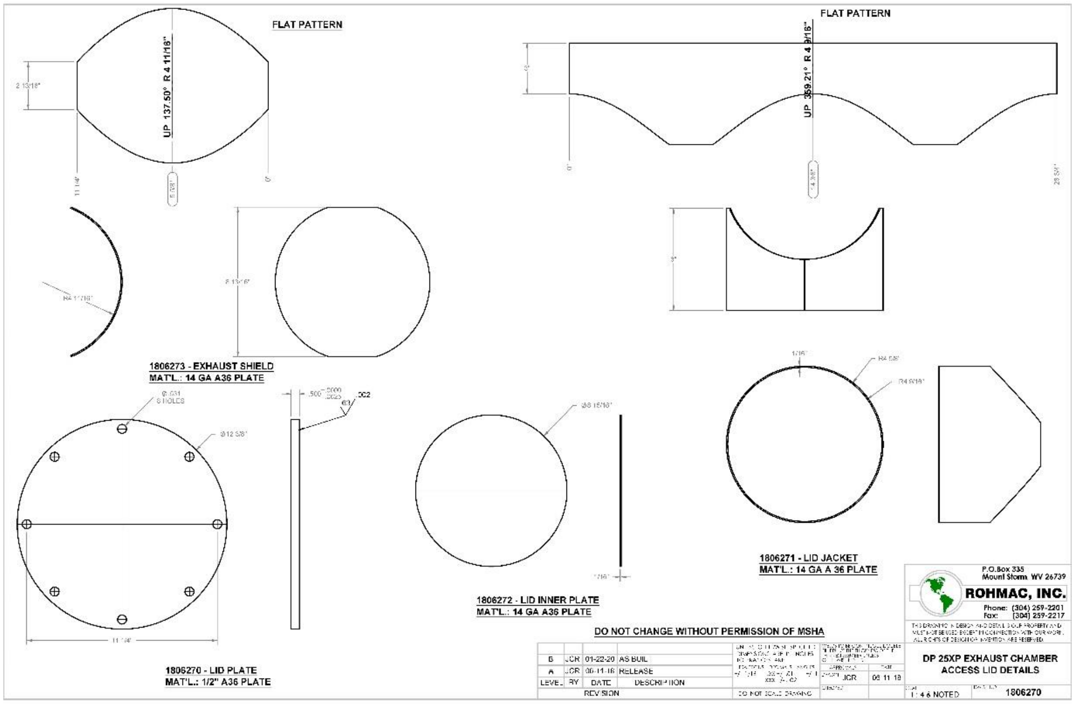
1906880 - DP 25XP INTAKE ASSEMBLY

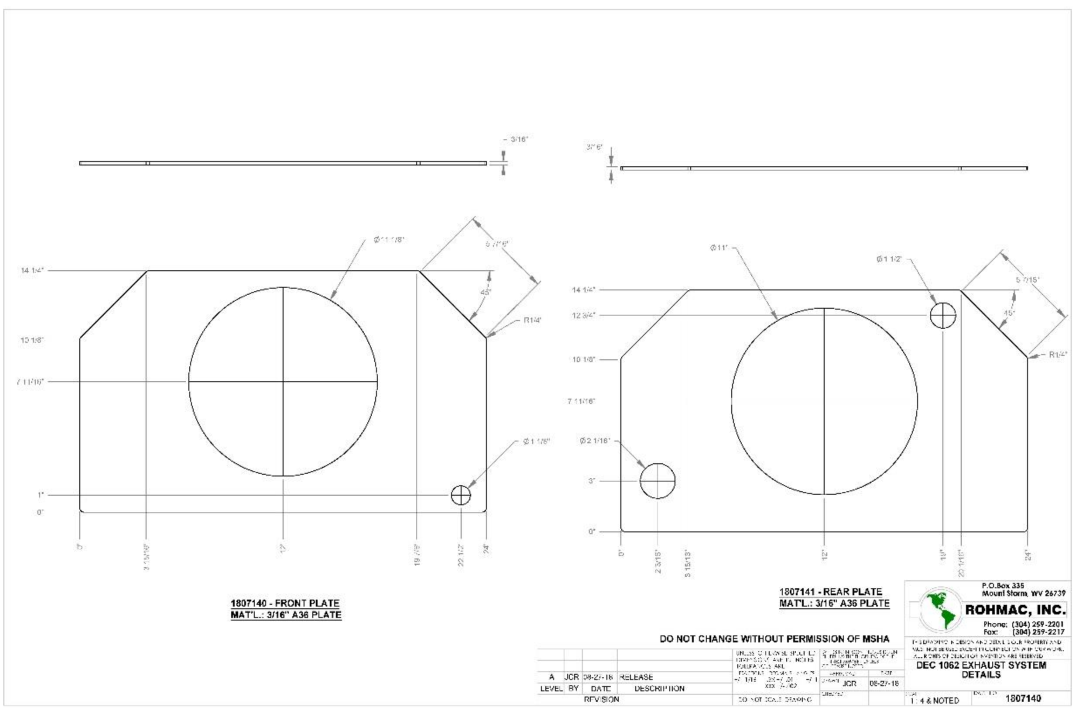
ITEM NO.	QTY.	PART NUMBER & DESCRIPTION
1	1	1807630 INTAKE MANIFOLD WELDMENT
2	1	0254007018 INTAKE FLAME ARRESTOR
3	1	0160586019 AIR FILTER ASSEMBLY 0160586020 FILTER ELEMENT
4	1	1807628 INTAKE SHUTDOWN MOUNT PLATE
5	1	0165000005 INTAKE SHUTDOWN VALVE
6	1	0464005048 3 INCH INTAKE ELBOW
7	2	1807642 FLAME ARRESTOR GASKET
8	1	1807640 INTAKE MANIFOLD GASKET

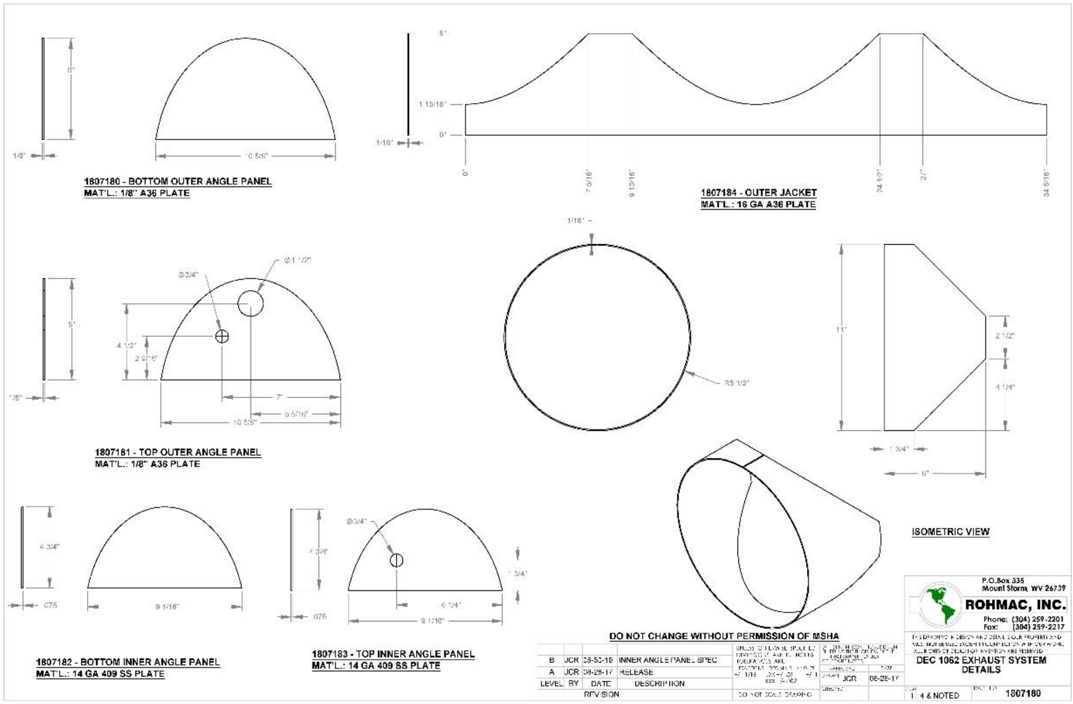


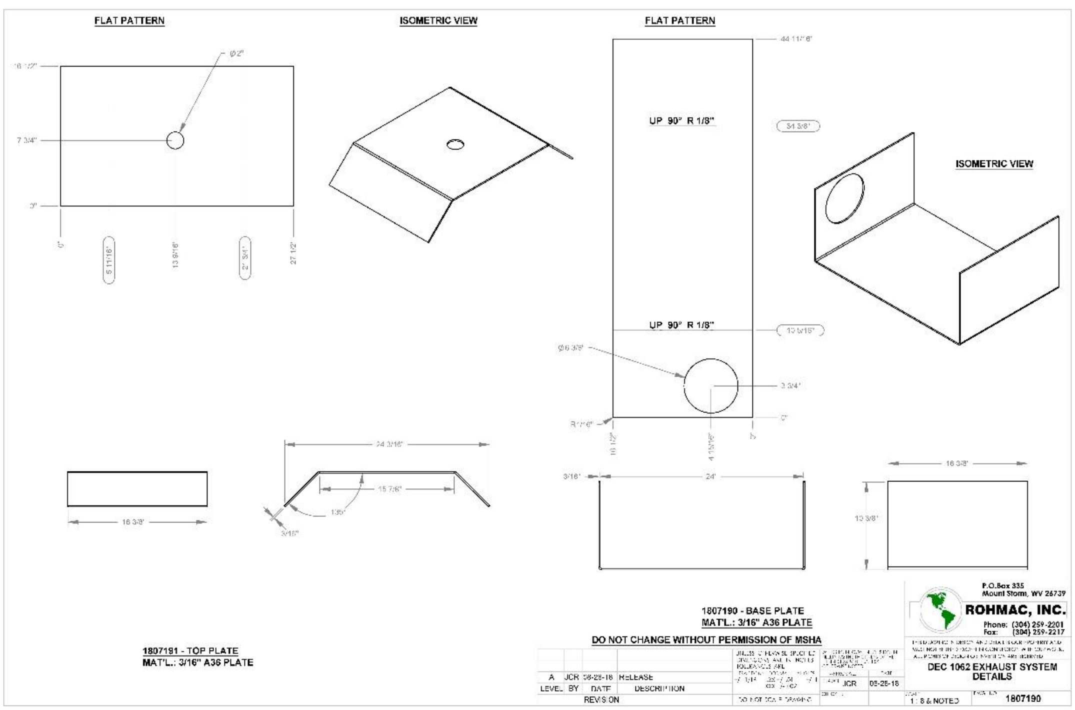

SECTION C-C
SCALE 1 : 2
1806080 - EXHAUST LID MOUNT RING
MAT'L.: 1" A36 PLATE
1806081 - FILTER MOUNT RING
MAT'L.: 3/4" A36 PLATE
Ø27/64"
TAP 1/2"-13 NC
6 HOLES
LEAVE 0.125" AT BOTTOM
DO NOT DRILL THROUGH
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
C JCR 02-17-20 FILTER MOUNT RING DIMS.
B JCR 03-20-19 FILTER MOUNT RING DIMS.
A JCR 03-18-19 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
DEC 1062 EXHAUST CHAMBER MOUNT RING DETAILS
1 : 2
1806080

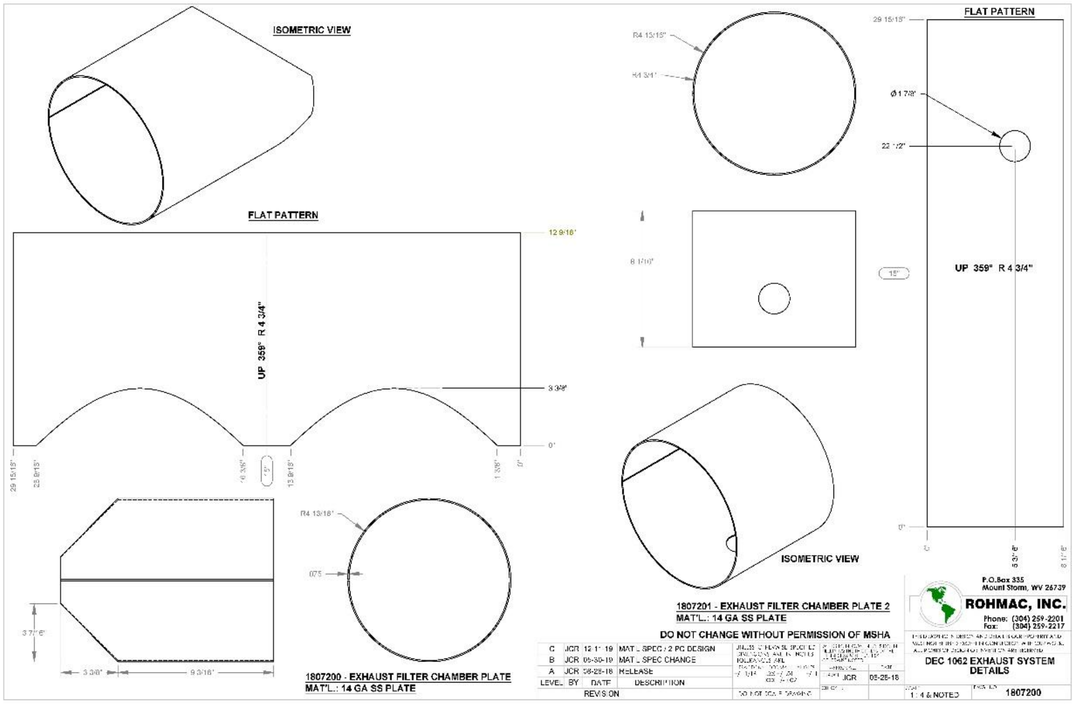

SECTION D-D
SCALE 1 : 2
Ø.31
TAP 3/8-16 NC
4 HOLES
1807120 - FLAME ARRESTOR MOUNT RING
MAT'L.: 3/4" A36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
A JCR 08-27-18 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
DEC 1062 EXHAUST SYSTEM DETAILS
1 : 2
1807120

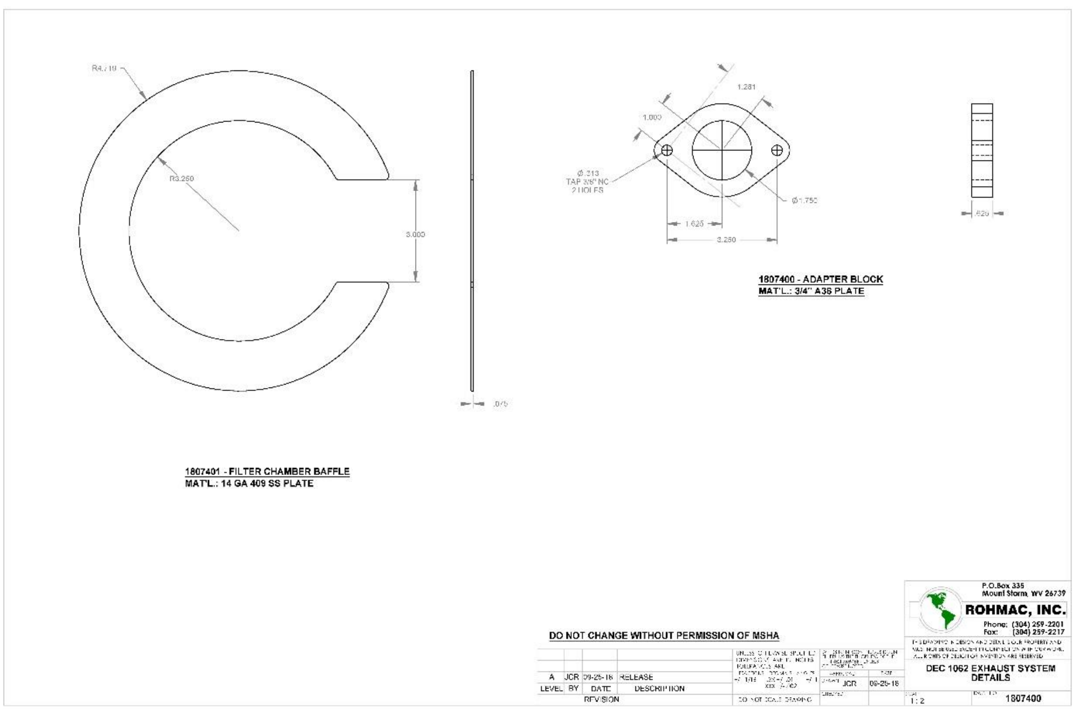

FLAT PATTERN
UP 137.50° R 4 11/16"
FLAT PATTERN
UP 359.21° R 4 9/16"
1806273 - EXHAUST SHIELD
MAT'L.: 14 GA A36 PLATE
1806270 - LID PLATE
MAT'L.: 1/2" A36 PLATE
1806272 - LID INNER PLATE
MAT'L.: 14 GA A36 PLATE
1806271 - LID JACKET
MAT'L.: 14 GA A 36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DP 25XP EXHAUST CHAMBER
ACCESS LID DETAILS
1806270

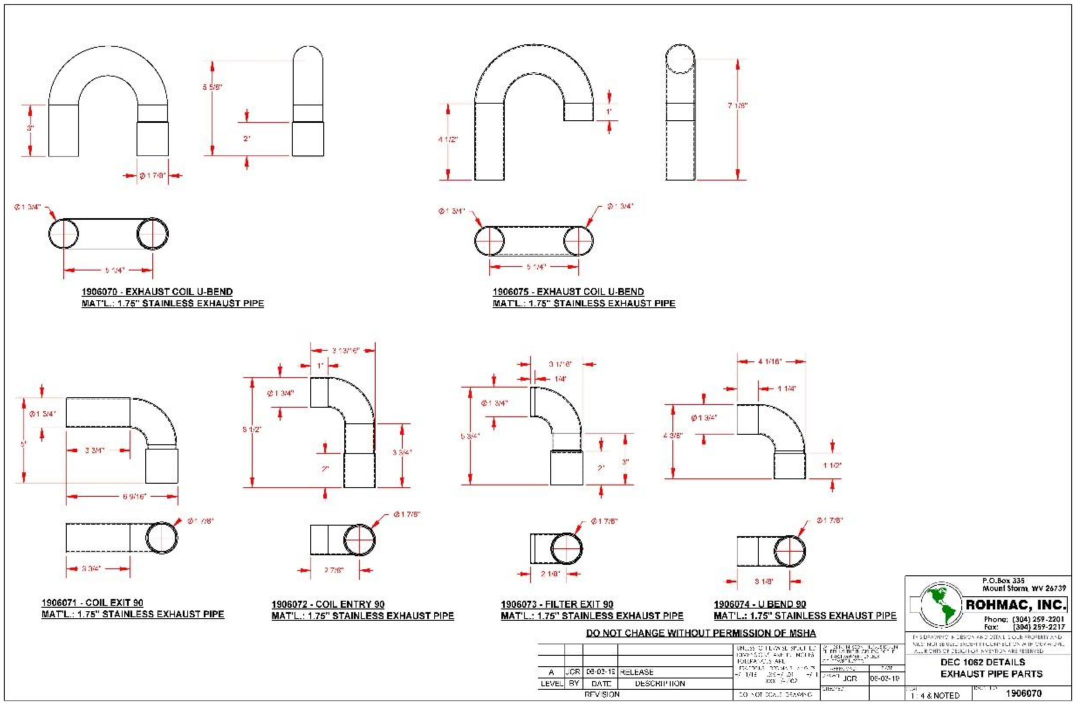

1807140 - FRONT PLATE
MAT'L.: 3/16" A36 PLATE
1807141 - REAR PLATE
MAT'L.: 3/16" A36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST SYSTEM
DETAILS
1807140

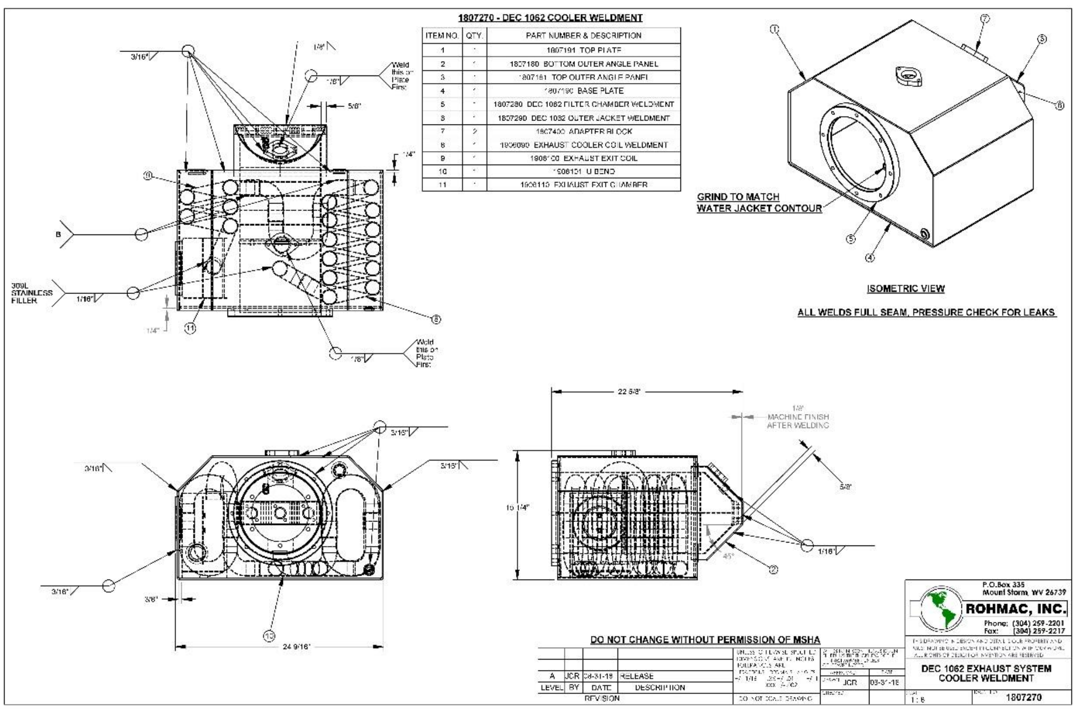

1807180 - BOTTOM OUTER ANGLE PANEL
MAT'L.: 1/8" A36 PLATE
1807184 - OUTER JACKET
MAT'L.: 16 GA A36 PLATE
1807181 - TOP OUTER ANGLE PANEL
MAT'L.: 1/8" A36 PLATE
ISOMETRIC VIEW
1807182 - BOTTOM INNER ANGLE PANEL
MAT'L.: 14 GA 409 SS PLATE
1807183 - TOP INNER ANGLE PANEL
MAT'L.: 14 GA 409 SS PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
B JCR 08-30-18 INNER ANGLE PANEL SPEC
A JCR 08-29-17 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST SYSTEM DETAILS
1:4 & NOTED
1807180

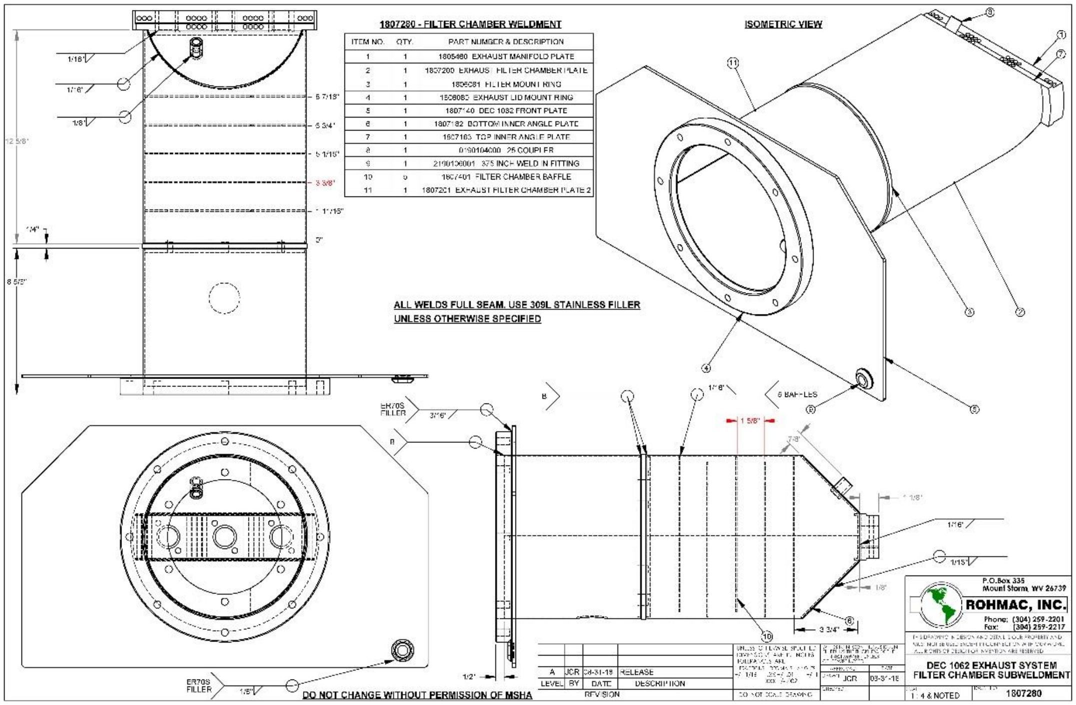

FLAT PATTERN
ISOMETRIC VIEW
FLAT PATTERN
UP 90° R 1/8"
UP 90° R 1/8"
ISOMETRIC VIEW
1807190 - BASE PLATE
MAT'L.: 3/16" A36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
1807191 - TOP PLATE
MAT'L.: 3/16" A36 PLATE
A JCR 08-28-18 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST SYSTEM DETAILS
1:8 & NOTED
1807190


ISOMETRIC VIEW
FLAT PATTERN
UP 359° R 4 3/4"
1807201 - EXHAUST FILTER CHAMBER PLATE 2
MAT'L.: 14 GA SS PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
1807200 - EXHAUST FILTER CHAMBER PLATE
MAT'L.: 14 GA SS PLATE
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST SYSTEM DETAILS
1807200


1807400 - ADAPTER BLOCK
MAT'L.: 3/4" A36 PLATE
1807401 - FILTER CHAMBER BAFFLE
MAT'L.: 14 GA 409 SS PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST SYSTEM DETAILS
1807400

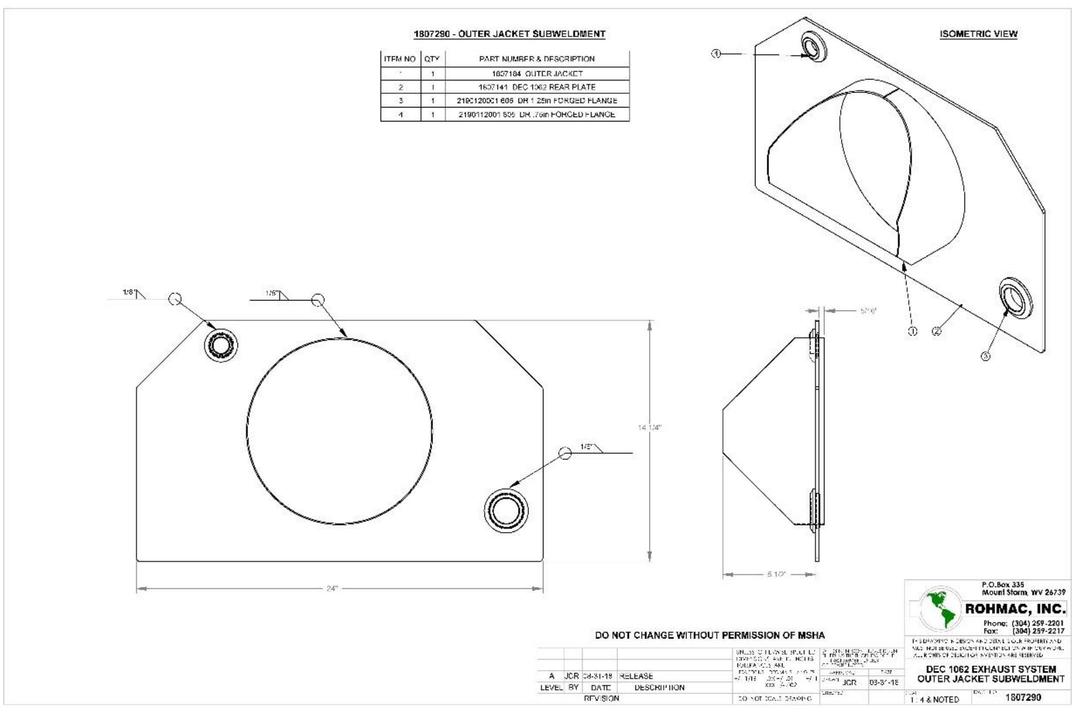

1906070 - EXHAUST COIL U-BEND
MAT'L.: 1.75" STAINLESS EXHAUST PIPE
1906075 - EXHAUST COIL U-BEND
MAT'L.: 1.75" STAINLESS EXHAUST PIPE
1906071 - COIL EXIT 90
MAT'L.: 1.75" STAINLESS EXHAUST PIPE
1906072 - COIL ENTRY 90
MAT'L.: 1.75" STAINLESS EXHAUST PIPE
1906073 - FILTER EXIT 90
MAT'L.: 1.75" STAINLESS EXHAUST PIPE
1906074 - U BEND 90
MAT'L.: 1.75" STAINLESS EXHAUST PIPE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 DETAILS
EXHAUST PIPE PARTS
1:4 & NOTED
1906070
A JCR RELEASE
LEVEL BY DATE DESCRIPTION
REVISION


1807270 - DEC 1062 COOLER WELDMENT
ITEM NO. QTY. PART NUMBER & DESCRIPTION
1 1807191 TOP PLATE
2 1807180 BOTTOM OUTER ANGLE PANEL
3 1807181 TOP OUTER ANGLE PANEL
4 1807190 BASE PLATE
5 1807280 DEC 1062 FILTER CHAMBER WELDMENT
6 1807290 DEC 1062 OUTER JACKET WELDMENT
7 2 1907400 ADAPTER BLOCK
8 1906090 EXHAUST COOLER COIL WELDMENT
9 1906100 EXHAUST EXIT COIL
10 1906101 U BEND
11 1906110 EXHAUST EXIT CHAMBER
Weld this on Place First
308L STAINLESS FILLER
GRIND TO MATCH
WATER JACKET CONTOUR
ISOMETRIC VIEW
ALL WELDS FULL SEAM, PRESSURE CHECK FOR LEAKS
MACHINE FINISH AFTER WELDING
22 5/8"
24 9/16"
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST SYSTEM
COOLER WELDMENT
1:8
1807270
A JCR RELEASE
LEVEL BY DATE DESCRIPTION
REVISION



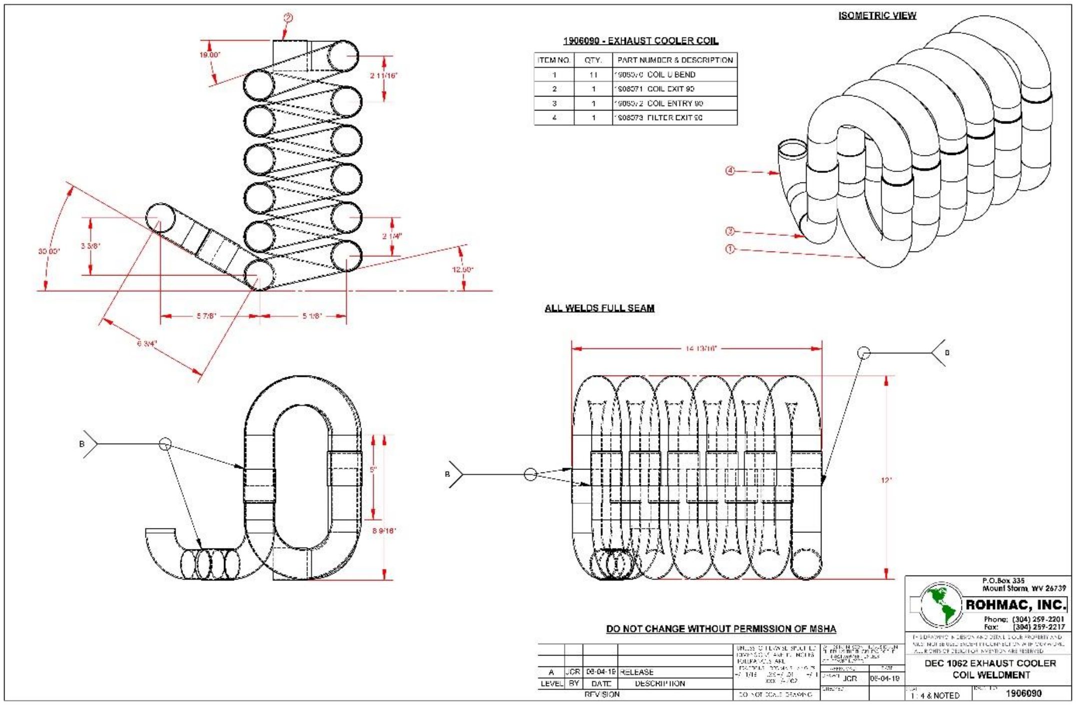
1807280 - FILTER CHAMBER WELDMENT

ITEM NO.	QTY.	PART NUMBER & DESCRIPTION
1	1	1805460 EXHAUST MANIFOLD PLATE
2	1	1807200 EXHAUST FILTER CHAMBER PLATE
3	1	1806081 FILTER MOUNT RING
4	1	1506080 EXHAUST LID MOUNT RING
5	1	1807140 DEC 1062 FRONT PLATE
6	1	1807182 BOTTOM INNER ANGLE PLATE
7	1	1807183 TOP INNER ANGLE PLATE
8	1	0190104000 .25 COUPLER
9	1	2190106001 .375 INCH WELD IN FITTING
10	5	1807401 FILTER CHAMBER BAFFLE
11	1	1807201 EXHAUST FILTER CHAMBER PLATE 2



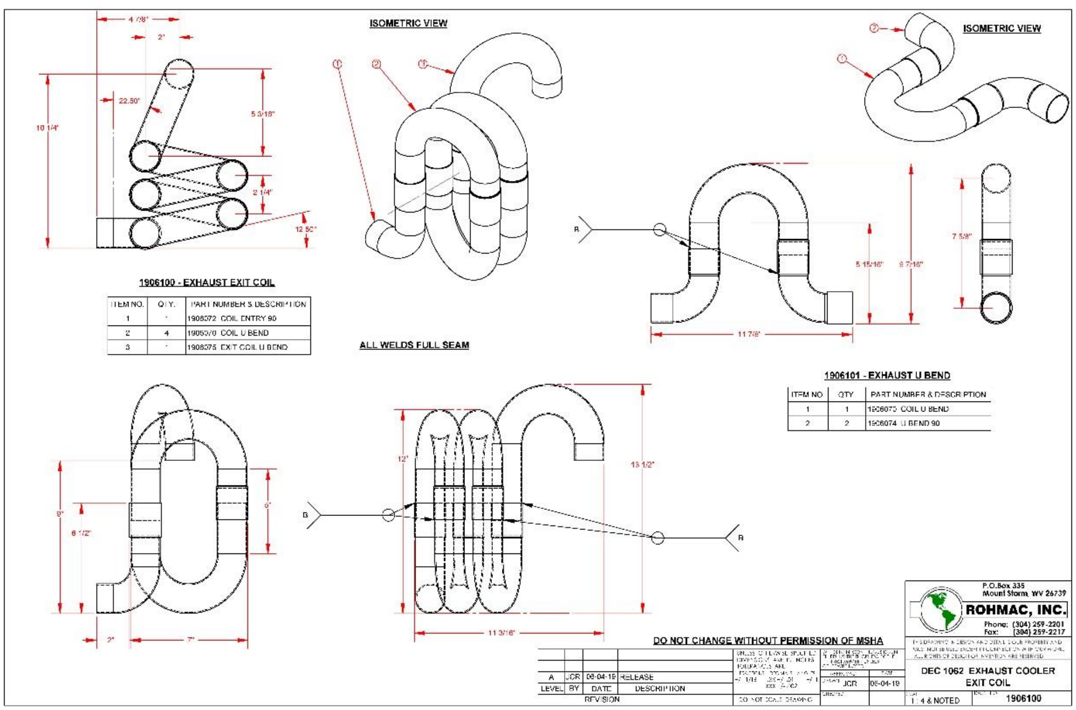
1807290 - OUTER JACKET SUBWELDMENT

ITEM NO	QTY	PART NUMBER & DESCRIPTION
1	1	1807184 OUTER JACKET
2	1	1807141 DEC 1062 REAR PLATE
3	1	2190120001 605 DR 1.25in FORGED FLANGE
4	1	2190112001 605 DR .75in FORGED FLANGE



1906090 - EXHAUST COOLER COIL

ITEM NO.	QTY.	PART NUMBER & DESCRIPTION
1	11	1906070 COIL U BEND
2	1	1906071 COIL EXIT 90
3	1	1906072 COIL ENTRY 90
4	1	1906073 FILTER EXIT 90

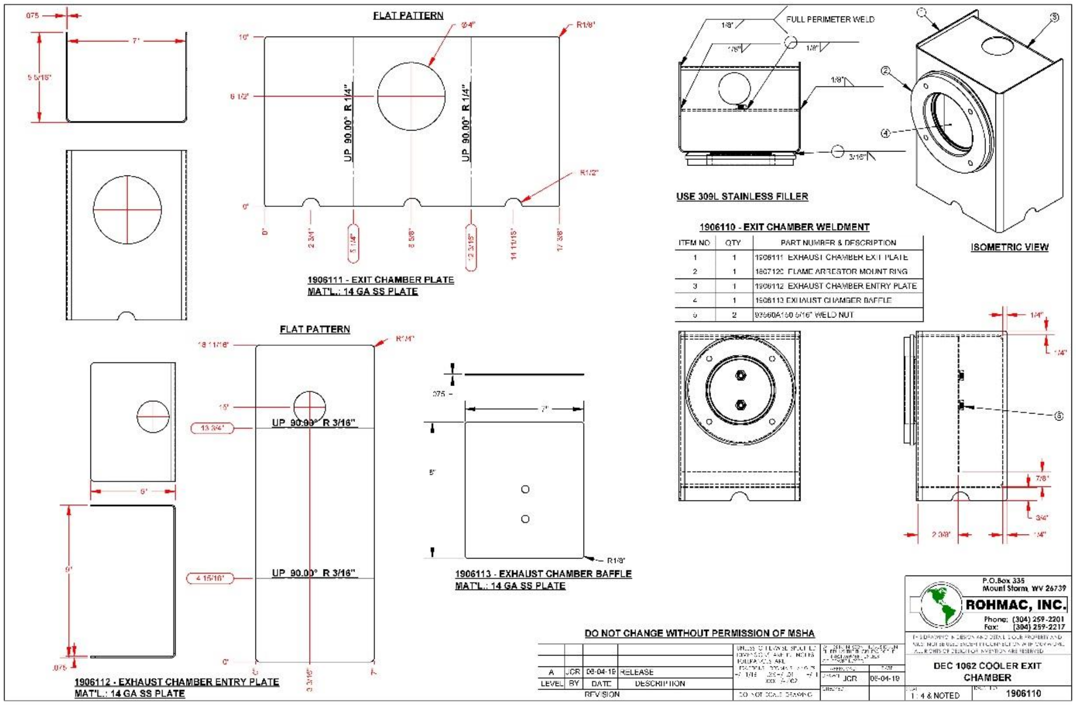


1906100 - EXHAUST EXIT COIL

ITEM NO.	QTY.	PART NUMBER & DESCRIPTION
1	1	1906072 COIL ENTRY 90
2	4	1906070 COIL U BEND
3	1	1906075 EXIT COIL U BEND

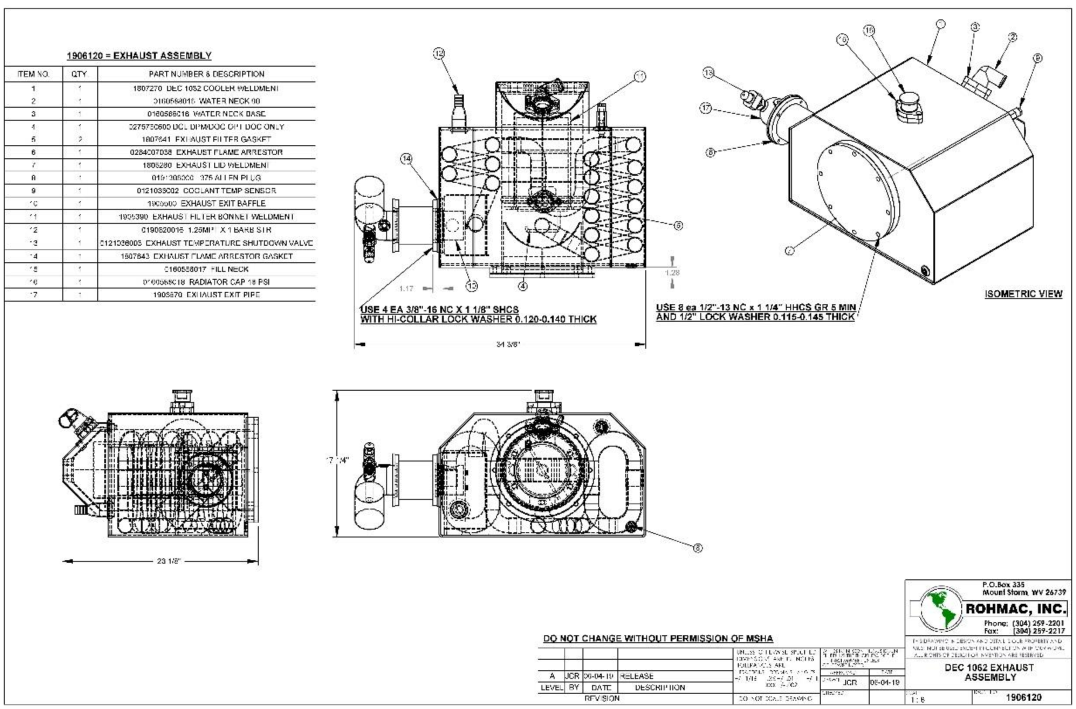
1906101 - EXHAUST U BEND

ITEM NO	QTY	PART NUMBER & DESCRIPTION
1	1	1906070 COIL U BEND
2	2	1906074 U BEND 90



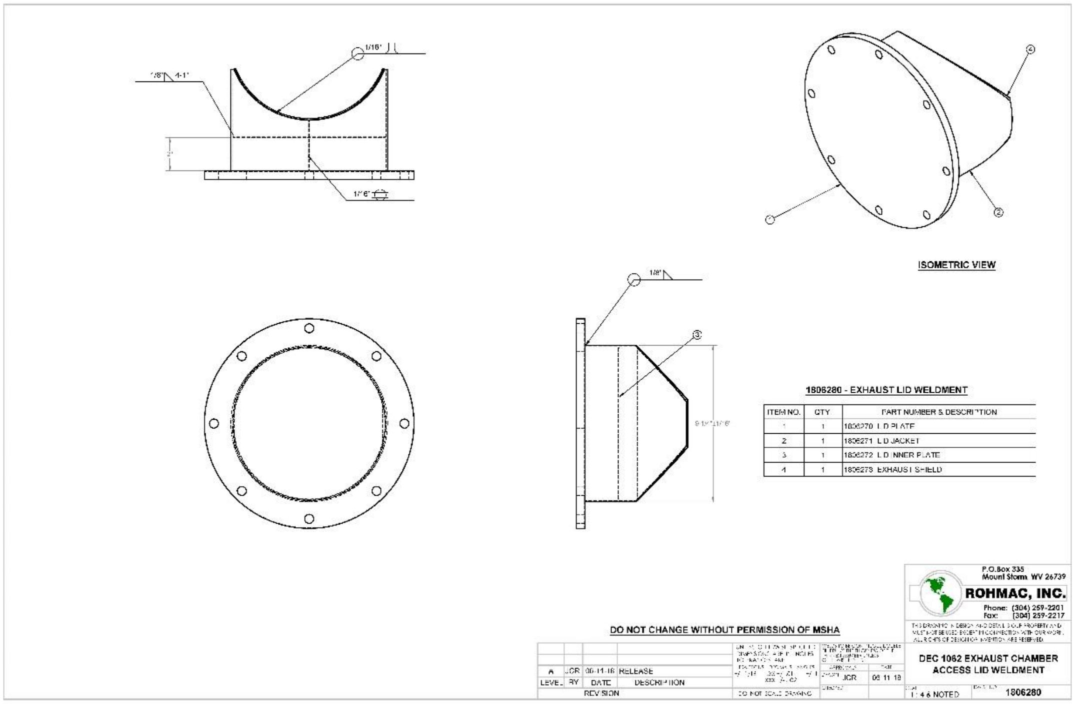
1906110 - EXIT CHAMBER WELDMENT

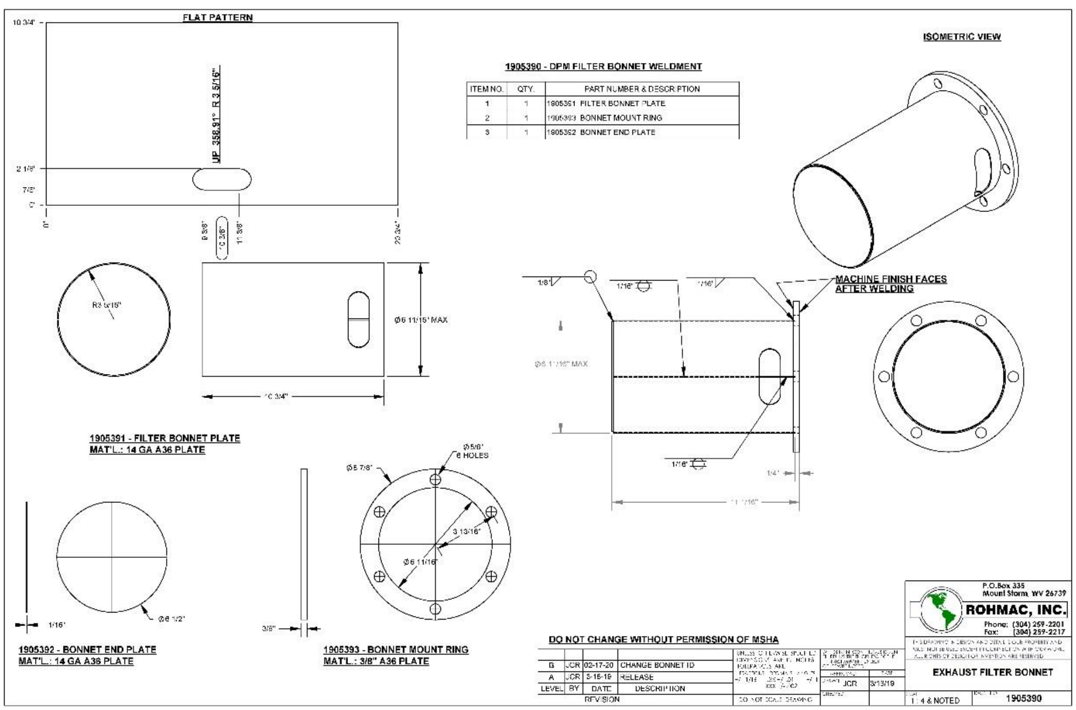
ITEM NO	QTY	PART NUMBER & DESCRIPTION
1	1	1906111 EXHAUST CHAMBER EXIT PLATE
2	1	1807120 FLAME ARRESTOR MOUNT RING
3	1	1906112 EXHAUST CHAMBER ENTRY PLATE
4	1	1906113 EXHAUST CHAMBER BAFFLE
5	2	93560A150 5/16" WELD NUT

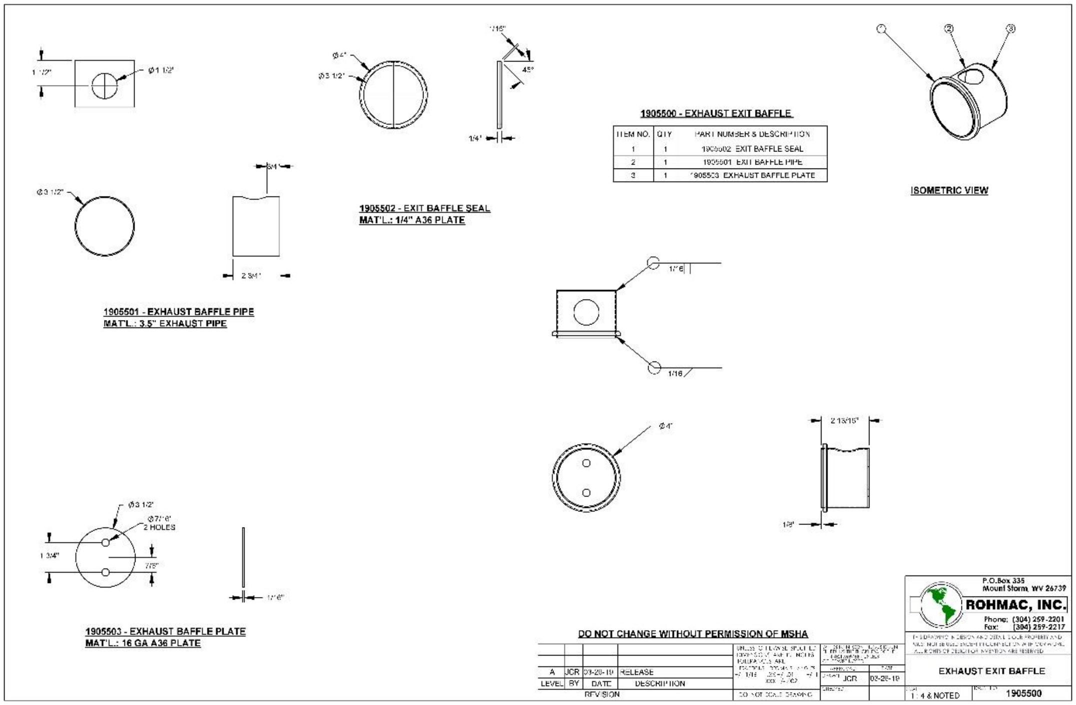


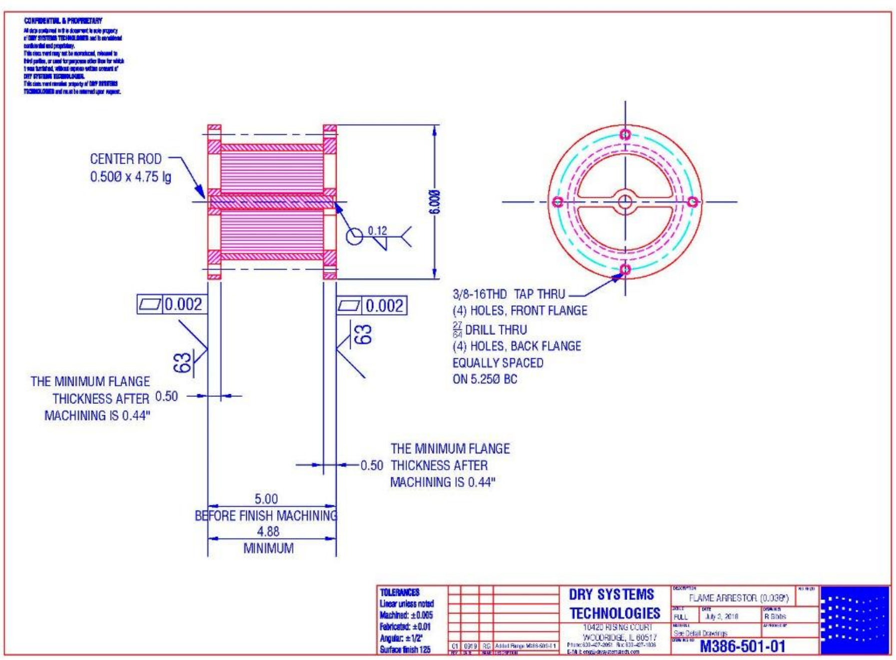
1906120 = EXHAUST ASSEMBLY

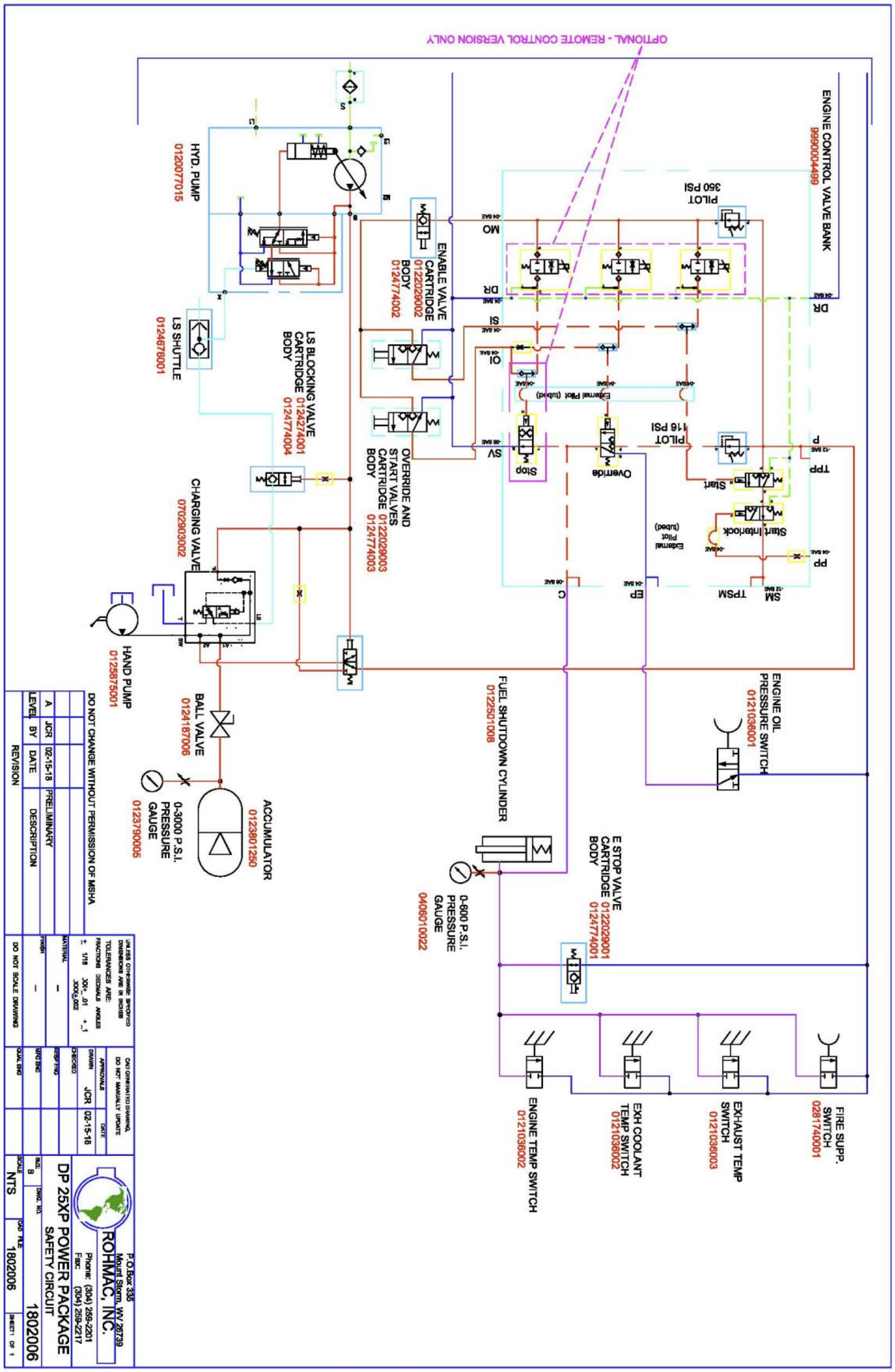
ITEM NO.	QTY.	PART NUMBER & DESCRIPTION
1	1	1807270 DEC 1052 COOLER WELDMENT
2	1	0160568016 WATER NECK 90
3	1	0160565016 WATER NECK BASE
4	1	0275750600 DCL DPM/DOC OPT DOC ONLY
5	2	1807641 EXHAUST FILTER GASKET
6	1	0284007038 EXHAUST FLAME ARRESTOR
7	1	1806280 EXHAUST LID WELDMENT
8	1	0191308000 .375 ALLEN PLUG
9	1	0121039002 COOLANT TEMP SENSOR
10	1	1905500 EXHAUST EXIT BAFFLE
11	1	1905390 EXHAUST FILTER BONNET WELDMENT
12	1	0190520016 1.25MPT X 1 BARB STR
13	1	0121038005 EXHAUST TEMPERATURE SHUTDOWN VALVE
14	1	1807643 EXHAUST FLAME ARRESTOR GASKET
15	1	0160538017 FILL NECK
16	1	0160565018 RADIATOR CAP 18 PSI
17	1	1905870 EXHAUST EXIT PIPE


ISOMETRIC VIEW
1806280 - EXHAUST LID WELDMENT
ITEM NO. | QTY | PART NUMBER & DESCRIPTION
1 | 1 | 1806270 LID PLATE
2 | 1 | 1806271 LID JACKET
3 | 1 | 1806272 LID INNER PLATE
4 | 1 | 1806273 EXHAUST SHIELD
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DEC 1062 EXHAUST CHAMBER
ACCESS LID WELDMENT
A JCR 06-11-18 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
1:4 & NOTED
1806280


FLAT PATTERN
UP 358.91° R 3 5/16"
ISOMETRIC VIEW
1905390 - DPM FILTER BONNET WELDMENT
ITEM NO. | QTY. | PART NUMBER & DESCRIPTION
1 | 1 | 1905391 FILTER BONNET PLATE
2 | 1 | 1905393 BONNET MOUNT RING
3 | 1 | 1905392 BONNET END PLATE
MACHINE FINISH FACES
AFTER WELDING
Ø6 11/16" MAX
1905391 - FILTER BONNET PLATE
MAT'L.: 14 GA A36 PLATE
Ø5/8"
8 HOLES
1905392 - BONNET END PLATE
MAT'L.: 14 GA A36 PLATE
1905393 - BONNET MOUNT RING
MAT'L.: 3/8" A36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
EXHAUST FILTER BONNET
B JCR 02-17-20 CHANGE BONNET ID
A JCR 3-18-19 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
1:4 & NOTED
1905390


1905500 - EXHAUST EXIT BAFFLE
ITEM NO. | QTY | PART NUMBER & DESCRIPTION
1 | 1 | 1905502 EXIT BAFFLE SEAL
2 | 1 | 1905501 EXIT BAFFLE PIPE
3 | 1 | 1905503 EXHAUST BAFFLE PLATE
ISOMETRIC VIEW
1905502 - EXIT BAFFLE SEAL
MAT'L.: 1/4" A36 PLATE
1905501 - EXHAUST BAFFLE PIPE
MAT'L.: 3.5" EXHAUST PIPE
1905503 - EXHAUST BAFFLE PLATE
MAT'L.: 16 GA A36 PLATE
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
P.O.Box 335
Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
EXHAUST EXIT BAFFLE
A JCR 02-20-19 RELEASE
LEVEL BY DATE DESCRIPTION
REVISION
1:4 & NOTED
1905500


CONFIDENTIAL & PROPRIETARY
CENTER ROD
0.500Ø x 4.75 lg
6.000
0.12
0.002
63
3/8-16THD TAP THRU
(4) HOLES, FRONT FLANGE
27/64 DRILL THRU
(4) HOLES, BACK FLANGE
EQUALLY SPACED
ON 5.250Ø BC
THE MINIMUM FLANGE THICKNESS AFTER MACHINING IS 0.44"
0.50
5.00
BEFORE FINISH MACHINING
4.88
MINIMUM
TOLERANCES
Linear unless noted
Machined: ±0.005
Fabricated: ±0.01
Angular: ±1/2°
Surface finish 125
DRY SYSTEMS TECHNOLOGIES
10420 RISING COURT
WOODRIDGE, IL 60517
FLAME ARRESTOR (0.039")
M386-501-01



OPTIONAL - REMOTE CONTROL VERSION ONLY
ENGINE CONTROL VALVE BANK 999004499
PILOT 350 PSI
PILOT 116 PSI
HYD. PUMP 0120077015
LS SHUTTLE 0124676001
ENABLE VALVE CARTRIDGE 0122029002 BODY 0124774002
LS BLOCKING VALVE CARTRIDGE 0124274001 BODY 0124774004
OVERRIDE AND START VALVES CARTRIDGE 0122029003 BODY 0124774003
CHARGING VALVE 0702903002
HAND PUMP 0125875001
BALL VALVE 0124187006
ACCUMULATOR 0123801250
0-3000 P.S.I. PRESSURE GAUGE 0123790005
FUEL SHUTDOWN CYLINDER 0122501008
E STOP VALVE CARTRIDGE 0122029001 BODY 0124774001
0-600 P.S.I. PRESSURE GAUGE 0406010022
ENGINE OIL PRESSURE SWITCH 0121036001
FIRE SUPP. SWITCH 0281740001
EXHAUST TEMP SWITCH 0121038003
EXH COOLANT TEMP SWITCH 0121038002
ENGINE TEMP SWITCH 0121036002
Stop
Override
Start
Start Interlock
MO
DR
SI
OI
SV
TPP
P
PP
SM
TPSM
EP
C
DO NOT CHANGE WITHOUT PERMISSION OF MSHA
A JCR 02-15-18 PRELIMINARY
LEVEL BY DATE DESCRIPTION
REVISION
DRAWN JCR 02-15-18
DO NOT SCALE DRAWING
P.O.Box 335 Mount Storm, WV 26739
ROHMAC, INC.
Phone: (304) 259-2201
Fax: (304) 259-2217
DP 25XP POWER PACKAGE
SAFETY CIRCUIT
1802006
NTS

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

30 August 2019

Doc ID 190830JCR02

DP 25XP Power Package Safety Shutdown System Description

This document describes the function of the Safety Shutdown system on the Rohmac model DP 25XP diesel power package:

Engine Shutdown Actuation

- The engine shutdown is accomplished by moving the OEM mechanical fuel rack shutdown arm on the fuel pump
- A spring return hydraulic cylinder is used to actuate the arm, spring pressure extends the cylinder and returns the arm to the shutdown position, hydraulic pressure retracts the cylinder allowing the fuel shutdown arm to move to the open position. The cylinder and arm are connected by a wire cable.

Safety System Control

- Hydraulic pressure is supplied to the circuit at 116 psi. Mechanical supply valves are used to pressurize the system and override the engine oil pressure valve, and to Stop the machine by releasing pressure to tank. Optionally, a control manifold can be added to the system, with permissible 12 vdc solenoids that can be used to control Override and Stop functions.
- 2 - AMOT 2230 valves, located at the engine thermostat housing and at the exhaust cooling chamber, monitor coolant temperatures and shutdown before exceeding 212 °F. An AMOT 1672 valve is used to monitor engine oil pressure, and an AMOT 4475 valve is used to monitor Exhaust Gas temperature and shutdown before exceeding 302 °F. A pilot operated 2 position 3-way valve is used to shutdown in the event of fire suppression activation. All safety shutdowns actuate to vent the system pressure to tank for shutdown.
- Initially, hydraulic pressure is supplied from the hydraulic accumulator. The Safety circuit is a closed circuit, but may be manually replenished by supply pressure from the main hydraulic pump as needed during operation.

Do Not change without permission of MSHA

2-Way Temperature Sensing Valves

Models 2230 and 4430

Overview

Model 2230/4430 is a normally-closed, 2-way valve which is opened by increasing temperature of engine cooling water, lubricating oil, high pressure gas or other fluids. The 2230/4430 can also be used to sensing high bearing or packing temperatures. Opening of the valve vents control pressure from an AMOT Mater Safety Control such as Model 2800 or 4261, and protects the engine, compressor, pump, gear case, and industrial machinery from over-temperature.

Type 2230 Valve (Brass) **Type 4430 Valve (Stainless Steel)**

Typical applications

- Lube oil
- Jacket water
- Discharge gases
- Bearings or packing

Key features and benefits

- Compact, rugged design
- Factory set, field adjustable
- Compatible in hydraulic or gas systems
- Easy maintenance; few moving parts
- Compatible with complete AMOT shutdown systems
- No electricity required; failsafe
- No wires to break or corrode
- Viton seals standard
- Brass (2230) or stainless steel (4430) construction
- Temperature setting available from 30°C to 118°C (95°F to 245°F) standard or 129°C (265°F) high temperature
- Maximum pressure at the IN Port is 8.6 bar (125 psi)
- Maximum internal pressure on the temperature sensing element is 551 bar (800 psi)

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2-Way Sensing Valves - Models 2230/4430

Operation

Model 2230/4430 operation is simple and straight forward. As the temperature of the sensed fluid increases, wax enclosed in the valve's temperature sensing element expands against a push rod, which in turn unseats a valve allowing flow to travel from the valve's IN port and out the valve's OUT port. For visual indication that the temperature valve has tripped, use AMOT Model 4054 Trip Indicator.

Model 2230/4430 Temperature Valves are set at the factory, and the trip temperature is stamped on the valve body. The valve will start to bleed control pressure at 2°F to 4°F below its calibrated setting. Do not operate 2230/4430 beyond the valve's maximum continuous operating temperature. Both models are field service/adjustable. See 'Adjustment' on page 5.

Specification

	2230D		4430B	
Standard materials				
Body & Nut	Brass		316 SS	
Seals	Viton		Viton	
Element	Brass		Brass	
Extensions	Brass		316 SS	
Maximum pressure on temp. element	55.1 bar	(800 psi)	55.1 bar	(800 psi)
Maximum pressure at IN Port	8.6 bar	(125 psi)	8.6 bar	(125 psi)
Maximum net weight	0.57 kg	(1 1/4 lbs)	0.57 kg	(1 1/4 lbs)
Maximum net weight of well	0.45 kg	(1 lb)	0.45 kg	(1 lb)

Stainless Steel Wells

Two types of stainless steel well may be used with Model 4430 Temperature Valves. The 2766L well has a 1" NPT insertion connection, and a heavy wall thickness for pressures up to 10,000 psi. The 3802L well has a 3/4" NPT connection, a thinner wall and is good for 5,000 psi. Pressures are the maximum allowable.

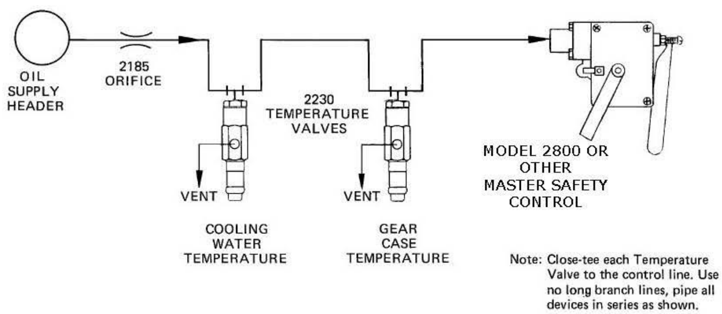
To obtain working pressure, factors of safety should be applied as required by appropriate codes or regulations. In certain adverse conditions, a corrosion or erosion allowance should also be made.

Installation

Before installing the Model 4430 it is advisable to run a 23"/32" dia. tap drill through the pipe fitting in which the unit will be placed. Some commercial fittings are not tapped deep enough and the threads may damage the valve's temperature element cup. Apply a quality thread sealant such as Loctite™ Pipe Sealant to pipe thread connections. Avoid introducing the sealant or other contaminants into the system.

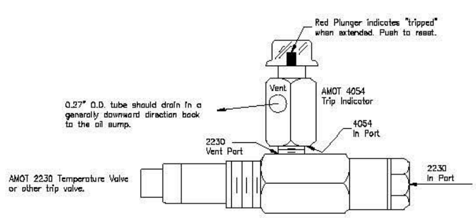
On a system using lubricating oil for control pressure, the vent port is connected to the engine oil sump. If natural gas is used, the vent port is connected to the system vent. No vent connection is required where air is the control medium, but the port should be protected from contamination by an AMOT 4125 vent closure or a tubing elbow turned downward.

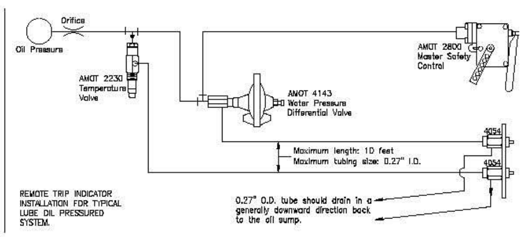
Typical Installation Diagram



Optional Visual Trip Indicators

A typical installation for lube oil pressured system. It is also suitable for air or gas systems when not vented back to the oil sump.





2-Way Sensing Valves - Models 2230/4430

How to order

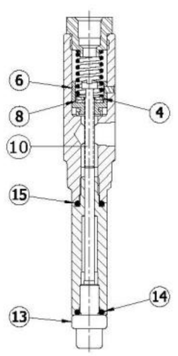
Use the table below to select the unique specification of your 2230/4430 2-way sensing valve

Example	2230D	1	2	0	E		N	210F	***	**Code Description**					
Basic Model	2230D									Basic Model - Brass					
	4430B									Basic Model - Stainless Steel					
										Finish and Thread					
Finish and Thread		1								Standard, NPT					
		2								Standard, BSP (TR)					
		3								Plated NPT					
		4								Plated BSP (TR)					
										Seal Material					
Seal Material			2							Viton					
										Temperature Element Extension		**Installed Depth of Wells**			
										Installed Depth "L"		3/4" 3802L Well "M"		1" 2766L Well "N"	
										inch	mm	inch	mm	inch	mm
Temperature Element Extension/ Installed Depth of Wells				0	(no extension)					1 3/8	34.9	-		-	
				1						2 3/16	55.6	1 11/16	42.9	2	50.8
				2						2 1/2	63.5	1 15/16	49.2	2 1/4	57.2
				3						3	73.2	2 7/16	61.9	2 3/4	69.9
				4						3 1/2	88.9	2 15/16	74.6	3 1/4	82.6
				5						4	101.6	3 7/16	87.3	3 3/4	95.3
				6						4 1/2	114.3	3 15/16	100	4 1/4	107.6
				7						5	127	4 7/16	112.7	4 3/4	120.7
										Temperature Range					
					Standard Element	Plated Element				Temperature Range without a well (add 10°F if in a well)				Max. Continuous Allowable Temp.	
										°F		°C		°F	°C
Temperature Range					A	K				65 - 95		18 - 35		120	49
					B	M				96 - 130		36 - 54		155	68
					C	N				131 - 160		55 - 71		185	85
					D	P				161 - 180		72 - 82		215	102
					E	R				181 - 210		83 - 99		230	110
					F	S				215 - 225		102 - 107		245	118
					G	T				226 - 245		108 - 118		255	124
					H	W				265		129		275	135
										Thermal Well Code					
Thermal Well Code							N			Not Fitted					
							V			Calibrated in a well (well not fitted)					
							1			3/4" NPT					
							2			1" NPT					
										Temperature Setting					
Temperature Setting								210F		In °F or °C					
										Special Requirements					
Special Requirements (made to order)									***	Customer Special Code					

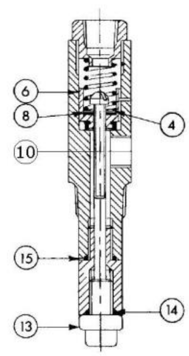
Adjustment

Refer to cut-away view below. To adjust the temperature seting of the 2230/4430, place a screwdriver through the IN port and in the slot of Adjusting Screw (Item 10). To RAISE the temperature setting turn the screw counterclockwise, to LOWER the setting turn the screw clockwise. One turn equals about 10°F. When changing the tripping temperature be sure that the valve is not adjusted beyond the range limit.

Service Parts



Model 2230
Cut-away View



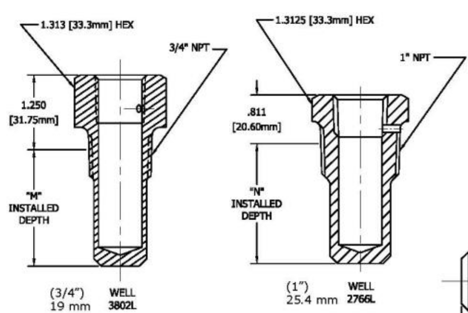
Model 4430
Cut-away View

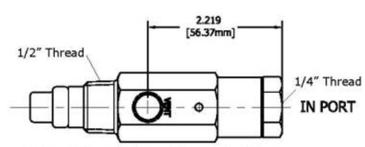
Refer to cut-away view to the left.

Ref no.:	Qty	Description	Part no. for standard finish
4	1	Washer	141
6	1	Valve Seat Assembly - Viton	2924X001
8	1	Valve Stem Seal - Viton	3555L001
13	1	Temp. Element	
		Standard	1981X
		Plated	1981P
14	1	O Ring - Viton	348L001
15	1	O Ring - For use on extensions only	348L001

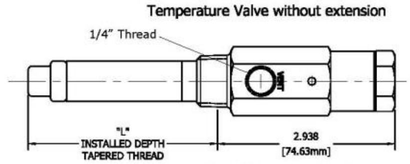
Dimensions

Dimensions in inches (mm). Refer to How to order table on page 4 for dimensions L, M and N.

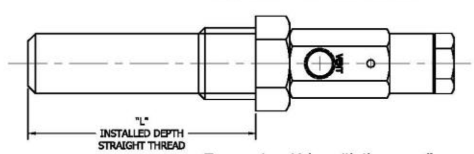




Temperature Valve without extension



Temperature Valve with extension



Temperature Valve with thermowell

Americas

AMOT USA
8824 Fallbrook Dr
Houston
TX 77064
USA

Tel: +1 (281) 940 1800
Fax +1 (713) 559 9419
Email sales@amotusa.com

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Rm 4102 - 4104 United Plaza
1468 Nanjing Road West
Shanghai 200040
China

Tel +86 (0) 21 6279 7700
Fax +86 (0) 21 5237 8560
Email shanghai@amot.com

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Singapore Post Centre
Singapore 408600

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Fax +65 6293 3307
Email singapore@amot.com

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Suffolk, IP33 3SZ
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Tel +44 (0) 1284 762222
Fax +44 (0) 1284 760256
Email info@amot.com

AMOT Controls GmbH
Rondenbarg 25
22525 Hamburg
Germany

Tel +49 (0) 40 8537 1298
Fax +49 (0) 40 8537 1331
Email germany@amot.com

www.amot.com

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High Temperature Valves
Models 4075D & 4475B

Typical applications

- Jacket water temperature
- Compressor discharge temperature
- Steam temperature
- Lube oil temperature
- Process temperature

Model 4075D

Key features and benefits

- 316 Stainless Steel or Cast Aluminum available
- Field adjustable from 54°C to 260°C (130°F to 500°F)
- Reliable protection
- Few moving parts
- Easy installation - low maintenance
- Thermowell included
- Compatible with complete AMOT shutdown systems
- Viton seals

Accreditations available

- PED Suitable for Group 1 & 2 liquids (Ensure materials are compatible)
- ATEX Ex II 2G TX X
- CE Complies with all relevant EU directives

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High Temperature Valves - Models 4075D/4475B

Contents

High Temperature Valves - Models 4075D/4475B

Overview

The 4075/4475 high temperature valve is used to sense gas or liquid high temperature conditions. The field adjustable temperature setting from 54°C to 260°C (130°F to 500°F) provides wide setpoint flexibility.

The standard thermowell provides extended life of the sensor and simplifies calibration and maintenance.

Operation

The 4075/4475 is widely used for sensing high pressure natural gas compressor discharge temperature. When a valve is positioned at each compressor cylinder discharge manifold, an increase in temperature past the valves set point will cause the valve to vent off a control signal.

Removal is quick and easy with the stainless steel thermowell which is supplied as part of the standard valve assembly. The valve assembly is held into the well by straight thread connections and a locking nut. Unscrewing the valve body/locknut and disconnecting the tubing fittings is all that is required to remove the valve from the well.

The bi-metallic temperature sensing discs arranged in a stack deflect uniformly as the temperature increases providing a long life, low maintenance actuator for the valve spool.

When the temperature of the fluid flowing past the well is below the tripping point, the temperature sensing element assembly is contracted and the loading spring keeps the valve spool in closed position. If the fluid temperature increases, the bi-metallic element assembly expands, moving the valve spool downward (opening valve) against the springs and opening the IN to the VENT port.

Adjustment

Refer to cut-away view on page 8. This model is checked at the factory for proper operation in a still air calibrating oven at approximately 150°C (300°F). To set the unit on the job to suit operating conditions, it should be piped into the safety control systems and be operational.

The master safety control shut off valve should be overridden during adjustments so the machine will continue running.

1) First remove cap ⑭ by pulling upward. It is held in position by a groove in the cap.

2) Gradually lower the setting by holding the flats of rod ⑤ firmly with a small adjustable wrench, and turning locknut ⑩ clockwise until the safety control indicator registers a trip.

3) Turn locknut ⑩ a turn or so counterclockwise, depending on the temperature rise desired for shutdown above the normal operating temperature.

4) One complete turn of the locknut ⑩ adjusts the temperature 25 to 35°F. Nut ⑩ should be turned sufficiently to effect a bubble-tight seal at the VENT port under normal operating conditions.

5) After adjustment, check to see that the unit operates by manually pushing down on the top of rod ⑤ (observing the shutdown indicator for that function).

6) If the recommended setting procedure is not possible, setting can be done using a pressure gauge in the VENT port, and turning adjusting nut ⑩ until the valve cracks open, giving a gauge reading.

High Temperature Valves - Models 4075D/4475B

How to Order

Use the table below to select the unique specification of your Model 4075D/4475B High Temperature Valve.

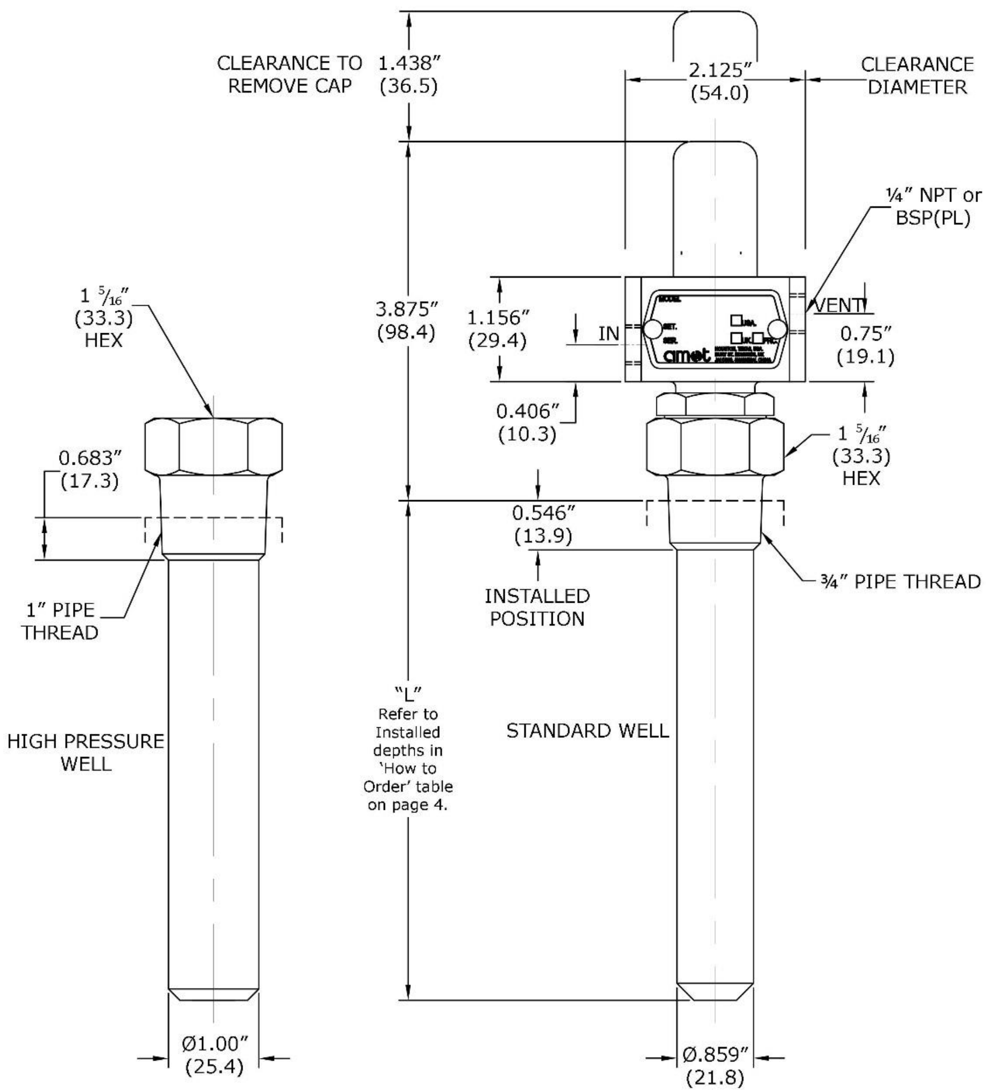
Example	4075D	1	01	-AA	Code description	Comments
					Model (A)	
Model (A)	4075D				Anodised aluminum	
	4475B				316 Stainless steel	
					Body thread (B)	
Body thread (B)		1			NPT	
		3			BSP (PL)	4075D ONLY

	Code (C)		**Thermowell (C)** Thread	Material S.S. class	Installed depth (L) inch	Installed depth (L) mm	Max. pressure psi	Max. pressure bar	Comments
Thermowell (C)	01		¾″ NPT	416	3 ¾″	95.3	5,500	379	4075D ONLY
	02		¾″ NPT	416	5 ¾″	146.1	5,500	379	
	03		1″ NPT	416	3 ¾″	95.3	10,000	689	
	04		1″ NPT	416	5 ¾″	146.1	10,000	689	
	05		¾″ NPT	326S36	3 ¾″	95.3	3,750	258	
	06		¾″ NPT	326S36	5 ¾″	146.1	3,750	258	
	07		1″ NPT	326S36	3 ¾″	95.3	6,000	413	
	08		1″ NPT	326S36	5 ¾″	146.1	6,000	413	
	11		¾″ BSP (PL)	326S36	3 7/16″	87.3	3,750	258	
	12		¾″ BSP (PL)	326S36	5 7/16″	138.1	3,750	258	
	13		1″ BSP (Tr)	326S36	3 ¾″	95.3	6,000	413	
	14		1″ BSP (Tr)	326S36	5 ¾″	146.1	6,000	413	
	31		¾″ NPT	316 S.S.	3 ¾″	95.3	3,750	258	4475B ONLY
	32		¾″ NPT	316 S.S.	5 ¾″	146.1	3,750	258	
	33		1″ NPT	316 S.S.	3 ¾″	95.3	6,000	413	
	34		1″ NPT	316 S.S.	5 ¾″	146.1	6,000	413	
	35		¾″ BSP (PL)	316 S.S.	3 ¾″	95.3	3,750	258	
	36		¾″ BSP (PL)	316 S.S.	3 7/16″	87.3	3,750	258	
	37		¾″ BSP (Tr)	316 S.S.	3 ¾″	95.3	3,750	258	
	38		¾″ BSP (Tr)	316 S.S.	5 ¾″	146.1	3,750	258	
	39		1″ BSP (Tr)	316 S.S.	3 ¾″	95.3	6,000	413	
	40		1″ BSP (Tr)	316 S.S.	5 ¾″	146.1	6,000	413	
	41		½″ NPT	416	3 ¾″	95.3	10,000	689	4075D ONLY
	42		½″ NPT	416	5 3/8″	136.5	10,000	689	
	43		½″ NPT	416	6″	152.4	10,000	689	

	Code (D)	Code description	Comments
		Special requirements (D)	
Special requirements (D)	-AA	Standard	
	-***	Made-to-order	

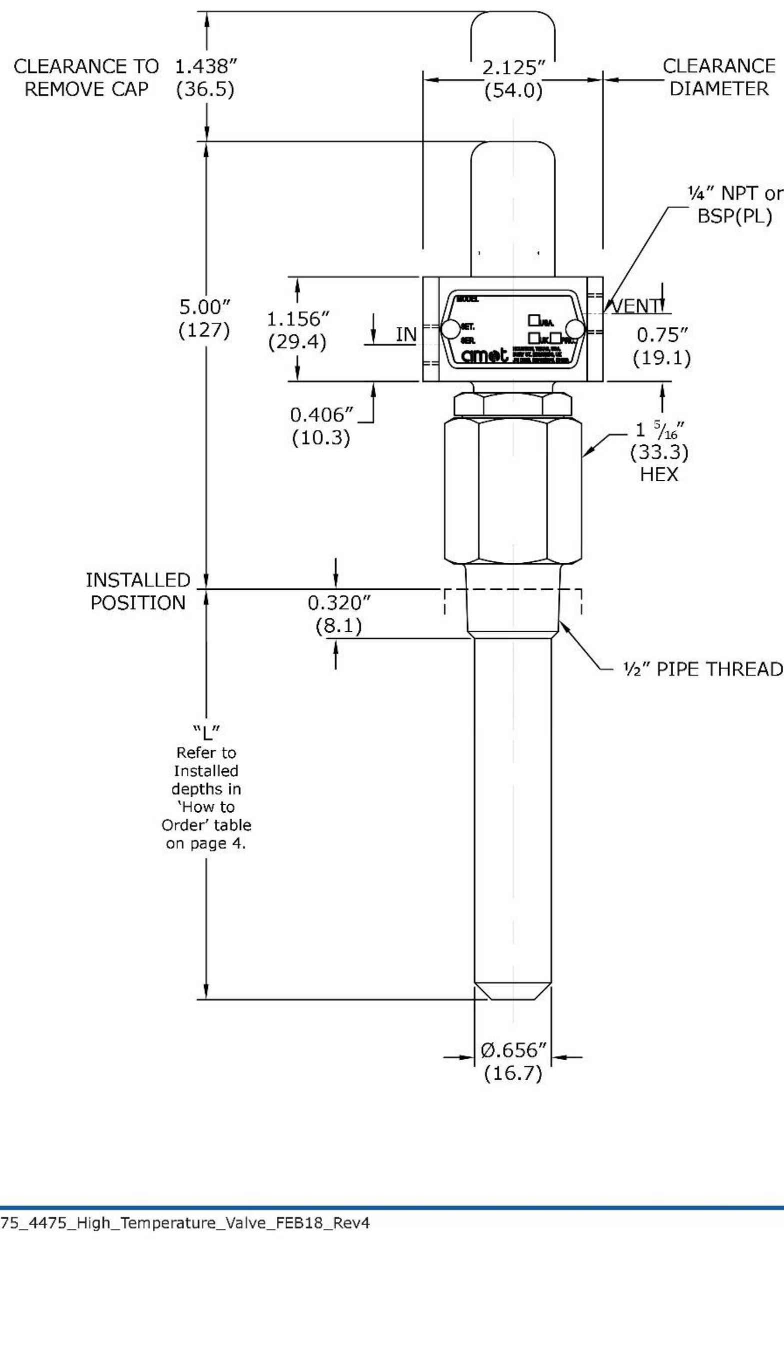
Dimensions

¾″ & 1″ NPT, BSP (PL) and BSP (Tr) thermowell thread
Dimensions - inches (mm)



Dimensions Continued

½" NPT thermowell thread
Dimensions - inches (mm)



High Temperature Valves - Models 4075D/4475B

Specification

		Metric units	English units
Valve body			
4075D	Anodised aluminum		
4475B	316 Stainless steel		
Valve well	Stainless steel		
Standard seals	Viton		
Sensor type	Bi-metallic disc		
Installation threads			
4075D	¾" BSP (PL), ¾" NPT, 1" NPT		
4475B	¾" BSP (PL), ¾" BSP (Tr), ¾" NPT, 1" NPT		
Port threads	¼" NPT		
Typical medium sensed	Gases		
Adjustable temperature trip range		54°C - 260°C	130°F - 500°F
Maximum allowable sensed temperature		260°C	500°F
Maximum pressure at IN port		8.62 bar	125 psi
Net weight (depended on well type selected)			
4075D		0.5 - 0.6 kg	1.1 - 1.3 lbs
4475B		0.7 - 0.8 kg	1.5 - 1.8 lbs

Maintenance and Service Parts

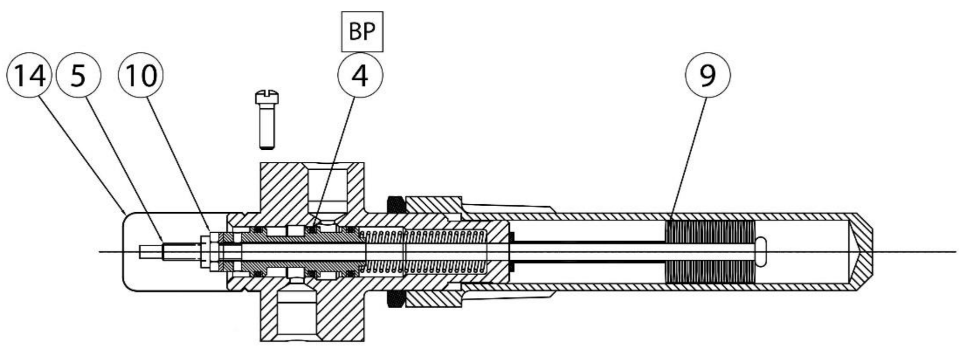
Over time, exposure to foreign chemicals and particulate matter as well as prolonged operation at extreme conditions may reduce the effectiveness of the valve. At such time, AMOT High Temperature Valves can be restored to original performance by replacing the service parts. Service parts for AMOT High Temperature Valves include discs, seals and seal components required for normal maintenance. Please order service parts using the part numbers, quantities and descriptions given in the service parts table below.

AMOT recommends a service interval of 12 months to ensure optimum valve performance.

AMOT designs and tests all its products to ensure that high quality standards are met. For good product life, carefully follow AMOT's installation and maintenance instructions; failure to do so could result in damage to the equipment being protected or controlled.

Service parts

Ref no.	Part no.	Qty.	AMOT part description	Valve part number restrictions	Comments
4	395L009	3	Oring, Viton	NONE	
9	9385	34	Disc	Thermowell (C) ≠ 41,42,43	
	9889	48	Bi-metallic disc	Thermowell (C) = 41,42,43	
10	534	1	Locknut, 10-32 LT HX flex cad	NONE	USA/Canada ONLY
	40884	1	Locknut, 10-32 UNF, black	NONE	Europe/Asia-PAC ONLY
14	9513L001	1	Cap - plated	Model (A) = 4075D	
BP	21721L001	1	Krytox GPL296 grease	NONE	
-	ISB-4075-4475-001	1	4075D/4475B Installation and Service Bulletin	NONE	



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Pressure Sensing Valve

Model 1672

Overview

AMOT Model 1672 Pressure Sensing Valves are 2-Way normally open sensors (closed under satisfied operation conditions) which are opened by the sensed pressure decreasing or increasing past the trip point. Dual purpose construction (trip on rising or falling pressure) provides a wide range of applications and permits easy field adjustment or changeover from trip on falling pressure to trip on rising pressure. The valve is snap-acting and suitable for hydraulic or gas control systems which up to 5.5 bar (80 psi) maximum control pressure.

Model 1672
Pressure Sensing Valve

Typical applications

- Engines
- Lubricating oil
- Cooling water
- Combustion air
- Control air
- Fuel oil
- Fuel gas

Key features and benefits

- Easy field adjustment
- Compatible in hydraulic or gas systems
- Factory set
- Gulfproofed finish and Viton seals
- Pneumatic lockout available
- Diaphragm sensor for pressure ranges from 0.3 - 21.7 bar (5 - 315 psi)
- Piston sensor for pressure ranges from 1 - 248 bar (15 - 3600 psi)
- Works in conjunction with other AMOT devices

Operation

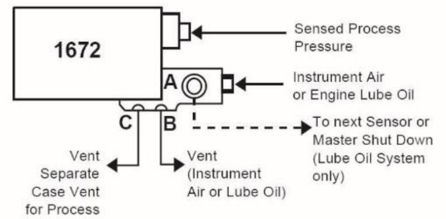


Figure 1

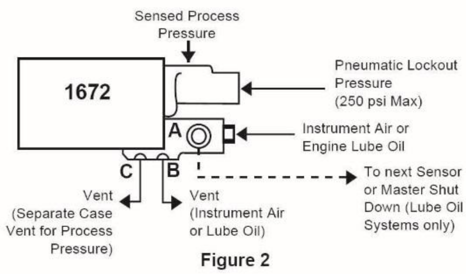


Figure 2

The operation of the 1672 Pressure Sensing Valve is simple and straightforward. Pressure ranges 1, 2 and 3 use a diaphragm sensor, and pressure ranges 4, 5, 6 and 7 use a piston sensor. The sensed pressure moves the diaphragm or piston operator against the larger adjusting spring. The motion is transmitted to the valve through a lever and fulcrum pin which operates the valve pushrod. Location of the pin in one of two holes in the case determines the rising or falling pressure trip function. See Parts List and cutaway view on page 6 and Figure 1 on left.

Pneumatic lock out is an optional feature which can eliminate the need for a separate blocking valve. For a tripping pressure of 1.1 bar (16 psi) falling, a 6.9 bar (100 psi) lockout pressure is required. For a tripping pressure of 2.1 bar (30 psi) falling, a 13.8 bar (200 psi) lockout pressure is required. The maximum lockout pressure is 17.2 bar (250 psi). This feature is only available on models in pressure range 1. See Figure 2 on left.

Adjustment (refer to cutaway view on page 6)

The trip-point setting is changed by turning adjustment nut (4) clockwise to raise the trip pressure on either a rising or falling pressure setting.

The small screw (25) which operates the valve pushrod is for factory adjustment and is not to be used to change the trippoint setting. It may, however, require minor adjustment when the trip action is changed from rising to falling if the valve leaks slightly with full pressure at the sensing port.

Installation factors

For easy mounting two 3/8" – 16 NC tapped holes run through the back of the valve's case. Bolts can be threaded into the case from the back or 1/4" bolts can be installed from the valve's inside and threaded into a mounting plate behind the valve.

Normally, the unit is installed with the vent connection (C) on the bottom however, it will operate in any position. Care should be taken to prevent dirt from entering Ports B & C when they are not pointed downward. The valve should not be supported by piping unless it is secured against vibration.

Pressure Sensing Valve - Model 1672

Specification

Housing	Cast aluminum		
Coating	Gulfproofed		
Internal parts	Aluminum and plated steel		
Control valve	Aluminum and stainless steel		
Standard valve seat & O-ring seal	Viton		
Standard diaphragm (ranges 1 - 3)	Buna N (Nitrile)		
Piston & Cylinder (ranges 4 - 7)	Stainless steel		
Piston seal (ranges 4 -7)	Teflon		
Flow coefficient	Cv = 0.3	Kv = 0.26	
Maximum valve operating pressure	5.5 bar	(80 psi)	
Net weight for:	Ranges 1 -3	2.0 kg	(4.5 lbs)
	Range 1 with lockout	2.5 kg	(5.5 lbs)
	Ranges 4 - 7	2.3 kg	(5.0 lbs)

Connections

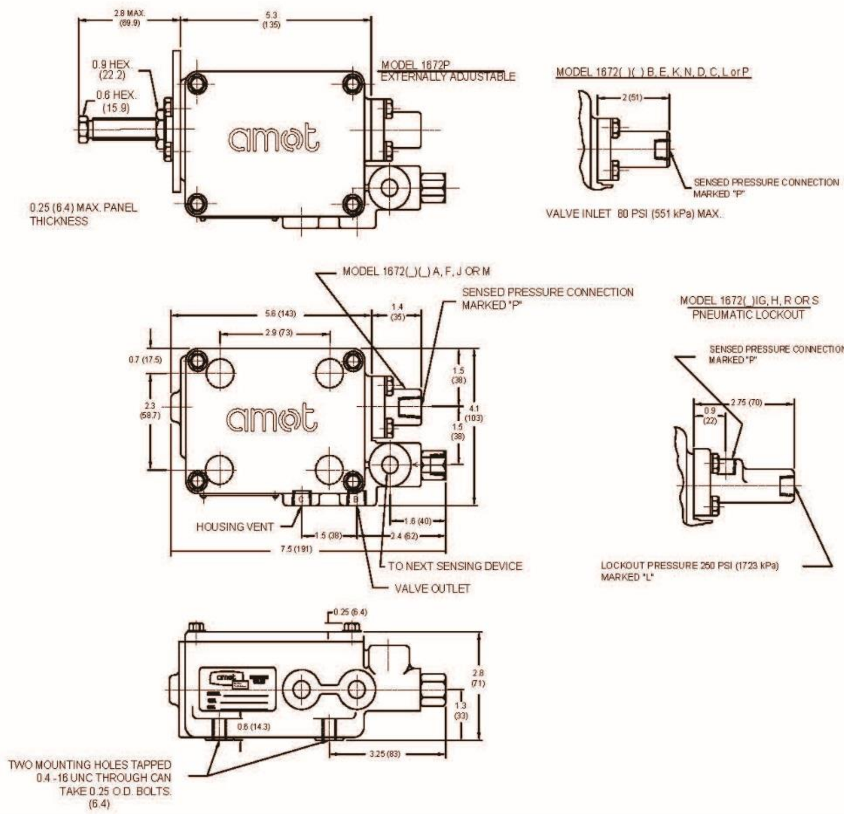
All valve connections are made with ¼" pipe thread fittings. Apply a quality thread sealant such as Locktite™ Pipe Sealant to pipe thread connections. This sealant must NOT enter the valve passages. Teflon thread sealing tape may be used but must be applied such that shreds of the tape do not enter the valve. The minimum tubing size recommendation for air or gas is ¼" OD, and the minimum for short lengths of lube oil (especially in cold weather) operation is 5/16" OD. Be sure that all scale, dirt, tubing chips etc are removed from fittings and tubing before they are connected to the valve.

Important: The 1672 Pressure sensing Valve has an auxiliary inlet port (A) cast into the housing. The connection must be used on lube oil pressured systems. Do not connect the inlet port to the end of a branch run or tubing off a main header, as the falling pressure signal will not be properly transmitted to the Master Safety Control. When using the valve on a gas pressured system, the valve outlet (B) should be connected to an outside vent line of large capacity, in such an application, the valve outlet (B) should be run to a vent line separate from the case vent (C) to prevent mixing potentially volatile fluids.

When sensing diesel fuel or other fluids that transmit medium to high frequency pulsations to the 1672 diaphragm, an AMOT 2185L001 or equal orifice should be ordered and installed at the diaphragm bonnet.

When checking an oil pressured system, be sure all trapped air is bled from the connection tubing. To do this, start at the first connection after the restriction orifice, and bleed each one until all air is purged. The most critical point is at the master safety control.

Dimensions



Differential

	Differential bar (psi)	Proof bar (psi)
Range 1	0.2-0.3 (3-5)	24 (350)
Range 2	0.3-0.7 (5-10)	24 (350)
Range 3	0.7-1.0 (10-15)	24 (350)
Range 4	0.7-1.8 (10-27)	69 (1000)
Range 5	0.6-2.7 (8-40)	69 (1000)
Range 6	2.1-4.1 (30-60)	276 (4000)
Range 7	2.1-9.7 (30-140)	276 (4000)

Differential is the change in sensed pressure above or below the trip point that is required to open the valve and cause an AMOT Pneumatic Indicating Relay to change from red to green with a 3.4 bar (50 psi) air pressure supply. The lower differential pressures shown are at the low end of the ranges and the higher pressures are for the higher end of the ranges.

Pressure Sensing Valve - Model 1672

How to order

Use the table below to select the unique specification of your 1672 Pressure Sensing Valve

1672E **1** **F** **1** **- (AA)**

Basic model number

(-AA) = Standard
(MTO) = Special requirements
Made to order

Sensed Pressure Ranges				Table A	Table B		Table C	
				Spring Code	Thread, Finish and Seal Code		Process Sensing Seal Code	
	bar	(psi)	trip		Gulfproof Finish, Viton Seals NPT	Gulfproof Finish, Viton Seals, (BSP) (PL)*	Buna N	Viton
Range 1	0.56 - 2.27 0.35 - 2.06	(8 - 33) (5 - 30)	rising falling	1	F	M	1	4
Range 1 with pneumatic lockout	0.56 - 2.27 0.35 - 2.06	(8 - 33) (5 - 30)	rising falling	1	H	S	7	8
Range 2	1.73 - 11.03 1.38 - 10.34	(25 - 160) (20 - 150)	rising falling	2	F	M	1	4
Range 3	4.14 - 21.71 3.45 - 20.68	(60 - 315) (50 - 300)	rising falling	3	F	M	1	4
Range 4	2.42 - 17.23 1.04 - 15.85	(35 - 250) (15 - 230)	rising falling	2	E			3
Range 5	6.21 - 44.18 3.45 - 38.61	(90 - 650) (50 - 560)	rising falling	3	E			3
Range 6	14.48 - 96.52 12.07 - 86.18	(210 - 1400) (175 - 1250)	rising falling	2	C			3
Range 7	24.14 - 248.21 17.24 - 227.52	(350 - 3600) (250 - 3300)	rising falling	3	C			3

* Available in UK only

When ordering please specify the following:

1. Basic model number
2. Tripping pressure
3. Tripping action:
   a. to trip on rising pressure
   b. to trip on falling pressure
4. Pressure range from model code Table A. If this number is not specified, a unit in which the specified pressure falls nearest the middle of the range will be furnished.
5. Thread Finish and Seal code selection Table B.
6. Process Sensing Seal Material code from Table C.
7. Finally, any of the following special features if required:
   a. Pneumatic lock out (available on Range 1 only)
   b. BSP Parallel Port Threads (instead of NPT)

The unit may be ordered using the full description as shown above or by constructing a model number using the table. The complete model number for a unit with Range 1, gulfproofed, NPT threads, Buna N seals and a 20 psi falling pressure setting is "1672E1F1 **set at 20 psi falling**".

Pressure settings are not part of this model code. The desired setting and whether it is trip on rising or falling pressure must be specified separately and will appear on the nameplate.

Note: Letters or numbers in the MTO space other than nothing, A1 or AA, indicate the unit is built to special requirements and some of the other code numbers may not be valid. Check with the AMOT for full specification of such models.

Pressure Sensing Valve - Model 1672

Maintenance

Properly applied and installed, Model 1672 series valves require minimal maintenance. An inspection of the unit at yearly intervals is adequate to detect and make provision for normal wear. The diaphragm seals and o-rings should be checked for wear, damage, and hazardous seals and o-rings with Dow Corning no. 33 Grease (AMOT part number 911L001) before installing them. Other internal parts should be inspected for excessive wear or damage or replaced as necessary. Use caution on assembly of seal (ranges 4 - 7) so the edge is not damaged. Cycle the valve about 12 times before making the final trip setting.

It is recommended that the valve should be checked monthly for proper function by simulating an unsafe condition if possible.

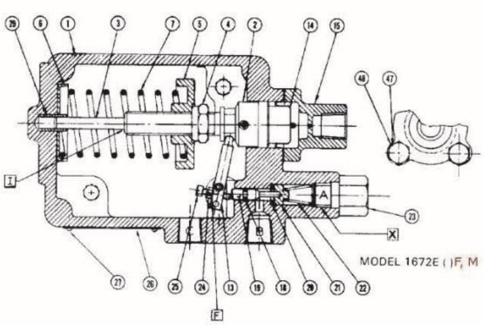
AMOT designs and tests all its products to ensure that high quality standards are met. For good product life, carefully follow the installation and maintenance instruction; failure to do so could result in damage to the equipment being protected or controlled.

Service Kits

Ref no.	Qty	Description
for model 1672E-F1, M1 Service Kit 9118X		
14	1	Diaphragm - Buna N (Nitrile)
18	1	O-ring - Buna N (Nitrile)
20	1	Valve seat - Buna N (Nitrile)
51	1	Gasket
for model 1672E-F4, M4 Service Kit 9118X001		
14	1	Diaphragm - Viton
18	1	O-ring - Viton
20	1	Valve seat - Viton
51	1	Gasket
for model 1672E-H7, S7 Service Kit 9118X002		
--	1	Service kit no.: 9118X
45	2	O-ring - Buna N
for model 1672E-H8, S8 Service Kit 9118X003		
--	1	Service kit 9118X001
45	2	O-ring - Viton
for model 1672E-E3 Service Kit 9112X001		
18	1	O-ring - Viton
20	1	Valve Seat - Viton
32	1	Seal
51	1	Gasket
for model 1672E-C3, Service Kit 9119X001		
18	1	O-ring - Viton
20	1	Valve seat - Viton
32	1	Seal
51	1	Gasket

When contacting AMOT regarding operation of a control always give the model number if ordering service parts, also include the description, part number and quantity desired. If any parts are ordered by reference number only, please also include the datasheet number.

Cutaway View



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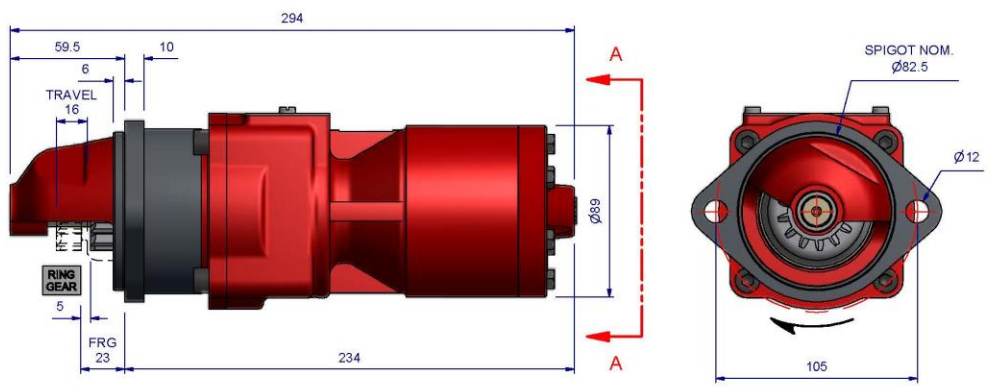
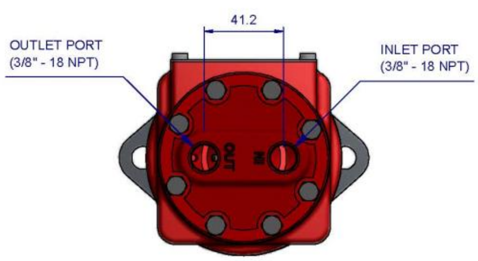
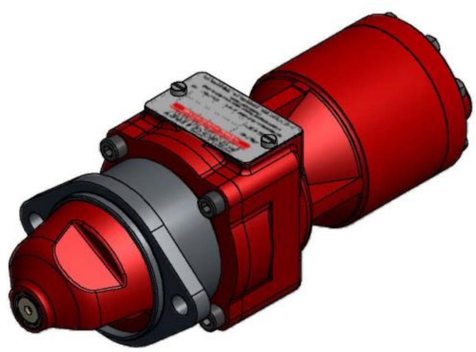
POWERSTART STARTING SYSTEMS	**Product Information Sheet**
www.pwrstart.com info@pwrstart.com Tel.: +27(0)11 203-9900	**Part no.: M10-DWZ46** STARTER MOTOR, 10T PINION, SAE 4 FLANGE, 23MM FRG
IN THE INTEREST OF CONTINUING DEVELOPMENT, SPECIFICATIONS MAY CHANGE WITHOUT PRIOR NOTICE	Date issued: 22/10/2013 Revision no.: 0



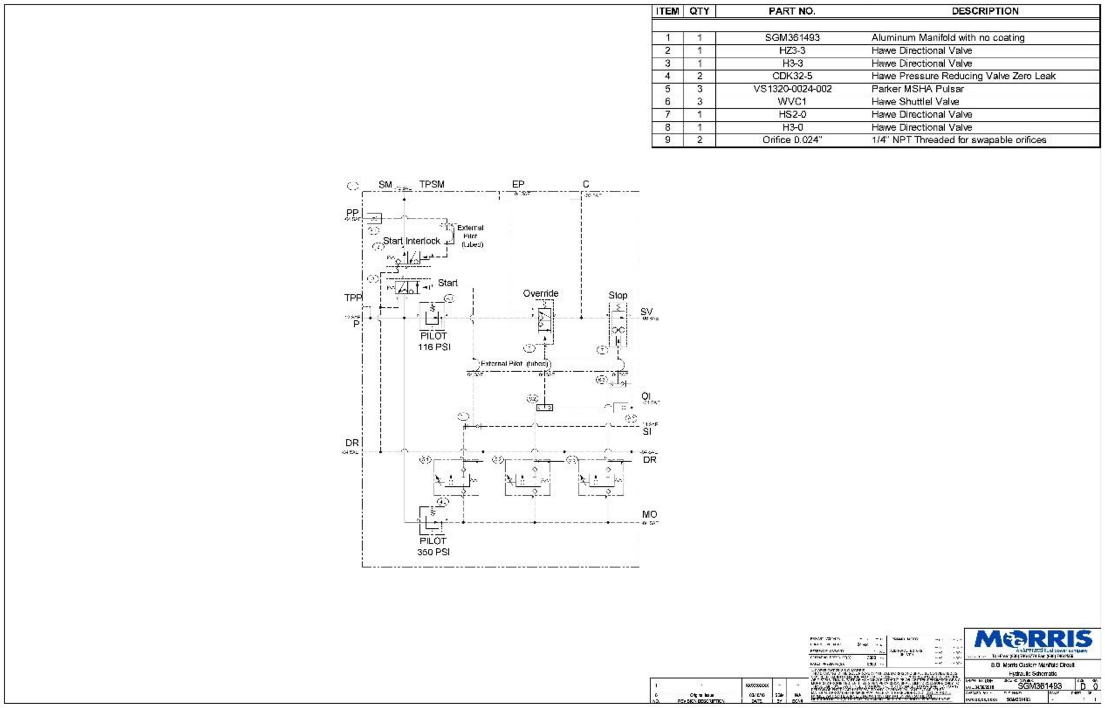


VIEW A-A

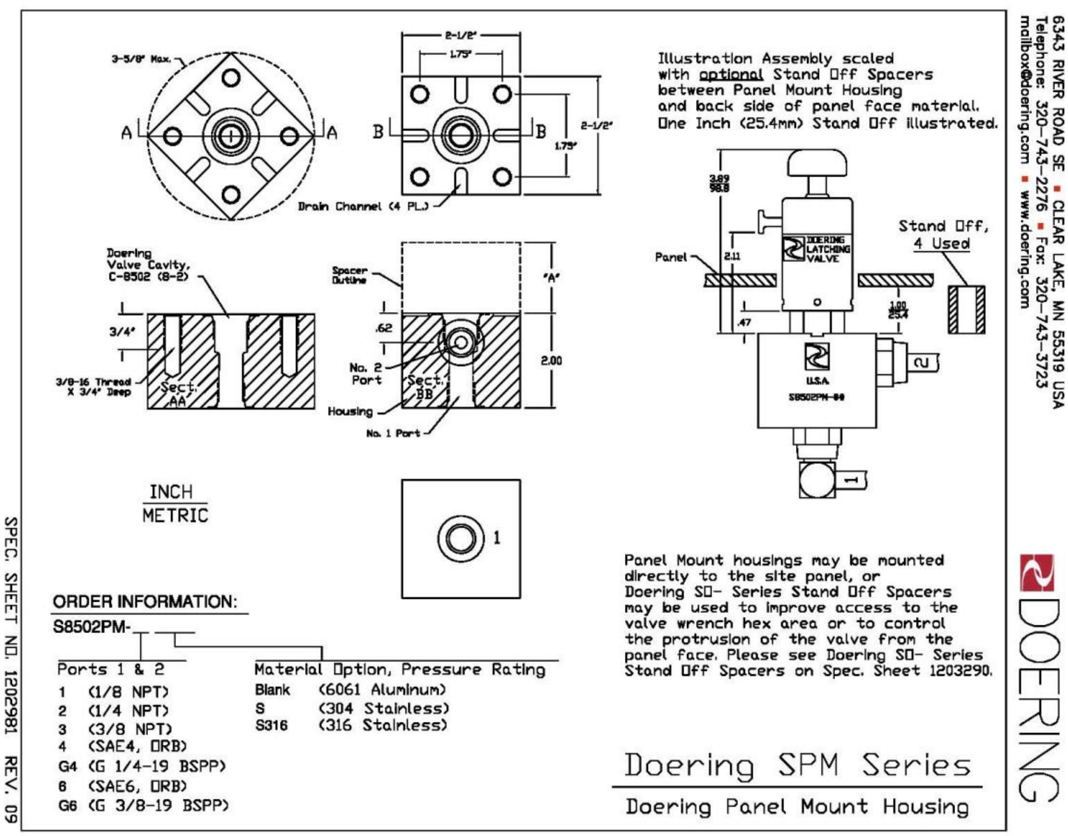


Performance Specifications	
Maximum inlet pressure	21 MPa
Maximum torque	30 Nm
Maximum power	12.6 kW
Maximum speed	4000 rpm
Displacement	10 cc/rev
Fluid Media	Mineral oil
Viscosity range	ISO 32 to 46
Operating temperature	-30°C to +100°C

Physical Specifications	
Construction	Cast iron
Pinion material	Alloy steel
Pinion details	13 Tooth, mod 2.5
Pinion outside diameter	40.8mm
Drive type	Inertia
Rotation (viewed from front)	CW
Flange type	SAE 4
Flange to ring gear distance	23 mm
Nett weight	8.5 kg



ITEM	QTY	PART NO.	DESCRIPTION
1	1	SGM361493	Aluminum Manifold with no coating
2	1	HZ3-3	Hawe Directional Valve
3	1	H3-3	Hawe Directional Valve
4	2	CDK32-5	Hawe Pressure Reducing Valve Zero Leak
5	3	VS1320-0024-002	Parker MSHA Pulsar
6	3	WVC1	Hawe Shuttle Valve
7	1	HS2-0	Hawe Directional Valve
8	1	H3-0	Hawe Directional Valve
9	2	Orifice 0.024"	1/4" NPT Threaded for swapable orifices



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ROHMAC INC

DP 25XP Diesel Power Package Permissibility Checklist

Document # 190905JCR01

MSHA Approved Diesel Power Package

MSHA Power Package Approval

24.8 HP Kubota model D1105 diesel engine

MSHA Engine Approval # 07-ENA140006 and 07-EPA20000x

This document lists components and functions that must be maintained in order for this diesel power package to be considered permissible. This checklist must be used in conjunction with an Electrical System Checklist and a Machine Checklist for a complete equipment permissibility evaluation.

Machine Serial or Property No. ______________________________

Date of Examination ______________________________

Indicated Hours on Machine ______________________________

Examination Conducted by ______________________________

Drawing # 190905JCR01 Rev A
5 September 2019

1. It has been determined that the area, in which tests are to be performed, is in FRESH AIR, in an area where permissible machines are not required.
2. This machine is equipped with a Kubota D 1105-E4 diesel engine.
3. The component and function checks in this document that are designated as "WEEKLY" must be performed during each weekly maintenance examination in accordance with 30 CFR, Section 75.1914

Air Intake System:

Components located upstream of the intake flame arrestor are not considered flameproof components and do not need to be checked for permissibility.

The Air Intake System of this Power Package includes the following flameproof components which are downstream of flame arrestor must be checked for permissibility:

1. intake manifold (metallic gasket needed)
2. flame arrestor (metallic gasket needed)

I. ____(Weekly) Components appear as shown in Figure 1.
II. ____(Weekly) The Air Cleaner housing, Air Filter, Rubber Elbow, and Clamps are in place and in good condition.

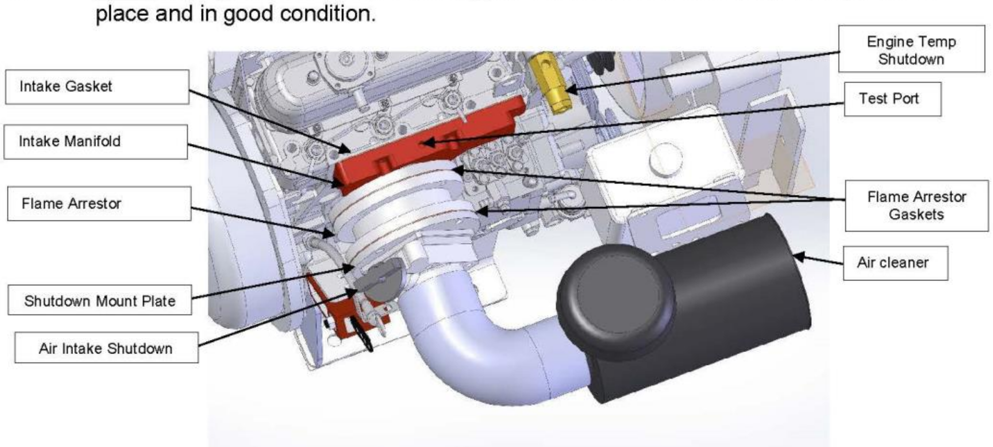

Figure 1 - Air Intake Assembly

III. ____(Weekly) The Air Intake Shutdown and Shutdown Mount Plate and gasket are in place, and the mounting bolts with lock-washers are in place and tight.

IV. ____(Weekly) The Flame Arrestor is in place and is secured to the Intake Manifold with bolts with lock-washers and bolts are tight.

V. ____(Weekly) A metallic gasket is installed between the Flame Arrestor and Intake Manifold. A 0.0015 inch feeler gauge cannot be inserted greater than 1/8".

VI. ____(Weekly) The Intake Manifold is in place and in good condition, bolts with lock washers are present and tight.

VII. ____(Weekly) A metallic gasket is installed between the Intake Manifold and cylinder head. A 0.0015 inch feeler gauge cannot be inserted greater than 1/8".

VIII. ____(Weekly) The Intake Test Port is plugged and secured with locking wire, or a flame proof port is installed and tight.

Exhaust System:

The Exhaust System permissibility checks of this Power Package includes the following flameproof components:

1. A dry-type exhaust conditioner with metallic gasket installed at its manifold inlet
2. An exhaust chamber lid with plane flange
3. An exhaust flame arrestor with metallic gasket installed at the exhaust exit

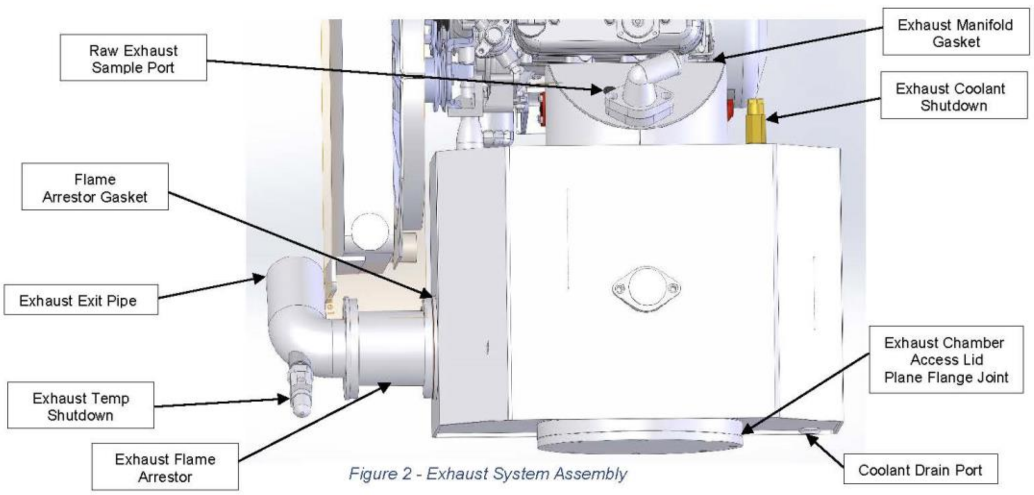

Figure 2 - Exhaust System Assembly

I. ____(Weekly) Components appear as shown in Figure 2.

II. ____(Weekly) The Exhaust Cooler is in good condition with no evidence of damage or coolant leaks

III. ____(Weekly) A metallic gasket is installed between the cylinder head and exhaust cooler with no evidence of exhaust leaks. A 0.0015" feeler gauge cannot be inserted greater than 1/8".

IV. ____(Weekly) The Exhaust Cooler is securely attached to the engine and machine and does not move freely.

V. ____(Weekly) A metallic gasket is installed between the exhaust cooler and flame arrestor.

VI. ____(Weekly) The flame arrestor is attached securely to the exhaust cooler with bolts and lock-washers that are tight. A 0.0015" feeler gauge cannot be inserted greater than 1/8".

VII. ____(Weekly) The exhaust chamber lid is securely fastened to the exhaust cooler with bolts and lock-washers that are tight. A 0.004" feeler gauge cannot be inserted greater than 1/8".

Function Checks

All function checks shall be performed in fresh air in an area where permissible Equipment is not required.

I. ____(Weekly) The high idle speed does not exceed 3000 rpm, record reading_________

II. ____(Weekly) At high idle, induce a load on the engine, the Intake Restriction Gage does not indicate over 22 inches of water, record reading_______________

III. ____(Weekly) At high idle, induce a load on the engine, the Exhaust Backpressure Gage does not indicate over 40 inches of water, record reading_______________

IV. ____(Weekly) The engine stops when the Stop control on the machine is activated, and, if applicable, when the stop on the radio remote control is activated.

V. ____(Weekly) With the engine running at high idle, actuating the intake shutdown stops the engine within 15 seconds.

VI. _____ The Engine coolant temperature sensor shuts down the engine if the coolant reaches 212°F, according to the following test procedure:

1. Remove the high coolant temperature shutdown valve.
2. Plug the opening for the high coolant temperature shutdown valve with a pipe plug while performing this test.
3. Heat a mixture a 50%-50% mixture of water & ethylene glycol.
4. Place high coolant temperature shutdown valve and thermometer.
5. Monitor temperature of mixture to note the engine shutdown temperature.
   a. With the engine running, the high coolant temperature shutdown valve must shut the engine down before exceeding 212°F.
6. Reinstall the high coolant temperature shutdown valve.

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Flame Arrestor Inspection Procedure (Intake and Exhaust Flame Arrestor)

1. Remove the flame arrestor assembly.

2. Place the flame arrestor assembly on a flat surface with a contrasting background under the flame arrestor, such as brattice cloth or clean white cloth.

3. Adequate lighting is required. Cap lamp lighting is not sufficient.

4. Visually inspect each side of the flame arrestor for openings or spaces obviously greater than the triangular openings of the core.

5. Visually inspect each side of the core for places where the windings of the flame arrestor core appear to be separated such that gaps can be seen. If such gaps exist, they must be checked as following:

    a.) The only measuring tool considered acceptable for performing this evaluation is a 0.038-inch diameter calibrated plug gauge for the exhaust flame arrestor and a 0.018-inch diameter calibrated plug gauge for the intake flame arrestor. The plug gauge is to be mounted in a gauge holder and must project at least 1.00 inch out of the end. The plug gauge should appear as shown in Figure 3.

    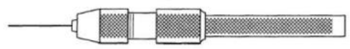

    Figure 3 - plug gauge

    b.) Grasp the gauge holder lightly between the index finger and the thumb. Place the wire tip at the point in question, making sure the plug gauge is vertical. Using only the weight of the gauge and holder, see if it will enter the apparent gap. Do not attempt to wiggle or push the gauge through the opening.

    c.) If the plug gauge enters the opening, the flame arrestor core must not be used on permissible equipment.

6. Visually inspect the triangles in the flame arrestor core (both sides) for triangles that appear to be larger than the rest. If such conditions exist, these openings must be checked as previously described in section 5 a, b and c.

7. Finally, if the flame arrestor core passes all the above evaluations, a final check should be performed on at least 5 randomly selected triangles on each side of the core using the procedures described in section 5 a, b and c. In performing this check, the tip of the plug gauge must be placed against a specific triangular opening. If this special care is not taken, the evaluation will be invalid.