

Chris Hamilton  
Senior Vice President  
West Virginia Coal  
Association

**WV Mine Safety & Technology Task Force  
Plan to Evaluate Proximity Detection Systems (PDS)**

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**A. Proposal Overview:** This proposal represents a carefully conceived plan to evaluate the use of proximity detection systems (PDSs) on place-change, non-bolter, continuous miners (CM) in select underground coal mines, assess their performance in terms of functionality with multiple personal wearable devices (PWDs), verify their reliability, and investigate their commercial availability from the various manufacturers of these systems. It is the goal of these systems to identify the entry of a person within known hazardous locations (zones) related to the machine, and upon such detection, deliver control inputs to the machine to stop its motion.

This plan defines a partnership among the West Virginia Mine Safety Technology Task Force of the WV Office of Miners Health, Safety and Training; the Mine Safety and Health Administration; the National Institute for Occupational Safety and Health; select mining companies; manufacturers of PDSs; select continuous miner manufacturers; the West Virginia Coal Association and the United Mine Workers of America.

Equipment operator behavior will also be examined to design a companion, industry-wide training program to safety train face personnel on "red zone" hazards.

During the test period, technology manufacturing capabilities and projected production schedules and commercial availability will also be identified and evaluated.

The information obtained during this period may be relied upon to guide future regulatory processes.

This plan will be conducted over a 6 month period after initial installation.

**B. Background:** Over the past several years there has been considerable discussion within the mining industry regarding the use of PDSs on face equipment to provide machine motion shutoff capabilities and warning indications for machine operators and others working in proximity to mining equipment. A careful review of mining accidents during this period suggests that PDSs would enhance mine. Past research of fatal equipment accidents by MSHA has shown that the first priority is for place change continuous miner operators and those miners working in proximity to continuous miners.

West Virginia and MSHA officials have been studying this technology for some time and several mining companies have experimented with PDDs on continuous miners with limited and varying degrees of operational experiences.

The WV Mine Safety Technology Task Force (WVMSTTF) and WV Board of Coal Mine Health & Safety have entertained technical discussions of the availability and functionality of proximity detection technologies with an eye towards a regulation mandating their use provided the performance objectives specified in Section D "Evaluation Objectives" are achieved within a predetermined range of acceptability.

**C. Plan:** The idea is to set up a pilot program through the WVMSTTF with 3 or 4 mining companies who would agree to install PDSs on one or more place-change, non-bolter, continuous miners with multiple PWDs for a period of time in order to properly field test and evaluate the PDSs:

- Patriot Coal Federal No. 2 Mine (Joy 12CM12 miner with VFD) ready in July/August 2009 – Nautilus Int'l
- CONSOL Energy Buchanan – Geo Steering Mining Services (September 2009)
- Alliance Coal Mine – Matrix Design Group System

Under this program, MSHA along with NIOSH, select equipment continuous miner manufacturers, and PDD manufacturers will play a support role providing resources and technical assistance.

**D. Evaluation Objectives:** Three (3) underlying objectives have been established to guide and ascertain the success of this study plan. They include: 1. Miner Operator Safety; 2. Reliability of PDSs; and 3. Capability of Manufacturing Resources.

#### **D. 1. Reliability of PDDs**

The reliability of PDSs is paramount to providing the needed miner detection envisioned by these technologies and must provide the claimed detection with accuracy and without causing interference with other mining systems present. Availability or robustness of the product will also be evaluated. Additional details may be found in Section F, Test Protocol.

#### **D. 2. Miner Operator Safety**

There is a concern that the implementation of this technology could cause the miner operator to place himself/herself in an unsafe location relative to other pieces of section equipment due to not being able to be placed in traditional mining locations by the PDSs. It is our objective to evaluate this through observation and interviews with the continuous miner operators at the sites being evaluated.

### **D. 3. Capability of Manufacturing Resources**

Recent past implementation of new technology has shown that the speed of implementation has, in most cases, been limited by manufacturing capabilities of the various vendors supplying the technology and in some cases their suppliers of component parts. These capabilities of the manufacturers of the PDSs being tested will be evaluated and best estimates of lead times will be stated.

In order to fully evaluate these areas, a discussion of desired parameters and functionality is required.

### **E. Study Parameters and Zoning**

The proximity detection system monitors for the presence of personnel in hazardous positions related to a mining machine. When this condition is detected, the system can inhibit machine motion. A PWD will be required to be worn by each person who can come in contact with the mining machine. The PWD provides the means for the system to identify a person. The PWD will be worn at all times and powered by its own battery or a cap lamp battery. Audible and visual feedbacks can be provided for defined actions. An audible device can be included in the PWD. A visual indicator mounted on the mining machine must be visible from the edge of the outermost zone or it could be included in the PWD. Belt-mounted PWD visual warnings may have a low probability of being detected since they are well outside typical visual fields utilized while operating a CM.

Two zoning types are described. One zoning type is for movement during cutting related processes and the second for moving the machine with the cutterhead off. All zone monitoring becomes active when machine control that can cause motion of the machine is enabled.

### **E. 1. Definitions**

**Mining Machine:** - A machine that cuts and loads coal in place-change type mining sequences. This does not apply to integral bolter miners or extended in-place mining sequences.

**Miner Operator** - A person who controls or operates the Mining Machine

**Miner** - Any person other than the Miner Operator.

**Mining Mode/Zone** - This is the time period from the start of the cutter motors until a designated time after the cutter motors are turned off.

**Non-Mining Mode/Zone** - All time outside the Mining Mode when machine motion is enabled.

**Personal Wearable Device (PWD)** - Device worn by all personnel to permit identification and location of personnel around the Mining Machine. It can include an audible emitter, lights and control features.

### **E. 2. Hazardous Locations**

The Proximity Detection System (PDS) identifies the presence of personnel in the proximity of known hazardous locations around the mining machine. This proximity would be perpendicular to surfaces of the machine noted in Figure 1. The PDS response for stopping the machine should be appropriate for the immediate mode of operation that is either the Mining Mode or Non-Mining Mode.

The action taken by the PDS would require verification for each installation. There are variations in machine dynamics, mine conditions, PDS response, machine control response and anticipated machine activity that determine the time and deceleration of the machine before all motion is stopped. The PDS system must prevent accidental contact between the machine and the miner.

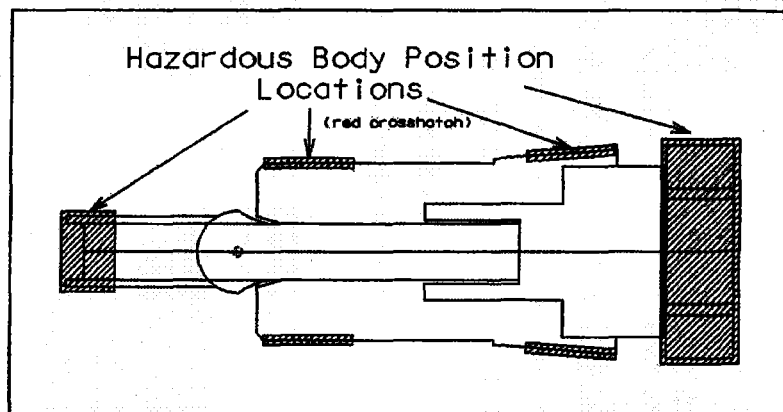


Figure 1. Hazardous Body Positions Related to Mining Machine

### E. 3. Zoning

Zoning types are depicted in Figure 2. The actual zone sizes, shapes, and relation to hazardous locations will depend on specific design variables. The Stop Zone (SZ) is required, and additional zones can enhance overall functionality.

Four zones are depicted in Figure 2: Identification Zone (IZ), Monitor Zone (MZ), Warn Zone- optional (WZ) and Stop Zone (SZ).

**Identification Zone** - When a Miner or Miner Operator enters the IZ, the PDS indicates a change in occupants of this zone. In order for the mining machine to operate, a PWD must be detected inside the IZ. The 40ft minimum indicated in Figure 2 allows the Miner Operator to operate the mining machine from a significant distance that is required in some parts of the job.

**Monitor Zone** - Inside the IZ is the Monitor Zone (MZ) where CM operators and helpers, if applicable, will typically be positioned during tramming. This zone is outside the Warning Zone, but still within the range of the proximity detection field. Anyone wearing a PWD in this zone will be continuously monitored by the PDS. When in the MZ, the PWD should remind miners that they are in the general vicinity of a CM to assure that their PWDs are sensing the field and to assure that they are being monitored.

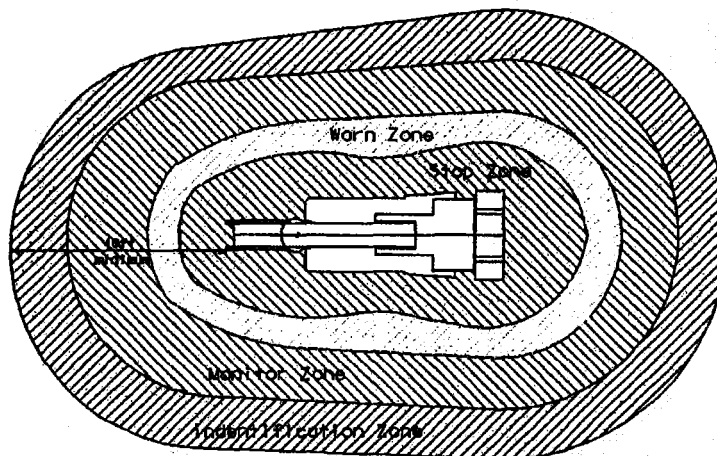


Figure 2. General Zones

**Warn Zone** - The Warn Zone (WZ) is optional. When a PWS enters the WZ, the PDS responds with a warning to indicate the person is near the Stop Zone. Audible and visual alarms could be presented. When the person moves outside of the WZ, the alarm stops. Machine motion is not inhibited by detection of a PWD inside the WZ. A downside of no warning zone is that this may lead to an excessive number of shutdowns since the operators will not have a visual or auditory cue that they are approaching the stop zone.

**Stop Zone** - This Stop zone is required. When a PWD enters the SZ, the Proximity Detection System will stop machine motion, and generate an audible and/or visible alarm. For most mining machines, the pump will continue to run as the inhibit defeats the specific controls, which can cause machine motion without completely shutting down the machine. The mining machine will resume normal operation when the identified PWD moves out of the SZ.

#### E. 4. Miner Operator Positioning

An Identification Zone (IZ), Monitor Zone (MZ) and Stop Zone (SZ) are depicted in Figure 3, but a Warning Zone or other zones could be applied. The actual zone sizes, shapes, and relation to hazardous locations will depend on specific design variables. In this case, the Stop Zone requires sizing to inhibit machine motion if the PWD is detected in a hazardous position related to the mining machine during the cutting and loading process. Also, the Stop Zone sizing must not force the Miner Operator into an

operating location that can expose the miner operator or other miners to additional hazards.

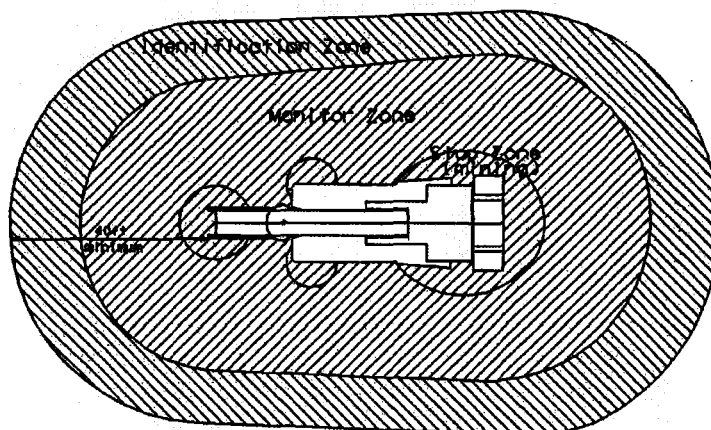
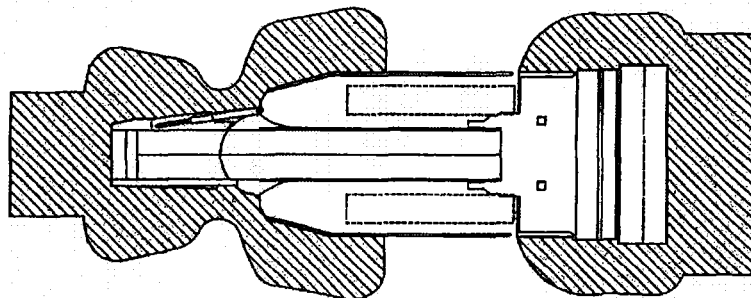


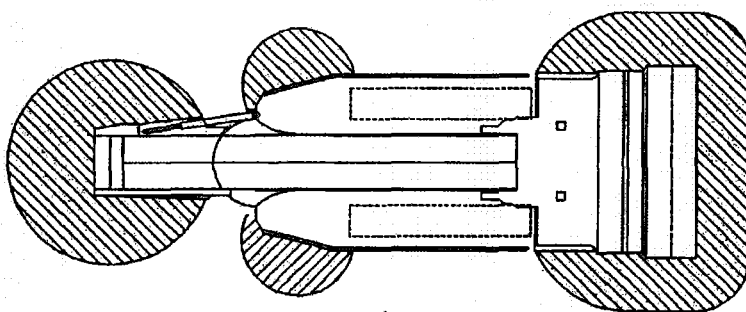
Figure 3. Miner Operator Zones – Mining Mode

Due to the concern over the PDS forcing the operator into a hazardous working area, these systems should be capable of providing operating notches or corridors which would allow the miner operator or helper to be close to the CM for necessary functions, while still providing protection in high hazard areas where fatalities and serious injuries are occurring. Figures 3.1, 3.2 and 3.3 show examples of alternate stop zones for mining mode only. Note that the Identification Zone and Monitor Zone are still present but not shown in the Figures. This in effect would create a quiet/Silent Zone to create the operating notch(es) or corridor that operators desire to perform necessary functions. One manufacturer referred to this as an anti-zone. This concept is illustrated in Figure 3.3 below. Activities designed to circumvent the test will not be tolerated.



MODIFIED RED ZONE

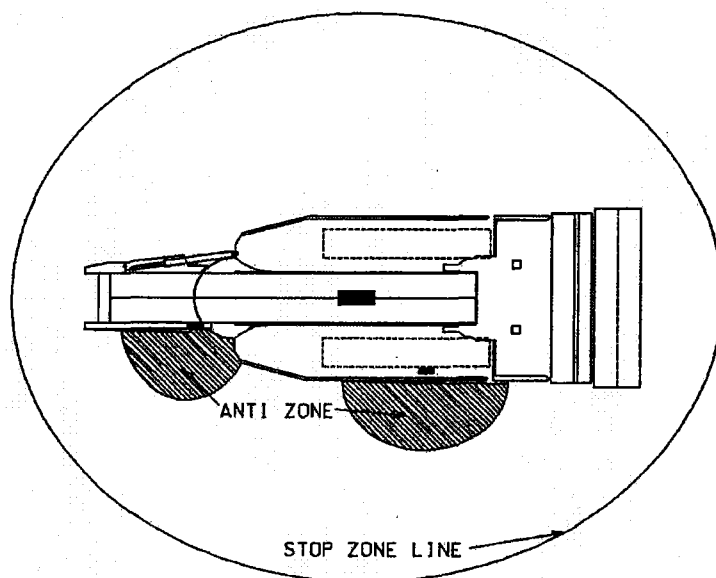
Figure 3.1 Modified Red Zone I



MODIFIED RED ZONE

Figure 3.2 Modified Red Zone II





**Figure 3.3 Anti-zone concept**

A combination of these concepts with some distances obtained from field trials on a re-built Joy 14CM15 DC traction drive continuous miner are shown in Figure 3.4 below.

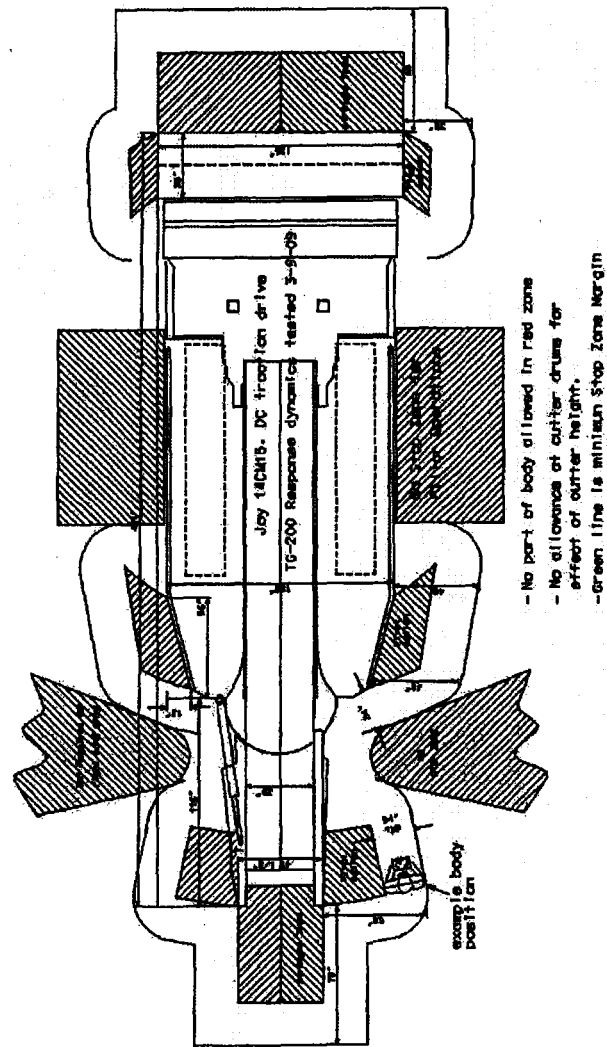


Figure 3.4 Example minimum Stop Zone margin.

#### **E. 5. Logging**

The system will record PWD ID# when a miner crosses into the Identification or Stop Zones. When override action is taken, the associated PWD ID# will be recorded. The data logging system will note the operating mode at the time of each PDS shutdown.

#### **E. 6. Overrides**

The system will provide for override capability for emergencies, system failures, maintenance, and unusual mining situations.

Emergency PDS Override - A safety feature that temporally bypasses the PDS system control during emergency situations and PDS failures.

PDS Maintenance Override - A PDS feature that permits the performance of mining machine maintenance and troubleshooting. Only one PWD permitted in the Stop Zone when the mining machine is enabled to run under this override. This would not be on a timer and require a secure pass code or key lock.

PDS Disable - Mine Management will have the ability to turn off and/or bypass the PDS in the case of special circumstances. This will be accomplished with a key lock or secure pass code.

#### **E. 7. Affects and Zones**

Zone geometries cannot be significantly affected by trailing cables, scoops, shuttle cars, or other equipment or systems used in the mining operation. The PDS cannot interfere with electronic or other systems used for communications, machine operation, atmospheric monitoring, etc.

#### **E. 8. Availability**

The PDD must have very high availability with a goal of 99.5% as related to mining machine operating time.

#### **F. TEST PROTOCOL**

The proposed test protocol involves a pre-commissioning surface test during which time personnel who will interact with the systems during the operational test will be interviewed concurrently to the engineering measurements, pre-operational surface (F.1) and underground (F.2) tests to confirm that the system's surface performance is reproducible underground, underground tests during a 3-month period of operation (F.3), and post-operation interviews of personnel who interacted with the systems, as well as analysis of logged data (F.4).

The protocol components can be broadly classified as an engineering evaluation and a human/machine interaction evaluation. The engineering evaluation will answer whether the PDSs generate reproducible zones over a wide range of conditions. The general shapes of the different zones will be mapped, repeatability will be assessed, and related physical measurements will be carried out. The human/machine interaction evaluation seeks to understand the factors that impact miners' acceptance of the systems, perceived or experienced problems, and related issues. In the previous field trials of earlier versions of some of the systems, these factors turned out to be barriers to the successful implementation of the systems. Documenting and investigating these issues systematically will allow for more rigorous conclusions as well as provide significant input to the refinement of future technology.

The purpose of PDSs is to save miners' lives. In order to realize this purpose, two things must happen: First, the devices must function as intended. Second, the humans operating the mining machines these devices are mounted on are expected to behave safely. Machine behavior and human behavior are two sides of the same coin. Both sides together make up a system.

The point at which humans and machines come together is called the "human/machine interface." The interface can be something like a set of controls, or, in the present case, a PWD. The International Organization for Standardization (ISO) 9241 defines three components of a workable interface: 1) effectiveness – does the device do the right thing? 2) efficiency – can users carry out their tasks with a minimum of expended effort? And 3) satisfaction – do users express satisfaction with the device? Each of these three components contributes to user acceptance.

It is known that in the past miners have disabled or otherwise thwarted safety devices that they considered inefficient or ineffective. In other words, if they were not satisfied with the interface, they attempted to change it. While sometimes this dissatisfaction might have stemmed from the fact that the device really didn't do the right thing the right way, most often their behavior could be attributed to misconceptions that grew out of a lack of familiarity with the interface. A lack of familiarity usually grew out of the fact that there was no attempt to consult with the end users (miners) while the interface was being developed, or even to provide sufficient training once it was in place.

It is important to learn more about how miners might perceive the interface, and to make interventions (such as training) where warranted. This is likely to increase acceptance of PDDs by the end-users. Acceptance of the PDDs combined with the belief from the human side that they are effective from the technical side will provide the best chance of preventing injuries and saving lives.

#### **F. 1. Pre-Commissioning Surface Test:**

##### **F.1.1 Functionality**

1. Conduct functional tests and note any differences from product description.

2. Ensure all machine interfaces are operational (e.g., warning light, pump motor shutdown, tram inhibit, boom swing, cutter interlock, etc.).
3. Ensure that all overrides mentioned in E.6 function properly.
4. Measure timer function for the stop zone (mining mode).

#### **F.1.2 Non-Mining Mode with General Zoning and Mining Mode with Miner Operator Zoning**

**Overall objective:** To establish a performance baseline for the zones of the non-mining mode and mining mode given various potential interference sources and continuous miner movements.

**Overall approach:** A pragmatic, risk-based approach will be taken for measuring the zoning size, shape, and how the zoning is affected by potential sources of interference. It will be extremely time consuming and difficult to measure the entire shape and size for every zone and for all possible conditions encountered during the operation and maintenance of a mining machine. For instance, the non-mining mode has up to four different zones for the general zoning of figure 2. For each zone, we calculate that there are at least  $2^9$  or 512 known combinations of conditions (i.e. shuttle car location, conveyor swing location, trailing cable amperage and location, etc.) that could potentially affect PDD operation. Therefore, measurements will be taken only at the hazardous locations that pose the greatest risk to miners as depicted in Figure 4, and measurements will be taken for those conditions that are most likely to affect the zoning.

**Repeatability:** Repeatability is commonly defined as the variation in measurements taken under the same conditions by a single person or instrument on the same item. Repeatability does not measure how changing conditions or sources of interference can change the size and shape of the zoning. Measurements of repeatability will be performed at locations that pose the greatest risk to miners based on the MSHA fatality data. These are locations 2, 3, and 5 of figure 4 for accidents occurring in the non-mining mode.

**Reproducibility:** Reproducibility is commonly defined as the variation in measurements taken under the different conditions. Reproducibility measures how changing conditions or sources of interference can change the size and shape of the zoning, and is a major focus of the protocol. For a given hazardous location (i.e. location 2 of Fig.4.), measurements of reproducibility will be taken for the conditions that include the mining mode, non-mining mode, various positions of conveyor swing locations, various locations of the trailing cable, and various locations of the shuttle car.

**PWD heights:** Two heights (5<sup>th</sup> percentile female kneeling position [LOW], 95<sup>th</sup> percentile male standing position [HIGH]). Measurements of the zone sizes relative to the hazardous locations specified in Figure 4 will be taken at two heights above the floor (ground) surface. These measurement heights will be referenced to the manufacturer's recommended PWD location on the operator's body. From this information, researchers will calculate the expected height of the PWD for a 5<sup>th</sup> percentile female operator in

kneeling posture and a 95<sup>th</sup> percentile male operator in a standing position. These PWD height positions would thereby cover the vast majority of possible PWD heights for CM operators. These measurements will be referenced to the floor surface located directly below the applicable machine surface.

**Note:** It is important to verify the accuracies at the PWD LOW position given that mining machine operators are often in a kneeling position when the coal seam height is low (approximately 50% of fatalities are in low coal).

**Reference for body heights:** USDOT, FAA, 2003, Human Factors Design Standard (HFDS), Report # DOT/FAA/CT-03/05 HF-STD-001.

**Note:** It will be highly desirable to have a test mode capability permitting switching to the mining mode without activation of the cutting drum. This is necessary due to the hazards involved in taking some measurements in the vicinity of the moving drum. Additionally, some of the data points in the baseline data need to be taken with the motor off so that the effect of running the motor on the field can be evaluated. This is indicated as "cutter head motor (test mode-simulated on)" in the initial machine states.

**General Measurement Procedures:**

- The PDS will be set to operate in mining or non-mining mode as appropriate.
- The PWD will be affixed to a measurement apparatus composed of non-conductive material to accurately measure the distance from the PWD to the mining machine surface. NIOSH investigators propose to develop a non-metallic device that will allow measurements to be taken in perpendicular orientation to the applicable machine surface.
- The PWD will be attached to a fixture that will be capable of moving the PWD towards the CM. The PWD will initially be positioned distally on the device (as far as possible from the mining machine surface). The PWD will be slowly moved towards the CM surface of interest until the PWD registers: 1) a signal indicating that the warning zone was entered (if applicable), and 2) a signal indicating that the stop zone was entered. The distance of the PWD to the machine surface will be measured and recorded for each of these occurrences.
- A laser measuring device (or other suitable measuring device) will provide information regarding the distance from the PWD to the CM.
- When the system indicates that the PWD has entered a new zone (for example, the warning zone or the stop zone), the distance of the PWD from the test point location on the CM will be recorded and the next test will commence.

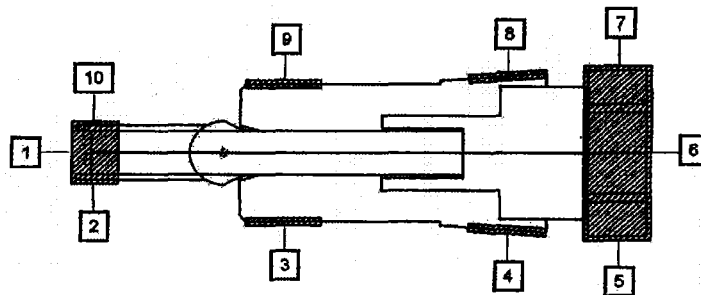


Figure 4. Proposed test locations for the mining and non-mining mode tests<sup>1</sup>

<sup>1</sup> Locations 5, 6 and 7 will not be tested when cutting head motor is on. Location 1 will not be tested when conveyor is on.

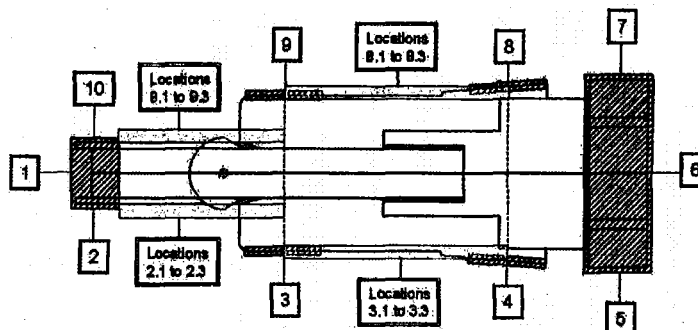


Figure 6. Proposed additional test locations for silent zones

#### 1. ID Zone Test

**Mode:** Non-mining

**Test Objective:** To verify that the ID zone extends at least 40 feet from the mining machine.

**Initial machine state:** hydraulic pump (off); electrical power (on); conveyor elevation (up); conveyor tail swing (center); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none).

**Initial location of PWDs:** ID zone, test location 1.

- 1.1. Place the PWD at the HIGH position on the test fixture 30 feet from and perpendicular to test location 1, and then record the distance and PDS zone (alarm) status.
- 1.2. Try to turn the continuous miner pump on by using the remote control pendant, and then record the continuous miner status and PDS zone (alarm) status.



- 1.3. Verify the operation of continuous miner by trying each of the following machine functions: tram forward; tram reverse; pivot left; pivot right; raise the conveyor; lower the conveyor; swing the conveyor right and left; turn the cutter head on and off; turn the conveyor on and off. Record the results for each machine function.

## 2. Zone Test

**Mode:** Non-mining

**Test Objective:** To establish a performance baseline for general zoning, and to conduct basic measurements of repeatability, variability, and potential interference sources.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor tail swing (center); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none).

**Initial location of PWDs:** Monitor zone, test location 1.

- 2.1. Place the PWD at the HIGH position on the test fixture within the monitor zone and perpendicular to test location.
- 2.2. Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDS zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDS zone indication status. Stop advancing the test fixture once the stop zone is reached, then record the distance, the state of the continuous miner, and the PDS zone indication status.
- 2.3. Move the test fixture in reverse from continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone status. Continue moving the test fixture in reverse until the monitor zone is reached.
- 2.4. Place the PWD at the LOW position on the test fixture within the monitor zone and perpendicular to test location. Repeat steps 2.2 and 2.3.
- 2.5. Repeat steps 2.1 to and 2.4 for the next test location until all test locations (1 to 10) are completed.
- 2.6. Place the PWD at the LOW position on the test fixture within the monitor zone and perpendicular to test location 3. Measurements of PWD to PWD variability and PWD orientation will be obtained:
  - PWD-PWD variability: test as many PWDs as are made available (but no more than 5).
  - PWD orientation: Test one selected PWD in standard orientation, and  $\pm 45$  and 90 degrees in pitch, roll, and yaw.
- 2.7. Repeat sections 2.1 to 2.5 for test locations 2, 3, and 5 twice.
- 2.8. Place the PWD at the HIGH position on the test fixture within the monitor zone and perpendicular to test location 3. Place the pendant for remote control between the PWD and the continuous mining machine. Repeat steps 2.2 and 2.3.

- 2.9 Place one PWD at the HIGH position on the test fixture and another PWD at the LOW position. Position the test fixture within the monitor zone and perpendicular to test location 3. Repeat steps 2.2 and 2.3.

**Mode:** Mining

**Test Objective:** To establish a baseline performance for the mining zone.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (center); conveyor chain (off); cutter head position (down); cutter head motor (test mode-simulated on); gathering head (up); stab jack (down); shuttle car (none); trailing cable position (normal).

**Initial location of PWDs:** Monitor zone, test location 1.

- 2.10 Repeat sections 2.1 to 2.5 for the continuous miner in the mining mode.

### 3. Influence of Conveyor Position Test

**Mode:** Non-mining

**Test Objective:** To determine if the general zoning is affected by the conveyor tail position (swing left and right) or conveyor elevation (up and down).

**Initial machine state:** hydraulic pump (off); electrical power (on); conveyor elevation (up); conveyor tail swing (center); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none).

**Initial location of PWD:** Monitor zone, test location 1.

- 3.1. Swing the conveyor fully left.
- 3.2. Place the PWD at the HIGH position on the test fixture within the monitor zone and perpendicular to CM.
- 3.3. Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDD zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDD zone indication status. Stop advancing the test fixture once the stop zone is reached, then record the distance, the state of the continuous miner, and the PDD zone indication.
- 3.4. Move the test fixture in reverse from continuous miner until the PDD stop zone indication changes to indicate the next zone. Record the distance and PDD zone status. Continue moving the test fixture in reverse until the monitor zone is reached.
- 3.5. Place the PWD at the LOW position on the test fixture within the monitor zone and perpendicular to test location. Repeat steps 3.3 and 3.4.

- 3.6. Repeat steps 3.2 to 3.5 for test location 2.
- 3.7. Repeat steps 3.2 to 3.5 for test location 3. If the distance measurement results are within  $\pm 5$  inches of the previous test for that location (section 2, conveyor tail is centered) then stop testing; otherwise, repeat steps 3.2 to 3.3 for the next test location. Stop advancing to the next test location once the results are within  $\pm 5$  inches for that location (section 2, conveyor tail is centered).
- 3.8. Swing the conveyor fully right, and place the PWD test fixture at test location 1.
- 3.9. Place the PWD at the HIGH position on the test fixture within the monitor zone and perpendicular to continuous miner.
- 3.10. Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDD zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDD zone indication status. Stop advancing the test fixture once the stop zone is reached, then record the distance, the state of the continuous miner, and the PDD zone indication.
- 3.11. Move the test fixture in reverse from continuous miner until the PDD stop zone indication changes to indicate the next zone. Record the distance and PDD zone status. Continue moving the test fixture in reverse until the monitor zone is reached.
- 3.12. Place the PWD at the LOW position on the test fixture within the monitor zone and perpendicular to test location. Repeat steps 3.10 and 3.11.
- 3.13. Repeat steps 3.9 to 3.12 for test location 10.
- 3.14. Repeat steps 3.9 to 3.12 for test location 9. If the distance measurement results are within  $\pm 5$  inches of the previous test for that location (section 2, conveyor tail is centered) then stop testing; otherwise, repeat steps 3.7 to 3.8 for the next test location. Stop advancing to the next test location once the results are within  $\pm 5$  inches of the previous test (test section 2, conveyor tail is centered) for that location.
- 3.15. Swing the conveyor to the center, and lower the conveyor elevation.
- 3.16. Repeat steps 3.9 to 3.12 for test locations 3, 2, 1, 10, and 9.

**Mode: Mining**

**Test Objective:** To determine if the mining zone is affected by the conveyor position.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (extreme left); conveyor chain (off); cutter head position (down); cutter head motor (test mode-simulated on); gathering head (up); stab jack (down); Shuttle car (none); trailing cable position (normal).

**Initial location of PWD:** Monitor zone, test location 1.

- 3.17. Repeat sections 3.1 to 3.15 for the continuous miner in the mining mode.

#### 4. Influence of Cutter Head Position Test

**Mode:** Non-mining

**Test Objective:** To determine if general zoning is affected by the cutter head position.

**Initial machine state:** hydraulic pump (off); electrical power (on); conveyor elevation (up); conveyor tail swing (center); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none).

**Initial location of PWDs:** Monitor zone, test location 6.

- 4.1. Raise the cutter head fully.
- 4.2. Place the PWD at the HIGH position on the test fixture within the monitor zone and perpendicular to continuous miner.
- 4.3. Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDS zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDS zone indication status. Stop advancing the test fixture once the stop zone is reached, then record the distance, the state of the continuous miner, and the PDS zone indication.
- 4.4. Move the test fixture in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone status. Continue moving the test fixture in reverse until the monitor zone is reached.
- 4.5. Place the PWD at the LOW position on the test fixture within the monitor zone and perpendicular to test location. Repeat steps 4.3 and 4.4.
- 4.6. Repeat steps 4.2 to 4.5 for test locations 8, 7, 4 and 5. If the distance measurement results for test locations 8 and 4 are within  $\pm 5$  inches of the previous tests for those locations (section 2, conveyor tail is centered and cutter head is not raised) then stop testing; otherwise, repeat steps 4.2 to 4.5 for the next test location. Stop advancing to the next test location once the results are within  $\pm 5$  inches of the previous test (test section 2, conveyor tail is centered) for that location.
- 4.7. Lower cutter head until it is in contact with the ground.

**Mode:** Mining

**Test Objective:** To determine if the mining zone is affected by the cutter head position.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (centered); conveyor chain (off); cutter head position (up); cutter head motor (test mode-simulated on); gathering head (up); stab jack (down); shuttle car (none); trailing cable position (normal).

**Initial location of PWDs:** Monitor zone, test location 6.

4.8. Repeat sections 4.1 to 4.7 for the continuous miner in the mining mode.

#### 5. Influence of Tramming Test

**Mode:** Non-mining

**Test Objective:** To determine if the accuracy of the stop zone is affected by tramming, and if the trailing cable location can affect the accuracy of stop zone while tramming.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (centered); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none); trailing cable position (normal).

**Initial location of PWDs:** warning zone

**Note:** Tram forward and reverse tests are conducted for the worst case (fast mode). The slow mode of tram operation is not tested. As a safety precaution, the PWD test fixture will be unattended; therefore, tram tests are limited to testing the stop zone.

##### 5.1. Forward tram fast test.

- 5.1.1. Place the PWD at the HIGH position on the test fixture and perpendicular to the continuous miner at test location 6. Locate the test fixture at least 15 feet from test location 6.
- 5.1.2. Clear all people from test location 6.
- 5.1.3. Tram the continuous miner at the fastest forward speed until the continuous miner stops, then record the distance, the state of the continuous miner, and the PDD zone indication status.
- 5.1.4. Place the PWD at the LOW position on the test fixture and perpendicular to the continuous miner.
- 5.1.5. Repeat steps 5.1.2 and 5.1.3.

##### 5.2. Forward tram reverse test.

- 5.2.1. Place the PWD at the HIGH position on the test fixture and perpendicular to the continuous miner test location 1. Locate the test fixture at least 15 feet from test location 1.
- 5.2.2. Clear all people from test location 1.
- 5.2.3. Tram continuous miner at the fastest reverse speed until the continuous miner stops, then record the distance, the state of the continuous miner, and the PDD zone indication status.
- 5.2.4. Place the PWD at the LOW position on the test fixture and perpendicular to the continuous miner.
- 5.2.5. Repeat steps 5.2.2 and 5.2.3.

##### 5.3. Trailing cable draped on cutter head.

- 5.3.1. Drape the trailing cable along the right side of continuous miner and onto the cutter head.
- 5.3.2. Place the PWD at the HIGH position on the test fixture and perpendicular to the continuous miner test location 6.
- 5.3.3. Clear all people from test location 1.
- 5.3.4. Tram continuous miner fast forward until the continuous miner stops, then record the distance, the state of the continuous miner, and the PDD zone indication status.
- 5.3.5. Place the PWD at the LOW position on the test fixture and perpendicular to the continuous miner.
- 5.3.6. Repeat steps 5.3.3 and 5.3.4.

#### 6. Influence of Continuous Miner Pivot Test

**Mode:** Non-mining

**Test Objective:** To determine if the accuracy of the stop zone is affected by continuous miner pivot actions, and if the trailing cable location can affect the accuracy of the stop zone during continuous miner pivot actions.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (centered); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none); trailing cable position (normal).

**Initial location of PWDs:** warning zone

**NOTE:** As a safety precaution, the PWD test fixture will be unattended and so pivot tests are limited to testing the stop zone.

##### 6.1. Pivot right

- 6.1.1. Place the PWD at the HIGH position on the test fixture and perpendicular to the continuous miner at test location 9.
- 6.1.2. Clear all people from test location 9.
- 6.1.3. Pivot the continuous miner right until it stops, then record the distance, the state of the continuous miner, and the PDD zone indication status.
- 6.1.4. Place the PWD at the LOW position on the test fixture and perpendicular to the continuous miner.
- 6.1.5. Repeat steps 6.1.2 and 6.1.3.
- 6.1.6. Repeat steps 6.1.1 to 6.1.5 for test location 4.

##### 6.2. Pivot left

- 6.2.1. Place the PWD at the HIGH position on the test fixture and perpendicular to the continuous miner test location 3.
- 6.2.2. Clear all people from test location 3.

- 6.2.3. Pivot the continuous miner left until it stops, then record the distance, the state of the continuous miner, and the PDD zone indication status.
- 6.2.4. Place the PWD at the LOW position on the test fixture and perpendicular to the continuous miner.
- 6.2.5. Repeat steps 6.2.2 and 6.2.3.
- 6.2.6. Repeat steps 6.2.1 to 6.2.5 for test location 8.
- 6.3. Pivot left with trailing cable draped on cutter head
  - 6.3.1. Drape the trailing cable along the right side of the continuous miner and onto the cutter head.
  - 6.3.2. Place the PWD at the HIGH position on the test fixture and perpendicular to the continuous miner test location 3.
  - 6.3.3. Clear all people from test location 3.
  - 6.3.4. Pivot the continuous miner left until it stops, then record the distance, the state of the continuous miner, and the PDD zone indication status.
  - 6.3.5. Place the PWD at the LOW position on the test fixture and perpendicular to the continuous miner.
  - 6.3.6. Repeat steps 6.3.3 and 6.3.4.
  - 6.3.7. Repeat steps 6.2.1 to 6.2.5 for test location 8.

## 7. Influence of Shuttle Car

**Mode:** Mining

**Test Objective:** To determine if the mining zone is affected by presence of a shuttle car.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (extreme left); conveyor chain (off); cutter head position (down); cutter head motor (test mode-simulated on); gathering head (up); stab jack (down); shuttle car (none); trailing cable position (normal).

**Initial location of PWD:** Monitor zone, test location 2.

- 7.1 Shuttle car will be brought into normal loading position, with CM tailpiece centered.
- 7.2 Place the PWD at the HIGH position on the test fixture within the ID zone and perpendicular to test location.
- 7.3 Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDS zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDS zone indication status. Stop advancing the test fixture once the SZ is reached, then record the distance, the state of the continuous miner, and the PDS zone indication status.
- 7.4 Move the test fixture in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone

status. If the warning zone is indicated, continue moving the test fixture in reverse until the monitor zone indication is given.

- 7.5 Place the PWD at the LOW position on the test fixture within the ID zone and perpendicular to the test location. Repeat steps 7.3 and 7.4.
- 7.6 Repeat steps 7.2 to and 7.5 for the next test location until all test locations (2 to 10) are completed.
- 7.7 Cutter head and conveyor motors will be turned on and steps 7.2 to 7.6 will be repeated, with the exception that no measurements will be taken at measurement points 5, 6, and 7.

## 8. Influence of Cable Position

**Mode:** Mining

**Test Objective:** To determine if the mining zone is affected by a snaking cable beside the CM.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (extreme left); conveyor chain (off); cutter head position (down); cutter head motor (test mode-simulated on); gathering head (up); stab jack (down); shuttle car (none); trailing cable position (normal).

**Initial location of PWD:** Monitor zone, test location 1.

- 8.1 Trailing cable will be snaked beside the CM.
- 8.2 Place the PWD at the HIGH position on the test fixture within the ID zone and perpendicular to test location.
- 8.3 Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDS zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDS zone indication status. Stop advancing the test fixture once the SZ is reached, then record the distance, the state of the continuous miner, and the PDS zone indication status.
- 8.4 Move the test fixture in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone status. If the warning zone is indicated, continue moving the test fixture in reverse until the monitor zone indication is given.
- 8.5 Place the PWD at the LOW position on the test fixture within the ID zone and perpendicular to the test location. Repeat steps 8.3 and 8.4.
- 8.6 Repeat steps 8.2 to and 8.5 for the next test location until all test locations (1 to 10) are completed.



## 9. Influence of Motors

### Mode: Mining

**Test Objective:** To determine if the mining zone is affected by CM cutter head, gathering arm, and conveyor motors.

**Initial machine state:** hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (centered); conveyor chain (on); cutter head position (up); cutter head motor (on); gathering head (up); stab jack (down); shuttle car (none); trailing cable position (normal).

**Initial location of PWD:** Monitor zone, test location 2.

- 9.1 Place the PWD at the HIGH position on the test fixture within the ID zone and perpendicular to test location.
- 9.2 Advance the test fixture to the continuous miner until a zone indication is given. Record the distance and PDS zone (alarm) status. Continue advancing the PWD until the next zone indication is given, then record the distance and PDS zone indication status. Stop advancing the test fixture once the SZ is reached, then record the distance, the state of the continuous miner, and the PDS zone indication status.
- 9.3 Move the test fixture in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone status. If the warning zone is indicated, continue moving the test fixture in reverse until the monitor zone indication is given.
- 9.4 Place the PWD at the LOW position on the test fixture within the ID zone and perpendicular to test location. Repeat steps 8.3 and 8.4.
- 9.5 Repeat steps 9.2 to 9.4 for the next test location until all test locations (2-4 and 8-10) are completed.
- 9.6 Swing the conveyor to extreme right and repeat steps 9.1 to 9.5.
- 9.7 Swing the conveyor to extreme left and repeat steps 9.1 to 9.5.

## 10. Influence of Multiple PWDs in Warning and Stop Zones

### Mode: Non-mining

**Test Objective:** To verify that a PWD functions as intended in the presence of other PWDs.

**Initial machine state:** hydraulic pump (off); electrical power (on); conveyor elevation (up); conveyor tail swing (center); conveyor chain (off); cutter head position (up); cutter head motor (off); gathering head (up); stab jack (up); shuttle car (none).

**Initial location of PWDs:** 1<sup>st</sup> PWD – just inside the warning zone at position 1, HIGH

2<sup>nd</sup> PWD – just inside the warning zone at position 3, HIGH

3<sup>rd</sup> PWD – just inside the warning zone at position 6, HIGH

4<sup>th</sup> PWD – just inside the warning zone at position 9, HIGH

- 10.1 Advance the test fixture holding the 1<sup>st</sup> PWD to the continuous miner until the stop zone indication is given. Record the distance and PDS zone (alarm) status of all.
- 10.2 Advance the test fixture holding the 2<sup>nd</sup> PWD to the continuous miner until the stop zone indication is given. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.3 Advance the test fixture holding the 3<sup>rd</sup> PWD to the continuous miner until the stop zone indication is given. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.4 Advance the test fixture holding the 4<sup>th</sup> PWD to the continuous miner until the stop zone indication is given. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.5 Move the test fixture holding the 1<sup>st</sup> PWD in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.6 Move the test fixture holding the 2<sup>nd</sup> PWD in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.7 Move the test fixture holding the 3<sup>rd</sup> PWD in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.8 Move the test fixture holding the 4<sup>th</sup> PWD in reverse from the continuous miner until the PDS stop zone indication changes to indicate the next zone. Record the distance and PDS zone (alarm) status of all PWDs.
- 10.9 Move each PWD to the LOW position.
- 10.10 Repeat steps 10.1 to 10.9.

**Mode: Mining**

**Initial machine state:** hydraulic pump (off); electrical power (on); conveyor elevation (up); conveyor tail swing (center); conveyor chain (on); cutter head position (up); cutter head motor (on); gathering head (up); stab jack (up); shuttle car (none).

**Initial location of PWDs:** 1<sup>st</sup> PWD – just inside the warning zone at position 1, HIGH  
 2<sup>nd</sup> PWD – just inside the warning zone at position 3, HIGH  
 3<sup>rd</sup> PWD – just inside the warning zone at position 6, HIGH  
 4<sup>th</sup> PWD – just inside the warning zone at position 9, HIGH

- 10.11 Repeat steps 10.1 to 10.10.

**NOTE:** In the mining mode, the 1<sup>st</sup> and 3<sup>rd</sup> PWDs are not tested due to safety issues of the drum and conveyor chain running.

## 11. Detection of Quiet Zones

Mode: Mining

Test Objective: To determine the size and location of quiet zones provided for the operator during mining.

Initial machine state: hydraulic pump (on); electrical power (on); conveyor elevation (up); conveyor swing (centered); conveyor chain (on); cutter head position (up); cutter head motor (on); gathering head (up); stab jack (down); shuttle car (none); trailing cable position (normal).

Initial location of PWD: Monitor zone, between location 2 and 3.

11.1 Place a tape measure on the ground extending from a point 2ft. from the body of the machine at test location 3 and extending parallel to the CM to a point perpendicular to test location 2.

11.2 Place the PWD at the HIGH position on the test fixture on the tape measure and perpendicular to test location 3. Record the PDD zone (alarm) status.

11.3 Move the test fixture along the tape measure towards the tail of the continuous miner until a zone indication is given. Record the distance to the machine, record the distance along the tape measure and PDD zone (alarm) status. If the warning zone is indicated, continue moving the test fixture along the tape measure until the monitor zone indication is given, then record the distance to the machine, the distance along the tape measure and PDD zone indication status. Continue moving the PWD along the tape measure until a zone indication is given. Record the distance to the machine, record the distance along the tape measure and PDD zone (alarm) status. If the warning zone is indicated, continue moving the test fixture along the tape measure until the stop zone indication is given, then record the distance to the machine, the distance along the tape measure and PDD zone indication status.

11.4 Move the test fixture along the tape towards the cutting head of the continuous miner until the PDD stop zone indication changes to indicate the next zone. Record the distance to the machine, record the distance along the tape measure and PDD zone (alarm) status. If the warning zone is indicated, continue moving the test fixture along the tape measure towards the cutting head until the monitor zone indication is given, then record the distance to the machine, the distance along the tape measure and PDD zone indication status. Continue moving the PWD along the tape measure until a zone indication is given. Record the distance to the machine, record the distance along the tape measure and PDD zone (alarm) status. If the warning zone is indicated, continue moving the test fixture along the tape measure until the stop zone indication is given, then record the distance to the machine, the distance along the tape measure and PDD zone indication status.

11.5 Place the PWD at the midway between the stop zones determined in steps 11.3 to 11.4 and perpendicular to test location, then record the distance to the machine, the distance along the tape measure and PDD zone indication status. Advance the test fixture perpendicular to the continuous miner until a zone indication is given. Record the distance to the machine, record the distance along the tape measure and PDD zone (alarm) status. If the warning zone is indicated, continue moving the test fixture perpendicular to the continuous miner until the stop zone indication is given, then record the distance to the machine, the distance along the tape measure and PDD zone indication status.

11.6 Move the test fixture in reverse from the continuous miner until the PDD stop zone indication changes to indicate the next zone. Record the distance and PDD zone status. If the warning zone is indicated, continue moving the test fixture in reverse until the monitor zone indication is given, then record the distance and PDD zone status.

11.7 Place the PWD at the LOW position on the test fixture on the tape and perpendicular to the initial test location. Record the PDD zone (alarm) status. Repeat steps 11.3 to 11.6.

11.8 If a quiet zone is provided on the left side of the machine, then place the PWD at the HIGH position on the test fixture on the tape measure and perpendicular to test location 9. Record the PDD zone (alarm) status. Repeat steps 11.3 to 11.7 for the opposite side of the machine.

Next location of PWD: Monitor zone, between location 3 and 4

11.11 Place a tape measure on the ground extending from a point 2ft. from the body of the machine at test location 3 and extending parallel to the CM to a point perpendicular to test location 4.

11.12 Place the PWD at the HIGH position on the test fixture on the tape measure and perpendicular to test location 4. Record the PDD zone (alarm) status.

11.13 Repeat steps 11.3 to 11.7.

11.4 9 If a quiet zone is provided on the left side of the machine, then place the PWD at the HIGH position on the test fixture on the tape measure and perpendicular to test location 8. Record the PDD zone (alarm) status. Repeat steps 11.3 to 11.7 for the opposite side of the machine.

### F.1.3 Training

It is imperative that comprehensive training be conducted for users of the proximity detection systems, management, and any personnel who will be affected by the tests. It

at the same stage for each mine and within as tight a window of time as possible (e.g., all mines within a 2-week period after the end of field testing). This type of interviewing was conducted previously in a study of the Personal Dust Monitor, and was run during production (the teams sent one miner at a time back to the interviewer during their shift). We will do the same style of interview to disrupt production only minimally.

The interviews will consist of two elements. First, the items from the pretest will be asked to provide a comparison point to determine if using the device has changed miners' perceptions of their own susceptibility, the severity of the potential for injury, and the barriers and benefits to using the PDS. This may clarify the most important issues for acceptance; if some issues have cleared up after usage, they will be addressed differently than others that have remained.

In addition, the researchers will ask questions about usability of the PDS, including elements such as whether they noticed the alarm going off on their PWD, whether they relied on the device to protect them, how inhibited they were in terms of where they could stand while cutting or tramming, were they able to take the first lift of a cut without the machine shutting down, among others. Miners will also be asked for any suggestions for improving the device based on their experience using the PDS.

- Quantitative data: Items identical to the pretest.
- Qualitative data: additional questions/items used in an individual setting (these may include the discussion questions used in the pretest but will likely include additional questions developed over the course of the study).

#### **F.5 Limitations of the Protocol**

The resultant data from the proposed protocol will enable the establishment of the main operating characteristics of the proximity detection systems as defined by the WV Mine Safety Technology Task Force. The proposed protocol uses a pragmatic, risk-based approach for testing and evaluating proximity detection systems under a limited set of test conditions. The protocol does not enable an exhaustive assessment of proximity detection systems that pertains to all makes and models of continuous miners, all operating scenarios, or all mine conditions. This limitation is due to time constraints and availability of the systems installed on CMs for more comprehensive testing. The NIOSH team would like to stress the following limitations and caveats:

1. Potentially, some dangerous failures will not be identified during the underground field tests. An example of a dangerous failure is that a miner operator enters the stop zone undetected or is detected and the machine does not shut down. Only obvious cases of dangerous failures could be observed (e.g. a miner gets within 1 foot of the machine, yet the machine does not shut down). There is not an independent system in place to accurately detect more subtle dangerous failures (e.g. a miner enters 1 foot into the stop zone, yet the PDS does not detect it or fails to shut down the machine).

2. The tests provide information on discrete locations and conditions. There will likely be fluctuations in the electromagnetic fields during operation that are not observed during testing.
  3. Due to safety concerns and the likelihood of measurement inaccuracies, tests with the cutting head under load, such as while cutting coal, will not be conducted. This situation causes significant additional currents that may be a source of interference.
  4. The tests only consider two simulated PWD locations, and the important issue of where the units will be worn on miners has not been resolved for all systems. Due to change of postures such as standing to kneeling, additional tests should be conducted if the PWDs on a system will be above or below the two heights proposed.
  5. NIOSH has not been provided specific dimensions for the stop and warning zones. It is not known if the actual zone shapes will be sufficient to protect miners during all activities performed during the tests, or if they are excessive. It is unclear how much these zones will vary from manufacturer-to-manufacturer.
  6. The results will be CM-specific, and cannot be extrapolated to other CMs or proximity detection systems. The tests do not apply to multiple instrumented machines in the same mine, etc.
  7. Various visual/audible alarms are used to provide miners indications that they are in the identification zone, that the system is working and monitoring them, that they are in a warning zone, or that they are in the stop zone. The protocol does not provide tests for determining if miners see or hear these alarms; thus the effectiveness of the alarms will be unknown. The warnings and alarms will be assessed only by the investigators relative to accepted ergonomics principles and expert judgment. An excessive frequency of continuous mining machine shut downs would occur if the visual/audible alarms are not effective. The alarm effectiveness would especially be of importance when the miner operator's attention is focused on mining tasks and the ambient noise level is high.
  8. Tram forward and reverse tests of the non-mining mode (general zoning) are conducted for the worst case (fast mode). As a safety precaution, the PWD test fixture will be unattended, and so tram tests are limited to testing the stop zone.
  9. The protocol assumes that PWD battery life does not affect function of any system to be tested.
  10. There is a concern that triggering the initiation of mining mode with the cutter motor will be ineffective for operating at the face. The locations that miners position themselves in just prior to taking the first lift of a cut would be well within the stop zone of the non-mining mode making it impossible for an operator to turn on the machine to start the first lift. This could cause acceptance issues with the operators.
- G. Project Management** -- Each mine test will include management representation assigned by:
- > WV Technology Task Force
  - > Mine Operator
  - > NIOSH
  - > MSHA

**H. Completion Indicators** – WV Technology Task Force concludes that at least one system is capable of performing to this program's objective or determines that further evaluation is not necessary.

**I. Data Collection**

- Test protocol and operator feedback data is collected, compiled, analyzed and reported by NIOSH
- Manufacturer data is downloaded periodically in the presence of team management and provided to NIOSH
- Manual observation data is recorded and reported by MSHA/NIOSH for initial field test operations and periodic follow-up observations.

**J. Final Study Evaluation**

- The WV Mine Safety Technology Task Force will analyze the data compiled, analyzed and reported by NIOSH in order to determine if the completion indicators have been met.