DOD OCCUPATIONAL EXPOSURE ASSESSMENT DATA COLLECTION PROTOCOL FOR BLAST OVERPRESSURE HAZARDS

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1. Purpose and Scope

The Department of Defense (DoD) Occupational Exposure Assessment Data Collection Protocol for blast overpressure (BOP) hazards describes requirements for evaluating Warfighter Brain Health (WBH)-related BOP risks to DoD Personnel.

The preparations, considerations, and methodologies outlined in this protocol are focused on the implementation of wearable blast instrumentation in both controlled and uncontrolled environments. This protocol is agnostic to the type of wearable sensor used. Gauges, gauge sets, dosimeters, sensors, and probes are collectively referred to as instrumentation within the protocol. Nonwearable blast instrumentation (e.g., pencil probes and other lab grade sensors) are important in certain types of data collection; however, this protocol applies to blast exposures representative of those encountered by Service members and Civilians involved in the operation of weapons systems and breaching operations. Instructions for the use of nonwearable blast instrumentation are already outlined in various publications and procedures (e.g., Test Operations Procedure (TOP)-04-2-831, 2008, International TOP (ITOP) 4-2-822A, 2019). This protocol is not intended to replace already established TOPs used in the test and evaluation community that support the Defense acquisition process. Also, this protocol does not include underwater blast data collection as all research relating to the bioeffects of underwater sound and blast and the development of evidence-based guidance are established by the Naval Submarine Medical Research Laboratory.

2. Definitions of Key Terms

The following are the definitions of key terms used throughout this protocol. Definitions may vary among DoD Component; however, the definitions below are used to provide context and mutual understanding of this protocol.

Action Level: The point at which certain provisions of the proposed standards must be initiated, such as periodic Service members/Civilian exposure measurements and training of Service members/Civilians (Leidel et al. 1975).

Allowable number of rounds (ANOR): Weapon firing restriction calculated for a type of round, type of charge, crewmember position (e.g., gunner), crewmember posture (e.g., standing) and weapon orientation (e.g., elevation) if applicable. ANORs represent the number of rounds that may be fired within a 24-hour period without producing injury to various organ systems due to blast exposure. ANORs are calculated based on the risk of impulse noise to produce hearing loss and the risk of BOP to produce lung injury. The lower the ANOR, the more hazardous the blast event.

Auditory noise: The component of a sound pressure wave that resonates at frequencies within the range of human hearing.

Blast overpressure (BOP): The sharp, instantaneous rise in ambient atmospheric pressure resulting from an explosive detonation (e.g., breaching operations) or the weapon system firing (Elsayed 1997).

Blast overpressure-time trace: A line displayed on a graph that depicts the variation in time-pressure measurements due to the changes in ambient air pressure associated with blast (Figure 1).

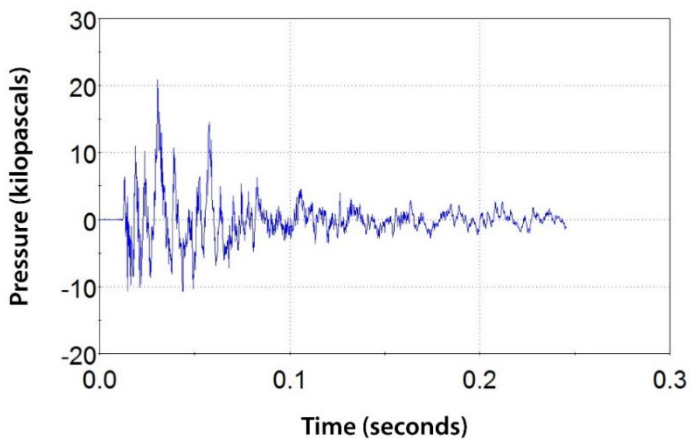

Figure 1. Blast Overpressure-Time Trace

Blast test device (BTD): A customized device that consists of an aluminum cylinder containing four transducers that correspond to the relative spatial proximity of a Service member's chest, back, and left and right sides. The BTD is a static instrument used to collect data for estimating the risk of lung injury from a BOP event.

Dynamic Data Collection: Involves an uncontrolled or minimally controlled environment. The collection of data occurs in an operational or training setting that is characterized by change due to the movement of a Service member, operational tempo, and environmental influences. Dynamic data collection will typically involve personal exposure monitoring of Service members.

Health Hazard Assessment (Weapon Systems): An independent review of the potential health hazards and anticipated risk associated with ordnance items, weapon components, or other materiel systems used or tested that can cause personnel death, injury, illness, disability, or reduced job performance by the Services across all land, sea, and air platforms.

Personnel Operating Mode: A type of mode that can be activated for most wearable blast instrumentation where sleep mode is enabled. This type of mode is used to put the instrumentation into low-power mode when there is no physical activity detected by the gauge. Once movement is detected by the instrumentation, it will return to active mode.

This type of mode can potentially miss blast events if the instrumentation does not experience motion or return to active mode in time but extends the amount of usable time by using less power.

Quantitative Exposure Assessment: The evaluation of exposure based on empirical methods that leads to a quantifiable measurement of exposure necessary to make risk decisions associated with potential or actual Service member or Civilian exposure to materiel systems (e.g., Joint Service member Occupational Health Assessments (JSOHAs) and Industrial Hygiene Exposure Monitoring).

Static Data Collection: Involves a controlled environment (e.g., during environmental mapping and developmental testing events). The collection of static BOP data is most likely to occur during the test and evaluation phase of weapons acquisition. Minimal influences are expected to occur in static environments and non-personal data is typical. In some circumstances, Civilians associated with the testing may require a dynamic data collection approach. Instrumentation such as BTDs, in concert with pencil probes, wearable dosimeters, and gauges fixed on stationary structures (e.g., mannequins and stakes), are used for this type of data collection.

Structure Operating Mode: A type of mode that can be activated for most wearable blast instrumentation where the active mode is always enabled. This type of mode is used when periods of no activity are expected or if the gauges are mounted on static structures. In this mode, sleep is disabled so the instrumentation is always active and ready to record. This type of mode uses more battery life than the Personnel Operating Mode but decreases the likelihood of missing blast events.

Weapon System: A weapon, with all the components necessary to its proper function, that produces blast as a result of its operation.

3. Applicable References and Glossary

Appendix A lists the references applicable to this data collection protocol. The Glossary contains a listing of the acronyms used this in protocol.

4. Blast Overpressure Data Collection Preparations and Considerations

Prior to data collection, develop an exposure assessment strategy. The strategy should identify and involve stakeholders (e.g., command and unit leaders) and other experts, such as engineers or subject matter experts. The exposure assessment strategy should include the purpose of data collection, specifically defined goals and objectives, as well as a definition of acceptable exposures that will be used for decision making. Once this is established, conduct a basic characterization of the work environment as well as intentional efforts to understand the roles and responsibilities of Service members or Civilians involved with weapons operations. Once an exposure assessment strategy and characterization of the work environment and has been completed, conduct an exposure assessment through data collection.

Considerations for dynamic BOP data collection and static BOP data collection in both live fire training and testing and evaluation environments are detailed below. Much of the preparation and considerations for dynamic and static data collection are similar. Regarding data collection during live fire training, while it is important to prepare for these events, the data collectors have little control over the schedule and flow of training. Training of Service members is prioritized over data collection, so developing a sampling strategy that is minimally intrusive will help prevent training disruption while ensuring data collection efficiency. The preparation steps and considerations for static BOP data collection within a testing and evaluation environment are more unique. In a testing environment, the data collectors have more control over the schedule, flow, and setup of the data collection event; and the static nature of the test allows for more instrumentation and types of instrumentation options.

A. Preparations for Dynamic Blast Overpressure Data Collection

This section outlines preparation for collecting blast data using wearable blast sensors in a dynamic manner. Many external influences are expected in environments where dynamic data collection is required (e.g., during weapons firing and in the training environment), and personal data collection is typical. Though this protocol is mostly focused on Service member data collection during weapons firing, it is important to note that dynamic BOP data collection may also be required for Civilians exposed to blast during weapons test and evaluation events. That type of data collection environment is more controlled than a live weapons training environment, but most of the following considerations still apply:

(1) Identify the weapon system or data collection event of interest. Determine the exposure scenario and characterize the work environment to include facts and inferences of the scenario and how exposure is likely to occur. Consider the data

collection objectives and purpose, and the blast characterization goal (e.g., characterization of the weapon itself or the training event in general).

(a) Identify the specific data collection event. Is this a familiarization, specialized, qualification, or a different type of training or weapons firing event?

(b) Determine whether multiple types of weapon systems will be fired or detonated during the event, or whether the event will focus on just one weapon system. If multiple types of weapon systems are used, consider how the data collected will be differentiated (if necessary). This may depend on the goal of the data collection event. If the goal is to characterize the blast exposure associated with a particular training event or training day, there may not be as much of a need to differentiate between weapon systems. However, if the goal is to characterize the blast exposure associated with a particular weapon system, it is necessary to specifically track the type of weapon system and time they are used.

(c) Determine the number of weapons systems present and utilized. When only one type of weapon system is used, there are often multiple weapons being fired simultaneously during training. Determine how far apart the weapon systems are from one another, and in what order weapon systems will be fired.

(d) Determine the type of ammunition that will be fired. BOP exposure can greatly differ depending on what ammunition/charge type is used. Ensure the ammunition/charge type is identified and documented.

(e) Determine the number of personnel who will be involved in operation of the weapon system, to include number of personnel involved in the weapon system crew if applicable. A minimum of six unique samples is recommended to perform statistical analysis. Although this may not be attainable in all situations, the number of samples should be sufficient to provide validity to the data collection purpose.

(f) Understand the event schedule and anticipated operations to determine the best data collection plan. Determine the anticipated total number of rounds that will be fired or detonated and the number per person, which is dependent on the weapon system and type of training event.

- In a weapon system familiarization training event with a low ANOR, it is possible that each Service member may only fire one round. In that case, consider sampling more Service members to increase the number of samples.
- For a training event with a high ANOR, each Service member may fire many rounds and sampling many Service members may be unnecessary.

(g) When characterizing the work environment, identify whether the operation is performed in an open area or whether there are any nearby surfaces that may impact the assessment. Weapons firing in an open area (no obstructions or reflective surfaces) will likely have differing results than if fired in an area where reflective surfaces or walls are nearby (indoor range, metal structure, concrete wall, room, etc.)

(2) Create a sampling plan and coordinate with stakeholders (e.g., command leaders, training point of contact, safety representative) to ensure it is the best way to integrate data collection into operation.

(a) Determine the number of Service members, crews, or personnel that will be sampled.

- When making this determination, consider the most efficient way to assign instrumentation. For example, does it make the most sense to assign each Service member instrumentation? In this case, the instrumentation would be used only for that Service member and would collect their exposure during the event. This is easier for tracking purposes but requires more set-up time to place instrumentation on each Service member and enough instrumentation to assign to each individual. As an alternative, assign an instrumentation set to each position being sampled. In this case, an instrumentation set is assigned to a particular crew member position, and this instrumentation set may be used on multiple Service members who will take turns occupying that position over the course of a training event.

(b) Determine how and where the instrumentation will be affixed to the Service members. This may change based on the type of weapon system, the required postures of the Service members during training, and the personal protective equipment (PPE) worn. It can take time to don gear onto Service members, especially if multiple types of instruments are used. Depending on the battle rhythm of the training event, there may be little to no time to don and doff equipment once weapons firing begins. Consider the use of Fighting Load Carrier (FLC) (Figure 2) or exposure sampling vests if instrumentation is assigned to a position, when donning time is limited before weapons firing, or when multiple types of instrumentation is used. Sampling vests allow for equipment to be placed and prepped before arriving to the range and enable quick switch-outs if multiple Service members are sampled with the same equipment. For example, during a familiarization training event where each Service member is only firing one round and firing teams are moving on and off the firing line very quickly, it may be easier to swap vests on and off than to move gauge sets and instrumentation while training is ongoing or to don every Service member with the instrumentation prior to training.

Figure 2. Fighting Load Carrier with Instrumentation

(c) Determine a naming and numbering convention to track where each blast instrumentation device will be placed.

- This may change depending on whether the instrumentation was assigned to each Service member, to each position, etc. Develop a preliminary plan for tracking the identification, placement, and shot times for each instrumentation/instrumentation set. Note who is being sampled by what equipment and at what time for specific exposure tracking for each individual sampled.

- Label the FLCs/vests or body armor of the personnel to indicate their crew member position and what instrumentation they have been assigned. This can make it easier to observe positioning and posture during dynamic live fire training.

(3) Set up and activate the instrumentation according to manufacturer's guidance. This will differ depending on which instrumentation type (e.g., gauge or dosimeter) is used. Label each blast instrumentation device or set. Each device or set is activated based on the decided naming and numbering convention. Some general considerations are as follows:

- Ensure the instrumentation triggering threshold is sufficient to collect the desired data. The lower the threshold, the more events will be captured.

- Determine if threshold settings affect the level of detail saved for each blast event. For example, ensure the threshold(s) chosen will result in full blast waveforms being collected as opposed to summary data if necessary.

- Most wearable blast instrumentation can be activated into different operating modes. While specific available modes may differ across each type of instrumentation, there is generally at least a power-saving mode type and an always active mode type. Refer to personal operating mode and structure operating mode definitions in Section 2. For dynamic data collection, recommend that blast instrumentation is activated in "power-saving" mode, or whatever mode is designated for personnel sampling. Consider the benefits and drawbacks of each operating mode (e.g., available battery life, ability of instrumentation to detect all blast events) to determine the best settings for each data collection event.

- Determine the best time to "turn-on" the wearable blast instrumentation. This depends on which operating mode is used and when wearable blast instrumentation will be set-up and activated. Consider that instrumentation set-up and activation may occur the day or many days before the actual data collection event. Instrumentation set in a power-saving mode may be okay to "turn-on" at the same time as set up, but instrumentation set in an active mode should be turned on close to the start of data collection to preserve battery life.

B. Preparations for Static Blast Overpressure Data Collection

This section outlines how blast data is collected using wearable blast sensors in a static manner. The collection of static BOP data occurs during a live fire training event or a test and evaluation phase of weapons acquisition. Minimal influences are expected in static environments and non-personal data is typical. The type of event, live fire or test and evaluation, does have differences explained below.

B.1. Static Data Collection During a Live Fire Training Event

(1) Consider the data collection objectives and purpose, and the blast characterization goal (e.g., characterization of the weapon itself or the training event in general). Identify the weapon system or data collection event of interest and determine the specifics of the scenario being sampled.

(2) Define the purpose of the data collection event. This will determine the number of instrumentations, types of instrumentation, and the test setup (e.g., where and how the instrumentation is mounted).

(a) Determine whether static data collection is being used to augment personnel data that is or has been collected to characterize the general blast area.

(b) Determine whether the purpose is to conduct a total environmental mapping of the BOP wave propagation around the weapon system being sampled.

(c) If Service members are conducting training in the same area where static data is collected, ensure that the stationary structures on which the blast instrumentation is mounted will not block the movement of personnel, vehicles, or equipment during training. Static data collection involves placing BOP instrumentation on stationary structures.

(3) Characterize the work environment, to include facts and inferences of the scenario and how exposure is likely to occur.

(a) Identify the specific data collection event. Is this a familiarization, specialized, qualification, or a different type of training or weapons firing event?

(b) Determine whether multiple types of weapon systems will be fired or detonated during the event, or whether the event will focus on just one weapon system. If multiple types of weapon systems are used, consider how the data collected will be differentiated (if necessary). This may depend on the goal of the data collection event. If the goal is to characterize the blast exposure associated with a particular training event or training day, there may not be as much of a need to differentiate between weapon systems. If the goal is to characterize the blast exposure associated with a particular weapon system, it is necessary to specifically track the type of weapons system and time they are used.

(c) Determine the number of weapons systems present and utilized. When only one type of weapon system is used, there are often multiple weapons being fired simultaneously during training. Determine how far apart the weapon systems are from one another, and in what order weapon systems will be fired.

(d) Determine the type of ammunition that will be fired. BOP exposure can greatly differ depending on what ammunition/charge type is used. Ensure the ammunition/charge type is identified and documented.

(e) Understand the event schedule and anticipated operations to determine the best data collection plan. Determine the anticipated total number of rounds that will be fired or detonated and the number per person, which is dependent on the weapon system and type of training event.

(f) Identify whether the operation is performed in an open area or whether there are any nearby surfaces that may impact the assessment. Weapons firing or a particular weapon system in an open area (no obstructions or reflective surfaces) will likely have differing results than if fired in an area where reflective surfaces or walls are nearby (indoor range, metal structures, concrete walls, etc.)

(4) Create a sampling plan and coordinate with stakeholders (command leaders, training point of contact, safety representative) to ensure it is the best way to integrate data collection into operation.

(a) Determine the location of all blast instrumentation and determine how many samples are required for analysis to meet the data collection purpose.

- A minimum of six unique samples is recommended to perform statistical analysis. Although this may not be attainable in all situations the number of samples should be sufficient to provide validity to the data collection purpose.

- Instrumentation location depends on the type of stationary structure used and the purpose of the data collection event. The most common stationary structures used to mount wearable blast instrumentation on during static data collection of a live fire training event are stakes/stands or mannequins. Consider what the stationary blast instrumentation is meant to represent and ensure the instrumentation is positioned in space and on the stationary structure accordingly. For example, if a stationary structure is meant to represent a Service member, that structure should be placed where a crew member would be located, and the blast instrumentation should be placed at a similar height and orientation as it would be if it were placed on a Service member. The position of the instrumentation on the stationary structure in reference to the ground, and the orientation of the instrumentation (e.g., parallel or perpendicular to the blast wave) will affect the blast values measured. Because of this, consider using multiple types of blast instrumentation (e.g., incorporate lab grade sensors in addition to wearables). For blast instrumentation where orientation of the sensor to the blast wave is not prescribed (e.g., wearable instrumentation), consider using multiple devices mounted with different orientations and/or different heights to further characterize the blast. Figure 3 shows an example of various blast instrumentation devices mounted on a stake during a blast characterization event.

Figure 3. Blast Instrumentation Mounted on a Stake

- For an environmental mapping-type scenario, characterize the blast through equal level curves in a manner such as that described in the ITOP 4-2-822A. This method involves placing blast instrumentation on radii from the blast origin point at regular increments. Figure 4 displays example measurement points. Please refer to the ITOP for additional information on instrumentation location considerations.

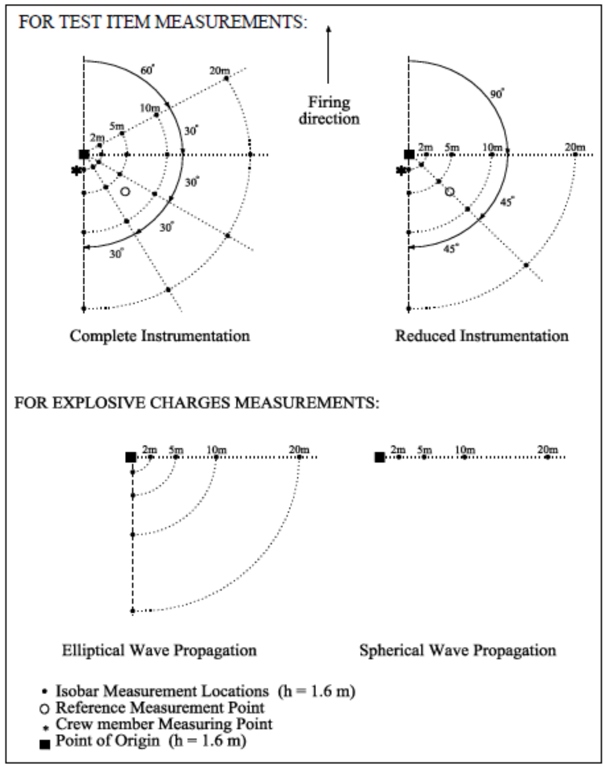

Figure 4. Blast Instrumentation Measurement Points
(Source: ITOP 4-2-822A)

(b) Determine the naming and numbering convention to track the placement of each instrumentation or instrumentation set.

- This will greatly depend on the data collection purpose and how the blast instrumentation will be set up. Develop a preliminary plan for tracking this information while in the field.

(5) Set up and activate the instrumentation according to manufacturer's guidance. This will differ depending on which instrumentation type (e.g., gauge or dosimeter) is used. Label each blast instrumentation device/set as it is activated based on the decided naming and numbering convention. Some general considerations are as follows:

- Ensure the instrumentation triggering threshold is sufficient to collect the desired data. In general, the lower the threshold, the more events will be captured.

- Determine if threshold settings affect the level of detail saved for each blast event. For example, ensure the threshold(s) chosen will result in full blast waveforms being collected as opposed to summary data if necessary.

- Most wearable blast instrumentation can be activated into different operating modes. While specific available modes may differ across each type of instrumentation, there is generally at least a power-saving mode type and an always active mode type. Refer to Blast Instrumentation General Operating Modes definitions in Section 2. For static data collection, it is generally recommended to activate blast instrumentation in “active” mode, or whatever mode is designated for mounting instrumentation on static structures. However, it is important to consider the benefits and drawbacks of each operating mode (e.g., available battery life, ability of instrumentation to detect all blast events) to determine the best settings for each data collection event.

- Determine the best time to “turn-on” the wearable blast instrumentation. This will depend on which operating mode is used, and when wearable blast instrumentation will be set-up/activated. Consider that instrumentation set-up/activation may occur the day or many days before the actual data collection event. Instrumentation set in a power-saving mode may be okay to “turn-on” at the same time as set up, but instrumentation set in an active mode should be turned on close to the start of data collection to preserve battery life.

B.2. Static Data Collection During a Test and Evaluation Event

Refer to existing BOP test and evaluation TOPs and protocols for more specific recommendations and procedures on implementing non-wearable blast instrumentation (e.g., BTDs, pencil probes, blunt cylinders) during weapons testing (e.g., TOP-04-2-831, 2008, ITOP 4-2-822A, 2019). Again, this protocol is not intended to replace already established TOPs used in the test and evaluation community that support the Defense acquisition process. This protocol is meant to provide guidance and considerations for augmenting test and evaluation data collection with wearable blast instrumentation. Collecting data with wearable blast instrumentation in a testing environment will allow for better comparison to blast data collected on Service members in the weapons training environment.

(1) Consider the data collection objectives and purpose, and the blast characterization goal (e.g., characterization of the weapon itself or of the general blast environment). Identify the weapon system, test item, or data collection event of interest and determine the specifics of the scenario being sampled.

(2) Define the purpose of the data collection event. This will determine the number of instrumentations, types of instrumentation, and the test setup (e.g., where and how the instrumentation is mounted).

(3) Characterize the exposure scenario specifics to determine what data will be collected.

(a) Identify the type of training event or operational environment this test event is meant to represent. Consider what types of data will need to be collected to fully characterize the blast associated weapon system or test item.

(b) Determine whether multiple types of weapon systems need to be fired or detonated during the testing event, or whether the event will focus on just one weapon system. If multiple types of weapon systems are used, consider how the data collected will be differentiated (if necessary).

(c) Determine the number of weapons systems that will be present and utilized. If multiple weapon systems will be used, determine how far apart they need to be from one another to avoid interference between data sets, and in what order weapon systems will be fired.

(d) Determine the type of ammunition that will be fired. BOP exposure can greatly differ depending on what ammunition/charge type is used. Ensure the ammunition/charge type is identified and documented. The ammunition/charges expected to produce the highest BOP levels should be tested if possible.

(e) Identify whether the operation should be performed in an open area or whether an enclosure or other reflective surfaces should be present to replicate the exposure scenario. Weapons firing or a particular weapon system in an open area (e.g., no obstructions or reflective surfaces) will likely have differing results than if fired in an area where reflective surfaces or walls are nearby (e.g., indoor range, metal structures, concrete walls, etc.)

(4) Create a sampling plan and coordinate with stakeholders (e.g., command leadership, training point of contact, safety representative) to ensure it is the best way to collect data representative of the exposure scenario of interest.

(a) Determine the location of all blast instrumentation and determine how many samples will be required for analysis to meet the data collection purpose.

- A minimum of six unique samples is recommended for each condition to perform statistical analysis. Although this may not be attainable in all situations the number of samples should be sufficient to provide validity to the data collection purpose.

- Instrumentation location depends on the type of stationary structure used and the purpose of the data collection event. The most common stationary structures used to mount wearable blast instrumentation during static data collection are stakes/stands or mannequins. See Figure 5 below for an example of mounting wearable blast instrumentation on a mannequin. BTDs are commonly employed to collect BOP data during weapons testing. Consider methods to collect BTD and wearable blast instrumentation data simultaneously, without affecting the quality of each type of data set.

- Consider what the stationary blast instrumentation represents and ensure the instrumentation is positioned on the stationary structure accordingly. For example, if a stationary structure is meant to represent a Service member, that structure should be placed where a crew member would be located, and the blast instrumentation should be placed at a similar height and orientation as if it were placed on a Service member. The position of the instrumentation on the stationary structure in reference to the ground, and the orientation of the instrumentation (e.g., parallel or perpendicular to the blast wave) will affect the blast values measured. Consider using multiple types of blast instrumentation (e.g., lab grade sensors in addition to wearable). For blast instrumentation where orientation of the sensor to the blast wave is not prescribed (e.g., wearable instrumentation), consider using multiple devices mounted with different orientations and/or different heights to further characterize the blast (see Figure 3 in Section 4.B.1).

- For an environmental mapping-type scenario, characterize the blast through equal level curves in a manner such as that described in the ITOP 4-2-822A. This method involves placing blast instrumentation on radii from the blast origin point at regular increments (see Figure 4 in Section 4.B.1). Please refer to the ITOP for additional information on instrumentation location considerations.

Figure 5. Blast Instrumentation Mounted on Mannequins

(b) Determine the naming and numbering convention to track the placement of each instrumentation or instrumentation set.

- This will greatly depend on the data collection purpose and how the blast instrumentation will be set up. Develop a preliminary plan for tracking this information while in the field.

(5) Set up and activate the instrumentation according to manufacturer's guidance. This depend on which instrumentation type (e.g., gauge or dosimeter) is used. Label

each blast instrumentation device/set as it is activated based on the decided naming and numbering convention. Some general considerations are as follows:

- Ensure the instrumentation triggering threshold is sufficient to collect the desired data. In general, the lower the threshold, the more events will be captured.

- Determine if threshold settings affect the level of detail saved for each blast event. For example, ensure the threshold(s) chosen will result in full blast waveforms being collected as opposed to summary data if necessary.

- Most wearable blast instrumentation can be activated into different operating modes. While specific available modes may differ across each type of instrumentation, there is generally at least a power-saving mode type and an always active mode type. Refer to Blast Instrumentation General Operating Modes definitions in Section 2. For static data collection, it is generally recommended to activate blast instrumentation in "active" mode, or whatever mode is designated for mounting instrumentation on static structures. However, it is important to consider the benefits and drawbacks of each operating mode (e.g., available battery life, ability of instrumentation to detect all blast events) to determine the best settings for each data collection event.

- Determine the best time to "turn-on" the wearable blast instrumentation. This will depend on which operating mode is used, and when wearable blast instrumentation will be set-up/activated. Consider that instrumentation set-up/activation may occur the day or many days before the actual data collection event. Instrumentation set in a power-saving mode may be okay to "turn-on" at the same time as set up, but instrumentation set in an active mode should be turned on close to the start of data collection to preserve battery life.

5. Blast Overpressure Data Collection Methodology

The BOP data collection methodology for wearable blast instrumentation, divided into dynamic and static, provides a comprehensive sampling assessment for either a pre-materiel fielded weapon system in the test and evaluation environment, or the post-materiel fielded weapon system where personal sampling of Service members is used to determine occupational exposures.

A. Summary of Dynamic Blast Overpressure Data Collection Methodology

(1) Implement the exposure assessment strategy and sampling plan developed as part of Section 4.A. of this protocol. Be prepared to be flexible and adapt the sampling plan as necessary. It is common for training plans and timelines to shift.

- Don all blast instrumentation on those being sampled.

(2) Use field data collection sheets to ensure that all required/desired information is collected. See Appendix B for blast data collection elements and examples of BOP field data collection sheets. These can be used as a guide or a starting point to develop data collection sheets specific to the sampling plan being implemented. Again, the exact data elements that need to be collected depend on the purpose of the data collection event. Below are general blast data collection recommendations:

(a) Record information on the weapon system and ammunition used, the location of the data collection event, and the unit/group on which data is being collected.

(b) Ideally, full waveforms should be captured for each blast event. At a minimum, the following blast metrics should be collected: peak overpressure, impulse, and positive phase duration.

- **Peak overpressure**: The highest-pressure level recorded during sampling for each event. Normally expressed in units of pounds per square inch (psi) or as kilopascals (kPa).

- **Impulse**: The incident overpressure occurring over time for every recordable peak (i.e., the area under the blast curve). Normally expressed in units of psi per millisecond (psi-msec) or kilopascals-milliseconds (kPa-msec).

- **Positive phase duration**: The total time of positive overpressure energy occurring once above atmospheric conditions until returning to the ambient pressure level for each event. Normally expressed in units of msec.

(c) For individual blast exposure monitoring, if data is expected or required to be entered into the Defense Occupational and Environmental Health Readiness System-Industrial Hygiene (DOEHRS-IH), there are minimum data requirements to enter a blast sample into the system. See Table B-1 in Appendix B for these required elements. The following individual data collection elements should be collected on each Service member sampled: position/role, posture, and PPE (hearing and body protection).

(d) Regardless of whether data will be entered into DOEHRS-IH, it is important to collect as much contextual and observational information as possible in addition to what is being recorded by the blast instrumentation. Contextual and observational data is necessary to understand and interpret the collected blast data, or to confidently determine the realness of a waveform. Information on the environment in which the blast data was collected and the orientation/position of crew members in relation to the blast wave source should be collected to fully characterize the BOP exposure and improve the quality of the assessment. Table B-1 contains environmental data collection elements important to characterizing blast exposure including weather information and the presence of reflective sources. The presence of reflective sources can have a huge impact on BOP exposure. Note the presence of the following reflective sources and where they are in relation to where data is being collected: enclosures, walls, berms, sand/sandbags, vehicles, trees, rocks, and foxholes. This may be further expanded on ships to include bulkheads, decks, overhead, passageways, bulwarks, and ladders.

(e) Shot times should be collected for each weapon system sampled. This information may be required to correctly analyze and interpret the BOP data and/or distinguish between different firing events/individuals using the same instrumentation. See Appendix B for an example Shot Times Field Data Sheet.

(3) The same general procedures outlined above should be used in the case of dynamic data being collected in a testing environment on Civilian personnel.

B. Summary of Static Blast Overpressure Collection Methodology

(1) Implement the exposure assessment strategy and sampling plan developed as part of Section 4.B. of this protocol. Be prepared to be flexible and adapt the sampling plan as necessary. It is common for training plans and timelines to shift.

- Mount all blast instrumentation on the stationary structures that will be used during sampling.

(2) Use field data collection sheets to ensure that all required/desired information is collected. See Appendix B for blast data collection elements and examples of BOP field data collection sheets. These can be used as a guide or a starting point to develop data collection sheets specific to the sampling plan being implemented. Again, the exact data elements that need to be collected depend on the purpose of the data collection event. For static data collection, there generally should not be a need to collect individual information. But it is still important to track where each stationary structure is located and how each piece of instrumentation is mounted. Below are general blast data collection recommendations:

(a) Record information on the weapon system and ammunition used and the location of the data collection event.

(b) Ideally, full waveforms should be captured for each blast event. At a minimum, the following blast metrics should be collected: peak overpressure, impulse, and positive phase duration. See Section 5.A. for definitions of these blast metrics.

(c) It is important to collect as much contextual and observational information as possible in addition to what is being recorded by the blast instrumentation. Contextual and observational data may be necessary to understand and interpret the collected blast data, or to confidently determine the realness of a waveform. Information on the environment in which the blast data was collected and the orientation/position of blast instrumentation in relation to the blast wave source and the ground should be collected to fully characterize the BOP exposure and improve the quality of the assessment. Table B-1 contains environmental data collection elements important to characterizing blast exposure including weather information and the presence of reflective sources. The presence of reflective sources can have a huge impact on BOP exposure. Note the presence of the following reflective sources and where they are in relation to where data is being collected: enclosures, walls, berms, sand/sandbags, vehicles, trees, rocks, and foxholes. This may be further expanded on ships to include bulkheads, decks, overhead, passageways, bulwarks, and ladders.

(d) Shot times should be collected for each weapon system sampled. This information may be required to correctly analyze and interpret the BOP data and/or distinguish between different firing events using the same instrumentation. See Appendix B for an example Shot Times Field Data Sheet.

6. Blast Overpressure Data Processing

This section outlines general BOP data processing considerations. Each type of wearable blast instrumentation may have different data processing requirements/steps. Some types of wearable blast instrumentation have data processing algorithms/capabilities built into their software. For example, when BOP data is downloaded, the software may output the blast waveforms collected by each individual sensor/gauge in addition to a “resultant” waveform or “resultant” blast metrics which take into account timestamp and orientation information. Additionally, external blast instrumentation algorithms/software packages have been developed by contracting companies to process data. However, there is still not consensus on a standardized approach to processing wearable blast instrumentation data. As this type of capability continues to be developed, the considerations below can be used to process and analyze blast data so it can be reported or entered into exposure records.

Summary of Blast Overpressure Data Processing. After the collection of data, the peak value versus time data provided by downloading the information from the sampling device should be statistically analyzed to understand exposures and provide a basis for risk assessment. Minimum statistical analysis should include descriptive statistics such as median, range, maximum value, minimum value, arithmetic mean, and standard deviation outlined in the Figure 6 example. Figure 6 illustrates what a typical data set outcome looks like for a blast gauge set considering multiple peak pressures recorded and determining the aforementioned descriptive statistics which are not limited to those listed. Specific information and guidance on commonly used blast instrumentation are included in Appendix C. While the Figure below displays statistics being performed on the data from a single gauge set, it may also be useful to perform statistical analysis on data from across different gauge sets or individuals to better characterize or compare the blast exposure differences between different crew member positions or environments. This exposure guideline should be used until additional DoD guidance is released. Additional statistical guidance and tools can be found in the American Industrial Hygiene Association, A Strategy for Assessing and Managing Occupational Health Exposures, 4th Edition (Jahn et al. 2015).

Peak OP vs Time*	
Time (Zulu)	Peak Overpressure (psi)
17 May 2023 17:32:30Z	2.28
17 May 2023 17:32:22Z	3.01
17 May 2023 17:32:10Z	2.86
17 May 2023 17:32:03Z	2.79
17 May 2023 17:31:58Z	2.90
17 May 2023 17:31:08Z	2.90
17 May 2023 17:30:39Z	2.25
17 May 2023 17:30:33Z	2.10
17 May 2023 17:30:27Z	2.14
17 May 2023 17:30:20Z	2.10
17 May 2023 17:29:40Z	2.14
17 May 2023 17:29:35Z	2.25
17 May 2023 17:29:29Z	2.18
17 May 2023 17:29:02Z	2.14
17 May 2023 17:28:22Z	2.28
17 May 2023 17:26:16Z	2.36
17 May 2023 17:26:10Z	2.28
17 May 2023 17:26:05Z	2.14
17 May 2023 17:26:00Z	2.21
17 May 2023 17:25:55Z	2.14

Occupaitonal Exposure Limit (psi)	4

Descriptive Statistics	
Mean	2.18
Standard Error	0.03
Median	2.14
Mode	2.10
Standard Deviation	0.25
Sample Variance	0.06
Kurtosis	2.51
Skewness	0.98
Range	1.41
Minimum	1.60
Maximum	3.01
Sum	196.20
Count	90.00
Confidence Level (95.0%)	0.05
95%ile	2.66
% above Occupational Exposure Limit	0.00%

Figure 6. Descriptive Statistics Example for Dynamic Blast Overpressure Data

When processing wearable blast instrumentation data, consider the orientation of the instrumentation to the blast wave. Figure 7 shows blast instrument orientations for collecting reflective and incident pressure measurements (Bass et al. 2012). These two different orientations result in blast measurements that signficantly differ. Blast measurements collected with instrumentation in the reflected orientation may have peak pressures two times as high as those collected with instrumentation in the incident orientation.

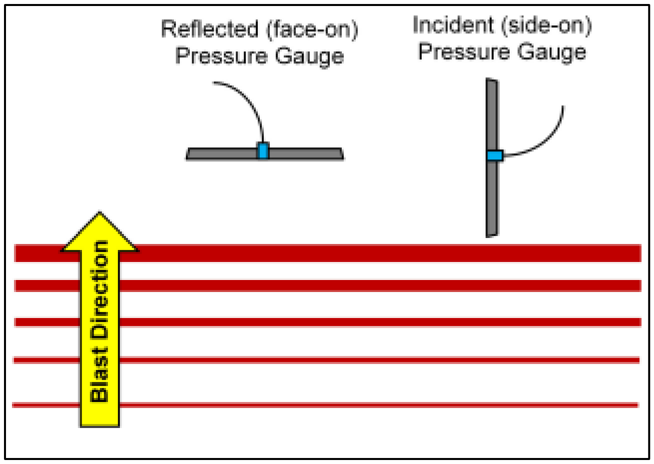

Figure 7. Pressure Transducer Orientation for Incident and Reflected Pressure Measurements
(Source: Bass et al. 2012)

Contextual/environmental information and shot time data can prove to be invaluable when processing and performing quality control and assurance on blast data. Go through each waveform collected to identify any suspicious or potentially erroneous waveforms. It is possible for blast instrumentation to collect “non-real” blast events due to the device being impacted, dropped, etc. Compare information collected about the exposure environemnt and shot times to any waveforms in question to improve the quality of the BOP data being assessed.

APPENDIX A

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APPENDIX B

DATA COLLECTION SHEET EXAMPLES

The following are examples of data collection sheets for evaluators to utilize and/or modify to fit their purposes. To ensure a complete data set for systems of record (e.g., Defense Occupational and Environmental Health Readiness System-Industrial Hygiene) the data elements listed in Table B-1 represent the minimum requirement along with additional elements for consideration. Copies of the blast data collection sheet Excel® spreadsheets are made available upon request to the authors of this protocol.

Table B-1. Data Collection Elements

Source	Required	Not Required
Individual	• Electronic Data Interchange Personnel Identifier (EDIPI) • Role (e.g., gunner) • Length of work shift • Helmet type • Shield • Body Armor • Hearing protection	• Posture (standing, sitting, etc.) • Proximity to Source • Orientation to Source • Orientation to Source Description • Position in Relation to Other Operators • Role Description • Helmet type description • Shield description • Body armor description • Hearing protection description • Service member UIC • Auditory, physical, cognitive, and emotional Signs and symptoms
Weapon	• Weapon system • Ammunition	• Weapon system other description • Ammunition other description
Environmental	• Installation • Latitude/Longitude	• Environmental General Comments • Ambient Air Temperature • Relative Humidity • Wind Speed • Ambient Barometric Pressure • Environmental Obstacle (Reflection source) • Range Name / Number • Course / School House UIC • Sample reason and exposure notes
Blast	• Peak pressure (non-auditory, blast overpressure) • Synchronized time stamp (Date/time) • Event date • Event time • Gauge body location • Make/model type • Generation • Gauge Software • Gauge Software Version • Display name • Use (training vs. operational) • Gauge unique identifier (serial number) • Gauge set number	• Impulse • Analysis description • Gauge body location description • Use Description • Trigger activate threshold • Trigger record threshold • Operating Mode Used • Unit name • Unit ID • Number of Significant Peaks • Rise Time • Positive Phase Duration

INDUSTRIAL HYGIENE (IH) BLAST OVERPRESSURE SAMPLE FORM   Sample Date:

IH UIC:__________ **IH Field Office**__________________**Command:**______________________________**UIC:**______________

Bldg./Hull/Range #: ____________**Shop Location:**________________________ **Shop Code/Name:**____________________________

Employee Name:____**SEG:**____________________**Gender:** M/F
Last First MI

DoD EDI PI:__________________________ **Job Title:** _______________________________________ **Mil/Civ/FN:** M/C/FN

TAD: Y/N **Parent Activity:** _________________________ **Parent UIC:**____________ SF600 Sent to: ____________________________

Shift:	1. Day	**Frequency of Operation**	1. Daily	2. 2-3/wk	3. Weekly	4. 2-3/ month	**Duration of Operation**	1. 0-15 min	2. 15-30 min	3. 30-60 min	4. 1-2 hr
2. Eve.	3. Night		5. Monthly	6. 2-3/yr	7. Yearly	8. Special		5. 2-4 hr	6. 4-6 hr	7. 6-8 hr	8. > 8 hr

	1	2	3	4	5	6
Sample number						
Task/Operation						
Operational Position						
Gauge make/model						
Gauge Set #/ SN						
Gauge Display Name						
Gauge Threshold level (psi)						
Gauge Waveform Level (psi)						
Gauge Location	Head Chest Shoulder	Head Chest Shoulder	Head Chest Shoulder	Head Chest Shoulder	Head Chest Shoulder	Head Chest Shoulder
Firing Position	Prone Kneeling Standing	Prone Kneeling Standing	Prone Kneeling Standing	Prone Kneeling Standing	Prone Kneeling Standing	Prone Kneeling Standing
Weapon						
Barrel Length (in)						
Configuration	Suppressed Unsuppressed Muzzle Brake N/A	Suppressed Unsuppressed Muzzle Brake N/A	Suppressed Unsuppressed Muzzle Brake N/A	Suppressed Unsuppressed Muzzle Brake N/A	Suppressed Unsuppressed Muzzle Brake N/A	Suppressed Unsuppressed Muzzle Brake N/A
Round Type						
Number of Rounds						
Handedness	Left Right	Left Right	Left Right	Left Right	Left Right	Left Right
Reflective Surfaces	Yes No	Yes No	Yes No	Yes No	Yes No	Yes No
Event Start Time						
Event End Time						
Sample Time (min)						
PPE	Muffs Plugs Eye protection Other	Muffs Plugs Eye protection Other	Muffs Plugs Eye protection Other	Muffs Plugs Eye protection Other	Muffs Plugs Eye protection Other	Muffs Plugs Eye protection Other

Results (psi) Note: LOQ=0.5psi

Max Peak						
Number of events						
Events ≥ 4 psi						
95%ile (all peaks)						

Exposure during the unsampled period is: ☐ Same as sample period ☐ Zero ☐ Other ____________________________________

Shift Length: ____________ **Actual Length of Sampled Work:** ____________________

Additional Weapon information:

Weapon DODIC number:

Ammunition DODIC number:

Time Course of Events and Comments, to include detailed description of any reflective surfaces (distances from personnel and type of surface, e.g. concrete, steel, etc.).

Diagram (include location of reflective surfaces)

Sampler: ____ **Date Completed:** _______________________

Reviewing IH: ____ **Date Reviewed:** _________________________

Data Entered By:_______________________________________ **Date Entered:** ___________________________

BLAST CONTEXTUAL FIELD DATA COLLECTION SHEET

UIC:	Activity Description:
Location:	
Bldg/Range #:	
Unit Name/ID:	
Date:	Start and Stop Times for Events:
Weapon System:	
Ammunition:	
Collector's Name:	

Measurements: *include units and instrument used below*	Time 1:	Time 2:	Time 3:	Time 4:	Time 5:	Time 6:	Time 7:	Time 8:
Air Temperature								
Wind Speed								
Barometric Pressure								
Relative Humidity								
Elevation								
Other								
Other								

BLAST INDIVIDUAL FIELD DATA COLLECTION SHEET

UIC:	Activity Description:
Location:	
Bldg/Range #:	
Unit Name/ID:	
Date:	Start and Stop Times for Events:
Weapon System:	
Ammunition:	
Trigger Thresholds:	
Collector's Name:	

Test Participant Information (Name, EDIPI, Job Series/Title, etc.)	BOP Gauge/Gauge Set Name:	Position/Role:	Posture:	Orientation and Proximity to Source:	Hearing Protection (Plugs, Muffs):	Body Protection (Helmet, Shield, Body Armor, etc.):	Other Description/Notes (e.g. don and doff times):

SHOT TIMES FIELD DATA COLLECTION SHEET

UIC:	Activity Description:
Location:	
Bldg/Range #:	
Unit Name/ID:	Start and Stop Times for Events:
Date:	
Collector's Name:	

Notes:	Crew/Team/Gun/ Vehicle:	Shot Number:	(indicate time zone):	Weapon System:	Ammunition:	Other Description:

BLAST STATIC FIELD DATA COLLECTION SHEET	Activity Description:					
UIC:						
Location:						
Bldg/Range #:						
Unit Name/ID:						
Date:	Start and Stop Times for Events:					
Weapon System:						
Ammunition:						
Trigger Thresholds:						
Collector's Name:						
Stationary Structure Name/Information	BOP Gauge/Gauge Set Name:	Position/Role Represented:	Posture Represented:	Orientation and Proximity to Source:	Instrumentation Position on Structure:	Other Description/Notes:

APPENDIX C

INSTRUMENTATION FOR COLLECTING BLAST OVERPRESSURE DATA

Measuring blast overpressure (BOP) exposures requires a variety of instrumentation of which the use is dependent on the test event and purpose of the data collection. Instrumentation include wearable dosimeters, pressure gauges, sensor, and probes. A variety of commercial instrumentation exist, and some with associated data processing software. This protocol does not endorse any commercial product; however, the following are examples of commonly used instrumentation for BOP data collection.

Figure C-1 shows the L3 Applied Technologies Incorporated Blast Dosimeter with three pressure sensors within one 3-D printed unit (on the top) and a BlackBox Biometrics (B3) Gen7 Blast Gauge (on the bottom) marketed as a three-sensor set placed on the back of the head, non-firing shoulder, and chest opposite of the non-firing shoulder. The B3 Gauges are capable of providing real-time results through a Bluetooth® connection. The L3 dosimeter calculates exposure dose while the B3 gauges independently measure exposure according to gauge location.

Figure C-1. L3 Applied Technologies Incorporated Blast Dosimeter (top) and a BlackBox Biometrics Gen7 Blast Gauge (bottom)

The Tascam DR-100MKIII linear pulse code modulation recorder with a GRAS 47BX-S7 microphone is featured in Figure C-2. This impulse noise recorder will sample up to 192,000 samples per second; however, in the field it is usually sampled at 96,000 samples per second.

Figure C-2. Tascam DR-100MKIII

Pencil-type pressure sensors or pencil probes are devices used in test and evaluation scenarios with a defined shock wave propagation and/or a fixed testing environment. The characteristic pencil shape minimizes the influence of the sensor geometry on the blast wave propagation. The probe is pointed radially toward the center of the explosion and effectively measures the side-on pressure of the propagating blast wave. This instrumentation is limited to static data collection due to its size, set-up, and data acquisition processor requirement. Pencil probes are considered the gold standard for blast overpressure measurement capabilities. Figure C-3 shows a PCB 137B23B pencil probe (A) and pencil probes mounted in a real experiment (B).

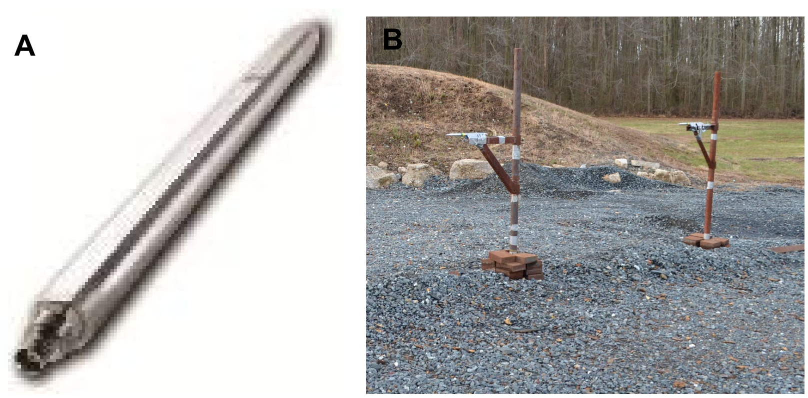

Figure C-3. PCB 137B23B Pencil Probe (A) and Typical Pencil Probe Set-up (B)
(Source: Showalter, 2020)

Figure C-4 shows the Blast Tracker, which is a wearable blast dosimeter that records, measures, and stamps blast events and accumulated blast exposure. It is one of the dosimeters that provides immediate feedback to the evaluator during an exercise.

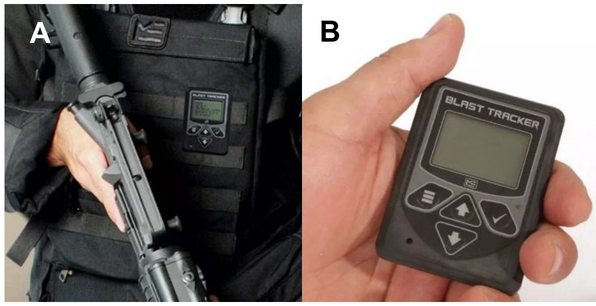

Figure C-4. MED-ENG Blast Tracker Mounted (A) and Unmounted (B)
(Source: https://www.med-eng.com/product/blast-tracker/)

New sensors and gauges will continue to emerge as technology advances. One example is the OmniBlast Air wearable gauge (Figure C-5) that uses several sensing elements for direction-independence to provide in-air blast data without the use of additional equipment. It has a range of 0.5 pounds per square inch (psi) to 100 psi. It is the responsibility of the evaluator to deteremine the most appropriate wearable dosimeter, pressure gauge, and probe for their data collecting purposes.

Figure C-5. OmniBlast™ Air Wearable Gauge
(Source: https://www.amadinc.com/omniblastair)

Blunt cylinder gauges (see Figure C-6) are for recording pressures of less than 40 kilo Pascals (kPa). The orientation of the gauges us dependent on the expected blast wave and the number of noise sources. The quality of the probe depends on the distance (d1) and on the diameter (Φ). More information is outlined in the International Test Operations Procedure (ITOP) 4-2-822A.

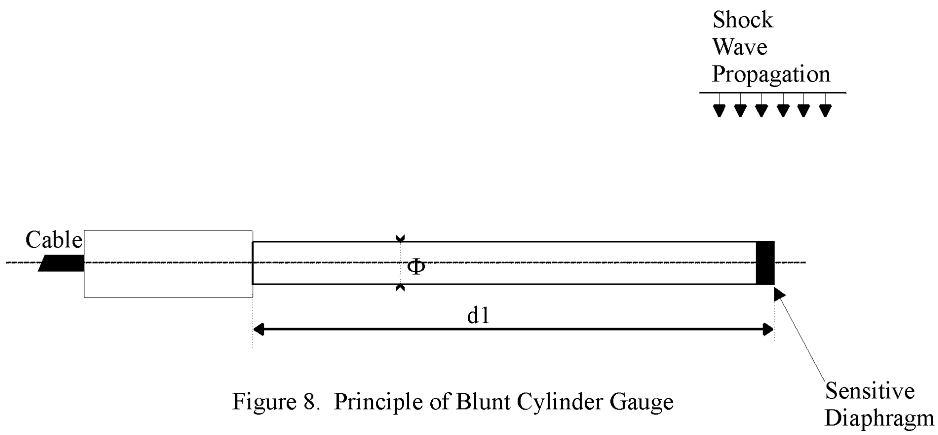

Figure C-6. Blunt Cylinder Gauge
(Source: ITOP 4-2-822A)

Proper care and handling of the instrumentation used to collect BOP exposures is necessary as standardization across the Department of Defense (DoD) is not fully established for wearable blast instrumentation. With further advancement into the understanding of Warfighter brain health (WBH) and blast exposure interaction, the development of exposure limits and definable measurement parameters will continue to evolve. Until this time, users will need to rely heavily on concurrence from WBH DoD working groups, related operational procedures, manufacturer guidance, and the understanding of instrumentation limitations. Blast and wearable instrumentation are inherently designed to perform in austere environments, but the function of accurate data collection will always hinge on environmental influences and the condition of the instrumentation. Users will need to be aware of potential environmental influences, such as extreme heat or cold, elevation, water exposure, etc. Visual inspection should follow every sampling event to identify physical damage that could potentially affect performance. Instrumentation software should be used to verify performance of instrumentation to the extent possible and when it cannot, the instrumentation should be returned to the manufacturer for maintenance.

GLOSSARY

ALARA
As low as reasonably achievable

ANOR
allowable number of rounds

BOP
blast overpressure

BTD
blast test device

HHA
health hazard assessment

HP
hazard probability

HS
hazard severity

ITOP
International Test Operations Procedure

JSOHA
Joint Service member Occupational Health Assessment

MILDEP
Military Department

MIL–STD
Military Standard

PSI
Pounds per square inch

SME
subject matter expert

TOP
Test Operations Procedure

WBH