Program Guidance for Blast Overpressure Analysis

Technical Information Paper No. 88-001-0411

PURPOSE.

The U.S. Army Public Health Command (Provisional)'s (USAPHC (Prov)) Ergonomics Program is responsible for analyzing blast overpressure (BOP) data using the Blast Overpressure Health Hazard Assessment (BOP-HHA) software developed by the U.S. Army Medical Research and Materiel Command and for establishing guidelines to ensure the integrity of the analyses it conducts.

BACKGROUND.

The BOP-HHA was originally designed as a rapid assessment method that would allow someone with minimal technical background to analyze weapons test data and estimate injury risk. To that end, we are striving to keep this assessment process as uncomplicated as possible without degrading the quality of the report.

WHAT IS BOP TESTING?

BOP testing is the process of collecting data that can characterize the changes in air flow and density that occurs as a result of detonation of an explosive device.

WHY IS BOP IMPORTANT?

BOP is important because exposures can produce injury. The risk of injury is related to the mechanics of the pressure wave and the physical properties of the tissue contacted. Air-containing organs (such as the heart, lung, esophagus, and stomach) are relatively more susceptible to damage than denser tissues such as bone.

HOW DOES USAPHC (PROV) PERFORM THE NON-AUDITORY ANALYSIS?

Analysis is performed by a software program called BOP-HHA. This software takes time and pressure data from the specially designed sensors called blast

test devices (BTDs) and uses a biomechanical model of the thoracic wall to calculate the amount of mechanical force that the blast wave would yield to a person occupying the position at which the BTD is located. Next, the software estimates the probability of lung damage that the blast could produce based upon data from animal experiments. (Note: Although BOP can damage any air-containing organ, the lung was selected as the organ upon which to base BOP-HHA's analysis because of the severity of the consequences of lung injury.) It should be noted that at this time BOP-HHA does not assess risk of injury to the tympanic membrane (eardrum).

WHEN SHOULD BOP DATA BE COLLECTED?

BOP testing should be conducted whenever analysis of the auditory test data demonstrates that the intensity of the blast pressure wave dictates that single hearing protection is needed to protect against exposures of five or less rounds.

HOW DO I REQUEST USAPHC (PROV)'S ASSISTANCE FOR ANALYZING BOP DATA?

To obtain USAPHC (Prov)'s assistance for analyzing BOP data, go to the USAPHC (Prov) Internet Web site and submit a request of Health Hazard Assessment (HHA) Services on the HHA Web page at http://phc.amedd.army.mil/topics/workplacehealth/hha/Pages/default.aspx.

HOW SHOULD THE WEAPON SYSTEM TEST BE DESIGNED?

In order to be analyzed at USAPHC (Prov), BOP data must be collected by an approved BTD. (Note: BOP-HHA cannot analyze data collected from single gage.) A BTD consists of a cylindrical metal tube containing an array of four pressure sensors (see Appendix A). To date, only two BTDs are approved for use: (1) the standard 30-inch device developed according to specifications established by JAYCOR is approved for testing both outside and within enclosures (inside vehicles, equipment or buildings) and (2) a 24-inch BTD validated by testers at the U. S. Army Yuma Test Center that is approved only for testing outside of enclosures (see Appendix B). Since it is not possible to attest to the validity of data collected by any devices other than the two just described, USAPHC (Prov) will not analyze data collected on unvalidated devices.

WHERE SHOULD BTDS BE PLACED?

The system developer is responsible for determining where the BTD should be placed. In order to ensure that BTD will accurately represent the hazard, BTDs

should be placed in locations that weapon crew personnel will actually occupy during live firing. Failure to locate BTDs properly will invalidate the data collected at the location(s) of the misplaced devices. Upon request, in special circumstances, USAPHC (Prov) may provide suggestions on BTD placement for the test plan.

WHAT DATA DO I NEED TO SEND IN ORDER TO ACCOMPLISH THE BOP ANALYSIS?

Since testing is typically conducted by specially trained weapon testers and doesn't require the on-site presence of the BOP assessor, USAPHC (Prov) requires both properly formatted data and a description that contains enough detail to describe the test. There are no formal requirements on the format for the descriptive information. It may be provided via e-mail or other documents accompanying the BOP data. The information should describe the scenario(s) used to test the weapon system and clearly communicate how the design of the test intended to collect information that was relevant to the health risks associated with the exposure. Failure to provide complete information will delay completion of the analysis.

The following paragraphs specify information needed by the USAPHC (Prov) analyst. This information is also presented in Appendix C. There is no requirement to use the Sample BOP Test Information form as the mechanism for conveying needed information as long as the essential facts are embedded in electronic documents submitted with the data. In other words, elements included on the Sample BOP Test Information form can help remind individuals about information that should be provided to USAPHC (Prov).

1. Weapon Testers' Contact Information. State the name, telephone number and e-mail address of at least one tester who can answer questions about design of the test and validity of the data.

2. Description of the Mission Scenario of the Weapon System. Provide a statement that details all aspects of the intended use of the weapon system that influence Soldiers' exposures to BOP. It is essential to include an estimate of the maximum number of blasts or shots to which weapon crew personnel will be exposed on a typical training day. Examples of other factors that should be reported include:

a. Describe the postures that personnel are expected to assume when firing the weapon (i.e., standing, sitting, kneeling, squatting, and lying down).

b. Describe the environment proximate to the personnel manning the weapon (outside or inside such as within a vehicle or enclosure). When appropriate, identify the name of the vehicle or dimensions of the enclosure from which the weapon will be fired.

c. When appropriate, describe the elevations at which the weapon will be fired.

3. Description of the Weapon Test.

a. The date(s) on which the test was performed.

b. The name of the test center where test was performed.

c. A description of the purpose of the test. See the following example:

> *The objectives of this test are to assess the peak magnitude and B-duration of sound signatures produced by the XM1028 cartridge when fired from the M1A1 Abrams tank and conditioned to the hot operational temperature (49°C/120°F), to measure the non-auditory blast overpressure at the chest area of each crew member in the M1A1 Abrams Tank and to determine whether the peak magnitude and B-duration of the sound signatures meets or exceeds the impulse-noise limit, category Z (MIL-STD-1474).*

d. A description of the kind of BTD(s) used to collect BOP data. State the length(s) of those devices.

e. A description of the test environment. Was the test conducted in an open-field environment, in the presence of obstacles, or within an enclosure? Specify the type of enclosure (i.e., inside a room or inside a vehicle) and the enclosure's dimensions.

f. A diagram or a written statement describing the location of Soldiers relative to the energy source (usually gun muzzle or explosive device) is helpful.

g. A description of the firing conditions that details the variables used and the number of rounds fired in each condition should be included. (Please note that rounds should be numbered in a manner that allows them to be readily associated with test conditions.) Table 1 illustrates one method of communicating test conditions.

Table 1. Firing Conditions and Rounds Associated with Each Condition

		Test Variables		
Conditions	**Round(s)**	**Elevation**	**Temp (^{o}F)**	**Hatch**
1	1 – 6	17	120	Opened
2	7 – 12	17	120	Closed
3	13 – 18	45	120	Opened

h. Identify erroneous rounds that should be excluded from the assessment or other conditions that occurred during testing that might influence the quality of the data collected.

4. Properly Formatted Data. The data should be formatted in a manner consistent with the JAYCOR Information Format (JIF) as explained in Appendix B. Any data not JIF-formatted will be returned immediately to the sender for conversion.

5. Health Hazard Assessment. Report whether or not the data is being provided in conjunction with an HHA. If the data was sent after the HHA request was made, also identify the name of the HHA Project Officer.

WHAT ARE THE FACTORS THAT MIGHT PROMPT USAPHC (PROV) TO EXCLUDE DATA FROM AN ANALYSIS? The following findings may prompt the USAPHC (Prov) assessor to exclude data from analysis.

1. Exclusion of Rounds. Rounds may be excluded when there is a complete loss of data from one or more channels or if an overt anomaly is found on the visual presentation of a trace viewed with the X-Y plot viewer. (Note: The USAPHC (Prov) BOP assessor views traces to identify gross anomalies. This task is not intended to be a substitute for error identification procedures used by testers who retain full responsibility for the quality of test data.)

2. Exclusion of Conditions. Conditions may be excluded if they include an insufficient number of rounds to yield a statistically significant result or if the condition is so poorly defined that it fails to represent the Soldiers' exposures.

HOW SHOULD THE DATA BE DELIVERED TO USAPHC (PROV)?

The BOP test results (the complete BOP Test Information and relevant data files) should be sent to the following address:

U.S. Army Public Health Commander (Provisional)
ATTN: MCHB-IP-OER/Mr. Don Goddard
Bldg E-5158 Blackhawk Road
Aberdeen Proving Ground, MD 21010-5403

WHAT IF I HAVE OTHER QUESTIONS?

For more information, contact the USAPHC (Prov) Ergonomics Program at commercial 410-436-2736 or DSN 584-2736.

Prepared by: Mr. Don Goddard, (410) 436-2736

Dated: 12 April 2011

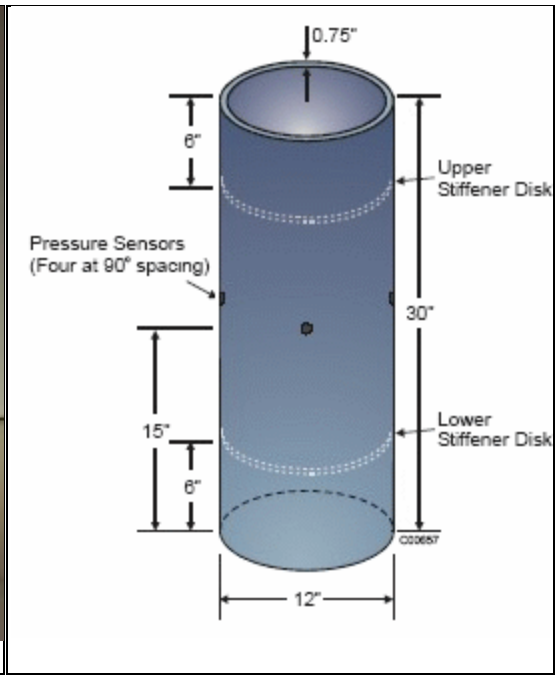
APPENDIX A
BLAST TEST DEVICE SPECIFICATIONS

SPECIFICATIONS

The BTD measures the external pressure loading on a human thorax due to BOP. The BTD, Figures A-1 and A-2, is a 0.75-inch thick, 12-inch outside diameter, 30[1] inch long, 6061-T6 aluminum tube. Two 0.75-inch thick internal stiffener disks, Figure A-2, are fastened to the interior of the cylinder, one 6 inches from the bottom and one 6 inches from the top. Four 1000 pounds per square inch (or psi) PCB® Electronics model 102A04 pressure transducers are screw-mounted into the cylinder with their faces flush with its surface. The pressure sensors are evenly spaced along the circumference at mid-height (15 inches from the base) of the cylinder. A PCB model 481A20 16-channel signal conditioner powers the pressure sensors. (PCB® is a registered trademark of PCB Group, Inc.)

The PCB model 102A04 pressure sensor has an integral shock mount specifically designed for shock tube and blast wave measurements. To insulate the pressure sensor from flash temperatures at the blast front, a 0.1-inch thick layer of General Electric Room Temperature Vulcanizing (or RTV)-type 106 silicone rubber coating is applied to the surface of the sensor diaphragm.

Figure A-1. BTD with Signal Conditioner



FigureA-2. Schematic of BTD

Endnotes:

[1] Currently both 24- and 30-inch BTDs are approved for data collection.

[2] For further information contact Michael J. Vander Vorst, Jaycor, Inc., 3394 Carmel Mountain Road, San Diego, CA 92121-1002, commercial 858-720-4124 or Fax 858-724-156.

APPENDIX B
JAYCOR INFORMATION FILE FORMAT SPECIFICATIONS

BOP TEST DATA

B-1. Overview.

The BOP test data are time-dependent measurements at various crew positions of the pressure field arising from the use of a weapon system for a given set of firing conditions. The measurements are made with a BTD, incorporating four pressure transducers spaced 90 degrees apart, mounted along the circumference of a steel cylinder at a given elevation. The four pressure signals recorded at each crew position represent the pressure felt on the chest, right side, back, and left side of a crew member. The BOP test data are a necessary part of the complete set of input data required for a BOP-HHA calculation. The pressure traces used by BOP-HHA must have any signal bias removed by the data provider and must be filtered appropriately to prevent aliasing effects due to digitization of analog data at finite sampling rates. Failure to adhere to these practices could result in an incorrect HHA of a weapon system. The user must provide a directory path to the BOP test data, and the data must be structured and formatted in a prescribed manner as described below.

B-2. Directory Structure.

The directory structure defines the various firing conditions and the shots (rounds) fired for each condition. In addition, the position names and gauge locations on the BTD are inherently defined by a simple-file naming convention. Provisions are also made for special files within the directory structure containing word descriptions for the system and for each condition. The directory structure conventions eliminate the need for specification in the user interface of conditions, accompanying shots, and crew positions for a weapon system. A sample data structure is shown below.

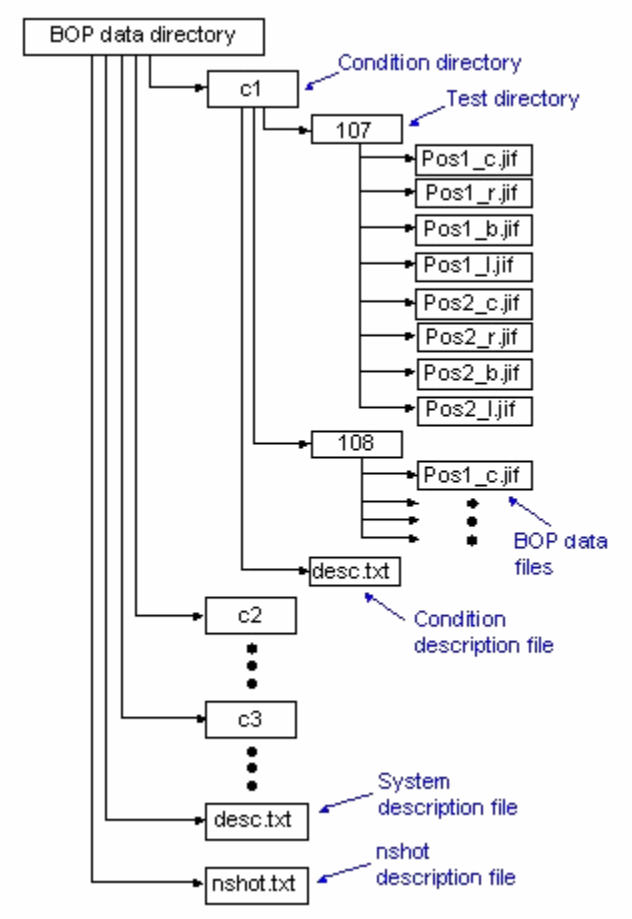


Figure B-1. Sample BOP Data Structure

Each condition must be assigned its own directory within the BOP data directory. Condition directory names must begin with the letter "c", which can be in lower or upper case. The remainder of the condition directory name must be the condition number, an integer from 1 to 30. Therefore, condition directories must be named c1, c2, c3 ... c30. All data that apply to a given shot number for a condition must be contained within a test subdirectory of the condition directory. The name of a test (or round) directory must be purely numeric, a positive integer from 1 to 99999. The BOP trace files for the four locations on the BTD and for all positions of the BTD in the weapon system are contained within the test subdirectory for each round. Optional files named "desc.txt" can be inserted in the BOP data directory and in each condition directory, containing text describing the weapon system and the conditions, respectively. Text from these files will be inserted into the printed output files from BOP-HHA. Another optional file

"nshot.txt" can also be placed in the BOP data directory. This file can be used to specify different numbers (nshot) of repeated shots for each condition, to be used in risk assessment code (RAC) calculations.

The same shot numbers can be used in different condition directories. For example, the three shot numbers 1, 2, 3 can be present in each of the condition directories c1, c2 and c3. The BOP data for the identically named shots will differ, of course. In many cases, the shot numbers are unique across conditions and represent test numbers or "round" numbers fired. The naming of the shots depends on the personal preference of the tester. If the shot names include non-numeric characters, the names must be mapped to purely numeric ones in order to be used by BOP-HHA.

The BOP-HHA is quite flexible with regard to omitting data for a given condition or round. For the same condition, some rounds may not have all positions present, due to some gauges malfunctioning. Also, some conditions might not have data for all possible positions, among all of their rounds. A master list of all unique positions among all conditions is maintained. If data are missing, the print-out usually reflects that situation by showing blanks where some results would ordinarily appear or displaying an appropriate message. Useful output data still appear for the data that are present. If data are unavailable for one to three of the four gauges mounted on a BTD, BOP-HHA will substitute missing traces with a logical counterpart of the trace or traces that are present.

In the sample data structure shown above, there are three conditions corresponding to directories c1, c2 and c3. Two test subdirectories are shown for condition 1, corresponding to test numbers 107 and 108. Files containing BOP test data are shown for two positions, "Pos1" and "Pos2", for test 107. The contents of an optional file "nshot.txt" for this sample could be:

Table B-1. Sample Contents of Optional File

Condition	**nshot**
1	5
2	10
3	3

In this sample, nshot would be set to 5, 10 and 3 for conditions 1, 2, and 3, respectively. In order for the information in file nshot.txt to be used in a RAC calculation, check boxes on the user interface must be set appropriately (refer to

the description of Min Shots/Day.) The first line of the nshot.txt file, "Condition nshot", is a descriptive header line and must be present. The condition number and nshot value are in free-field format. They must be separated by at least one space.

B-3. BOP File Naming Convention.

The individual pressure trace files must follow a prescribed naming convention. The first part of the file name indicates the crew position at which the measurements were made. This should be a string of 1 to 7 alphanumeric characters with no embedded blanks allowed. For example, "Gunner", "Loader", "#1man", are valid examples of position names. The next character of the file name should be an underbar (_) character. The character following the underbar should be one of the letters, "c","r","b" or "l", denoting the chest, right, back and left gauge positions on the blast test device. Additional characters between the BTD gauge-position character and the file name extension are not allowed. The extension must be "jif", indicating that the files are in JIF. See also the description of Trace Data Format. The JIF binary files with extension "JIB" can also be read, but their use is not recommended for reasons of portability. If JIB files are used, the JIB version must be 32 bit and not 16 bit. The file naming convention can be summarized as:

position_x.jif

where "position" is a 1 to 7 character descriptor for crew position, and "x" denotes the letter c, r, b, or l, representing the chest, right, back and left positions on the BTD. Lower- or upper-case characters can be used in these file names.

B-4. Trace Data Format.

The BOP trace data must be in JIF. Each JIF file constitutes a pressure versus time trace for a given location on the BTD. The JIF format is a free-field text format which allows variables names and units to be stored along with the data. A listing of a sample time history JIF file follows this description. For the sake of portability and simplicity, the JIF format here is subject to the following restrictions:

- Header lines in a file must appear exactly as shown. These are the lines including and preceding the record: "data (Time, Pressure)".

- Units of time and pressure must be milliseconds (ms) and kilopascals (kPa), respectively.

- The time and pressure variables must be named "Time" and "Pressure".

- Only text files are permitted (use of binary counterparts "JIB" are not recommended.)

- A file can contain only a single pressure time history.

- The time and pressure data must appear in consecutive pairs.

- The value of time must precede the pressure in each pair.

B-5. Sample Contents of a JIF File.

```
float(Time[ ],Pressure[ ]);
units(Time,"ms");
units(Pressure,"kPa");
data(Time,Pressure)
  0.000        0.000

  0.820        0.000

  1.640        -95.909

  2.460        5754.511

  3.280        -863.177

  4.100        -4603.609

  4.920        -3884.295

  5.740        -2781.347

  6.560        -4651.563

  7.380        -2925.210

  8.200        4315.884

  9.020        4651.563

  9.840        1774.308

  10.660       -911.131;
```

The four header lines should be specified exactly as shown above. The left and right lower-case bracket characters ([ ]) should always follow the variable names "Time" and "Pressure" in the first line of the header (the "float" descriptor line). It is unnecessary to specify a point count in the JIF file. The interleaved time and pressure data can be in free-field format, with each consecutive value separated by one or more spaces. Commas cannot be used as delimiters. Blank lines can appear anywhere and are ignored. The time and pressure data can be given in either FORTRAN "F" or "E" format. At the end of the time and pressure data block, a semicolon character (;) must appear. This character can appear at the end of the last line of data, or on the next line by itself. An error will result if the semicolon character is omitted.

APPENDIX C
SAMPLE BOP TEST INFORMATION

_____
Weapon System Name

Tester's Name: _____ Phone: _____

Email Address: _____

Test Date(s): _____ Test Center: _____

Has a Health Hazard Assessment been requested for this system? ☐ Yes ☐ No HHA Project Officer: _____

Purpose of the test:

_____

_____

_____

Indicate the type of BOP test conducts:

☐ Inside Vehicle. Describe: _____

☐ Inside Enclosure. Describe: _____

☐ Other Type. Describe: _____

List any rounds that should be excluded from due to errors or because they were “warmer” rounds:

_____

_____

_____

List all conditions tested with relevant descriptive information:

Condition #	Position[1]	Posture[2]	BTD Type[3]	Variables[4]	Exclude?[5]
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes

Condition #	Position[1]	Posture[2]	BTD Type[3]	Variables[4]	Exclude?[5]
					☐ Yes
					☐ Yes

Notes:

[1] Position refers to the Soldier's title on the weapon firing team, such as gunner, ammo bearer, driver, commander.

[2] Posture refers to the position of the Soldier's body when the weapon is fired such as standing, sitting, kneeling, lying down.

[3] BTD Type refers to the type of BTD that represents the Soldier for the test such as: 36 in, 30 in, 24 in, or Advanced BTD.

[4] Variables are aspects of the test that are varied to yield difference in exposures, such as weapon elevation, conditioning temperature of the round, or a special configuration, for a vehicle or enclosure (hatch opened, hatch closed).

[5] Check "yes" to identify conditions that should not be tested due to error or other problem that may negatively impact the quality of the results; also note individual rounds that should be excluded from the assessment in the appropriate area on page one.