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Acoustic Resonance Spectroscopy (ARS)

ARS300

OPERATIONS MANUAL

Software Version 2.01

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Chapter 1: Introduction

1.1 Introduction

Acoustic Resonance Spectroscopy (ARS) is a nondestructive evaluation technology developed at the Los Alamos National Laboratory. The ARS technique is a fast, safe, and nonintrusive technique that is particularly useful when a large number of objects need to be tested.

Any physical object, whether solid, hollow, or fluid filled, has many modes of vibration. These modes of vibration, commonly referred to as the natural resonant modes or resonant frequencies, are determined by the object's shape, size, and physical properties, such as elastic moduli, speed of sound, and density. If the object is mechanically excited at frequencies corresponding to its characteristic natural vibrational modes, a resonance effect can be observed when small excitation energies produce large amplitude vibrations in the object. At other excitation frequencies, i.e., away from resonances, the vibrational response of the object is minimal.

For filled objects, the natural resonances are modified by the physical properties of the fill material and the fill level. Consequently, the resonance spectrum of such an object, or the vibrational characteristics over a band of frequencies, contains relevant information regarding the fill material.

The resonance spectrum, obtained by continuously exciting the object over a wide frequency range (sine-wave frequency sweep) and measuring its response, provides an acoustic signature of the object. The measurements can be made with direct contact transducers such as piezoelectric crystals. Typically, the frequency sweep range used for chemical munitions lies between 3 kHz and 30 kHz and the entire frequency sweep can be carried out in less than 60 seconds. The actual frequency sweep range used depends largely on the size of the object and the type of information desired.

1.2 Purpose for Nondestructive Evaluation

The primary purpose for nondestructive evaluation, as opposed to invasive techniques, is to protect inspection personnel from possible exposure to hazardous materials by minimizing the need for such exposure. Acoustic Resonance Spectroscopy (ARS) is one such technique. ARS can classify chemical weapon munitions by comparing a measured acoustic signature to a known standard or template. An ARS evaluation of an object is fast, taking less than 60 seconds, and requires little or no sample preparation, making ARS very attractive for screening large numbers of munitions

1.3 Basic Concepts

All objects have natural modes of mechanical vibration. Figure 1a, illustrates the one-dimensional vibrational modes of a taut string, such as you would find on a violin or guitar. Each mode can be viewed as a set of standing waves. Figure 1b shows some of the two- dimensional modes of a drum head. In musical terms, each mode corresponds to a tone. Each mode has it own shape and frequency of vibration. Objects vibrate preferentially, or resonate, at these mode frequencies, i.e., a small excitation at these frequencies will produce a large response. If you strike an object, these are the frequencies and patterns at which it will vibrate.

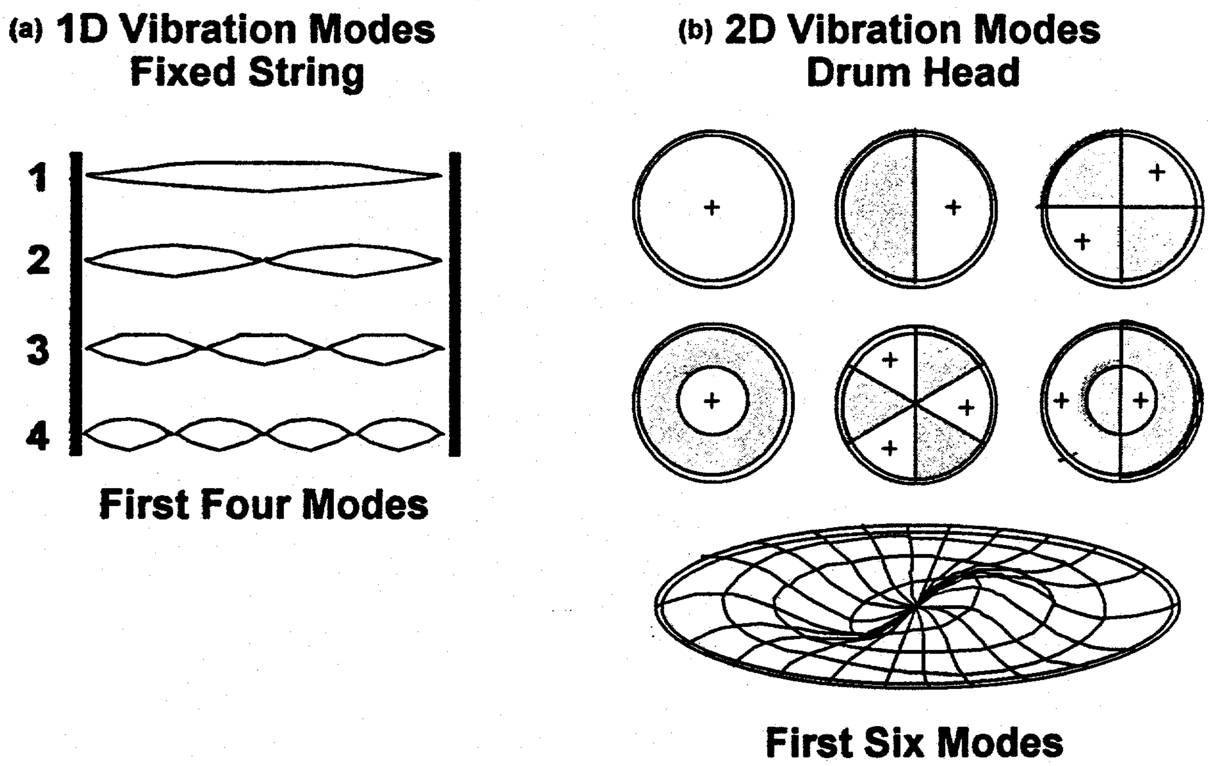


Figure 1. Resonance Modes - String and Drum

The resonant modes of an object are determined by its mechanical properties, including its physical shape, and the material properties of its components. Analytic formulas exist for calculating the modes of simple, idealized objects such as a one-dimensional string, a two-dimensional drumhead, or a simple three-dimensional cylinder. However, for more realistic objects, the complex effects of the various shape and material parameters make the modes impossible to describe analytically. In this case, the vibration modes can only be estimated numerically. Figure 2 illustrates the three-dimensional shapes of three modes of an empty 105mm artillery munition. The figures represent quarter section views of the munition. The vibrational deflections are greatly exaggerated for clarity.

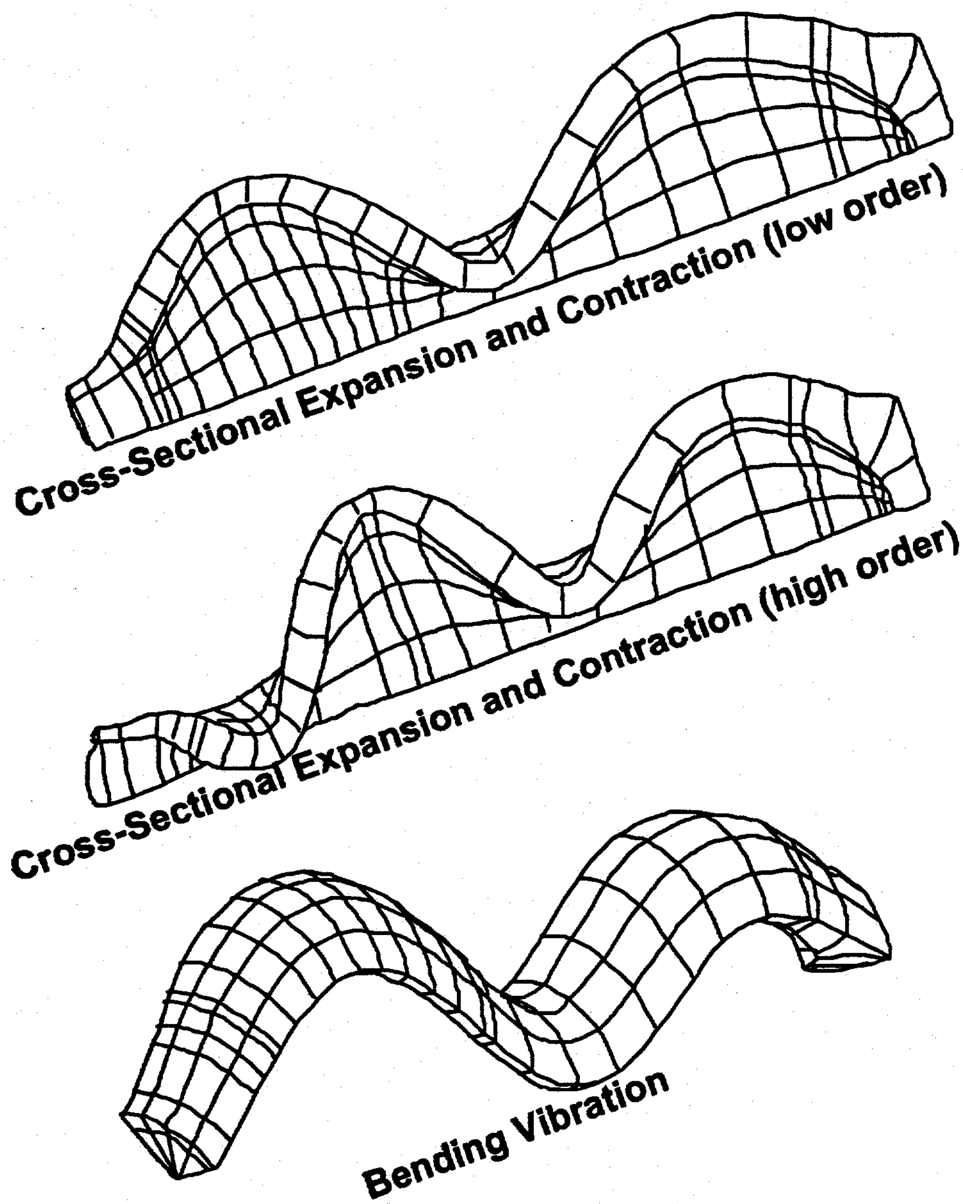


Figure 2. Numerical Modeling of 105mm Munition

The acoustic resonance spectrum of an object is simply the set of its resonant frequencies. For an ideal, lossless elastic object, these will appear as spectral lines, as shown on the left in Figure 3. Real objects, unlike ideal ones, dissipate energy. After you strike a bell, the sound eventually dies away. Energy dissipation causes the spectral line to widen, as shown on the right in Figure 3. A long-lasting mode will have a narrow or sharp resonance peak. A mode that dies away quickly will have a wide resonance peak.

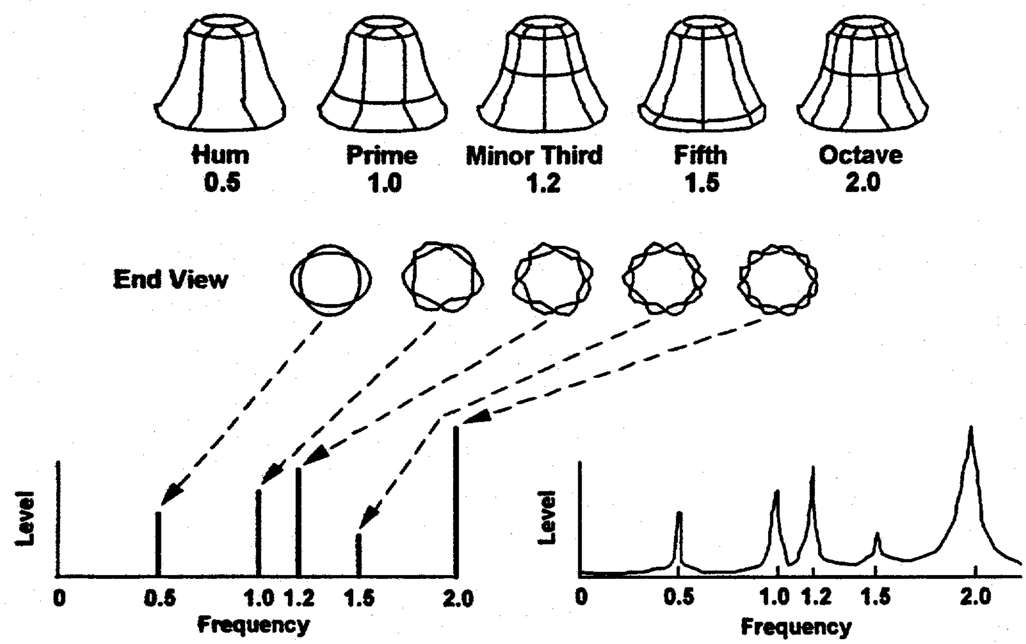


Figure 3. Resonant Spectra for an ideal case versus a real case

Figure 4 shows the correspondence between discrete vibrational modes and the acoustic resonance spectrum. The dotted vertical lines at the top show the frequencies for different vibrational modes of an empty 105mm munition shell, computed numerically using a finite element model. Below the dotted vertical lines is the measured acoustic spectrum of the munition. Each of the peaks in the acoustic spectrum corresponds to one of the computed vibrational modes.

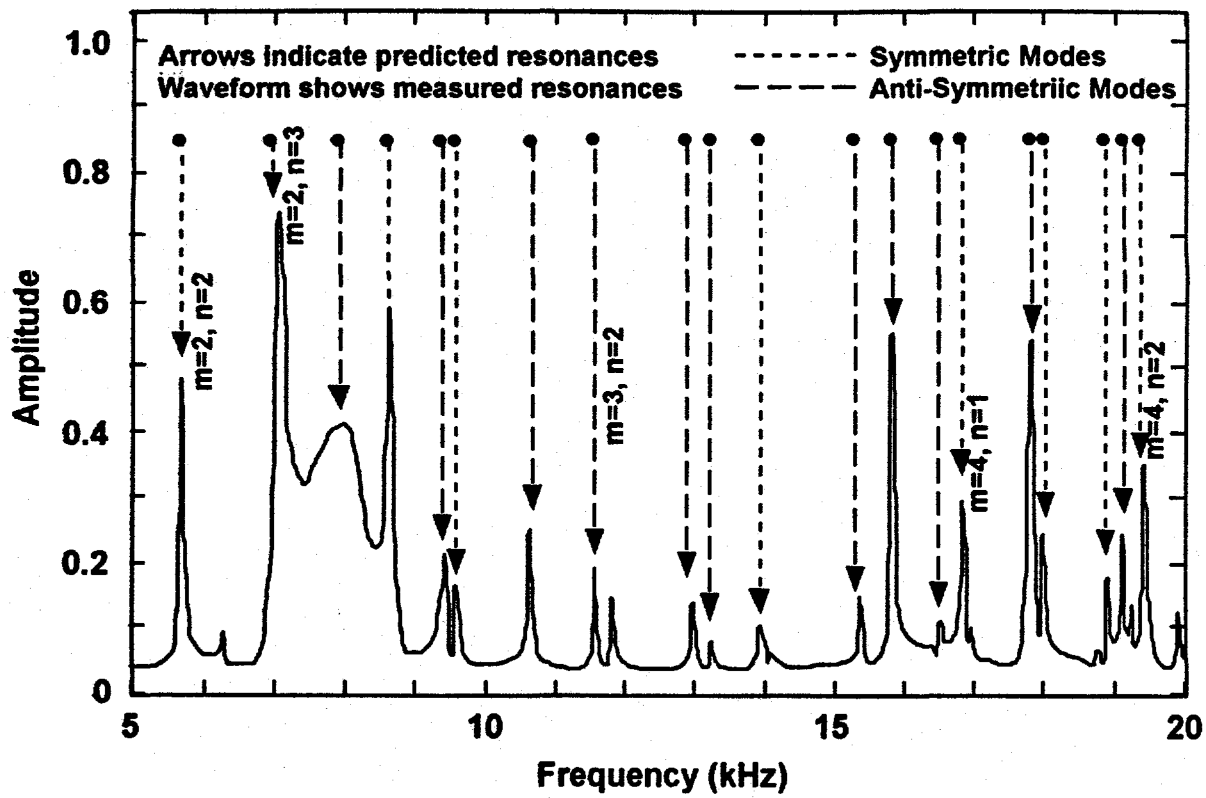


Figure 4. Acoustic Spectrum of 105mm Shell and Resonance Modes

All the mechanical and material parameters of a munition influence its acoustic resonance spectrum. A number of these parameters are illustrated in Figure 5. The spectrum will be affected by the munition size, and smaller munitions will have higher frequency resonances than larger ones. The casing thickness will affect the spectrum, and thinner walls will produce higher resonance frequencies than thick walls. The resonance spectrum is also affected by the physical properties of the munition and its fill materials, such as the density, sound velocity, viscosity, and material stiffness. For example, stiffer material will produce higher frequency resonances than will more flexible material. Viscous, or heavy liquid fills will produce wider resonance peaks than light liquid fills.

Since the effects combine in a complex manner, it is not possible to invert the process. You cannot take an acoustic spectrum of an object and derive its structure or its ingredients. The acoustic spectrum will not provide you with any sort of image of the object's internal construction. In more specific terms, you cannot independently deduce the design parameters of a munition from its acoustic spectrum alone. The acoustic resonance spectrum provides a signature of a munition. This signature can be compared with signatures of other munitions to determine whether they are of the same type or class. Different types of munitions have different acoustic signatures.

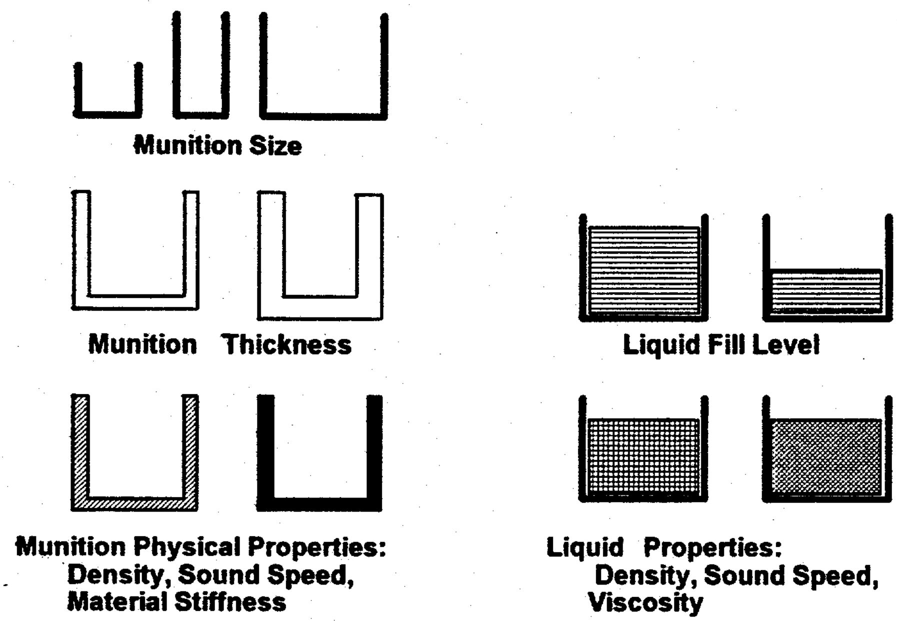


Figure 5. Parameters Affecting the ARS Spectrum

1.4 Basic Measurement Approach

The acoustic resonance spectrum of an object can be measured in various ways. In our instrument, we employ a bistatic swept-frequency technique, as illustrated in Figure 6. A computer-controlled frequency synthesizer generates a sinusoidal signal that drives a transducer. This transducer vibrates the munition at the frequency of the driving signal. A second transducer is used to measure the induced vibrations in the munition. The computer reads this measurement and calculates the amplitude and phase of the munition's response. This provides one point in the spectrum. To measure the portion of the spectrum of interest, we sweep the frequency of the driving signal from the lowest frequency to the highest frequency. In the case of munitions, we generally measure the spectrum in the range of 1 to 30 kHz. The driving power required to measure a munition's acoustic spectra is approximately 1 mW and the vibrations induced are approximately 100 A^{o}, (orders of magnitude below the vibration levels induced by ordinary handling of munitions).

A single ARS measurement will not detect every mode of vibration, because the receiving transducer measures motion in a single direction only. Consequently, the measured acoustic resonances will be a subset of the vibration modes. Furthermore, the amplitudes of the resonance peaks will vary with measurement location. This can be understood by recalling the standing wave interpretation of a mode. If the driving and receiving transducers are located near the tops of waves, a large response will be measured. If they are located between waves, a smaller response will be measured. As a consequence, while the peak locations of an ARS measurement are robust and insensitive to transducer placement, the peak amplitudes are not.

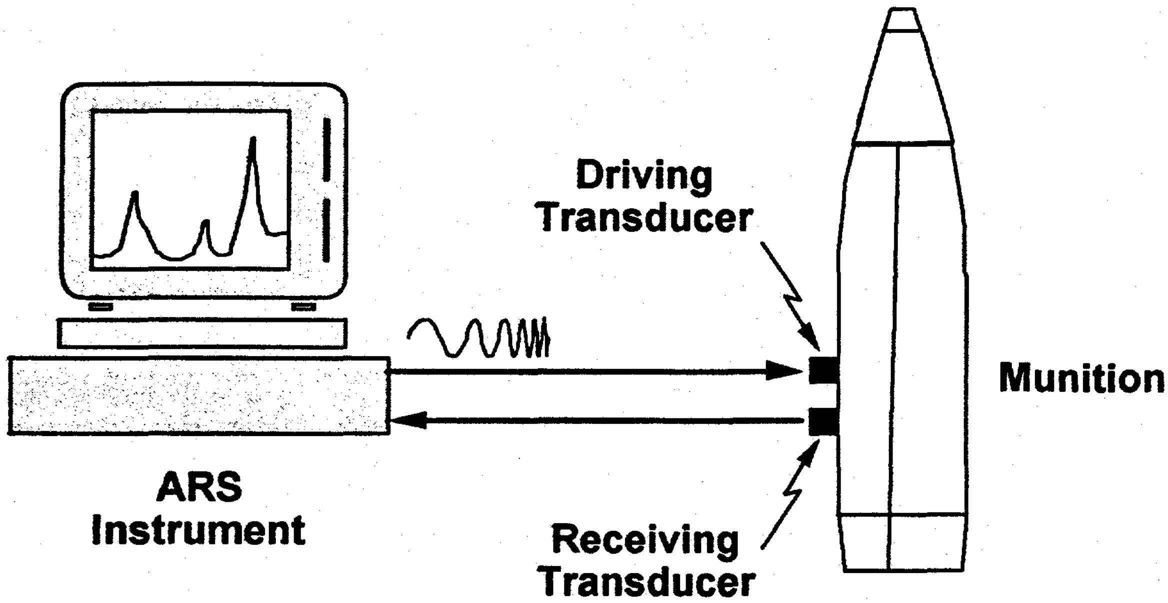


Figure 6. ARS Measurement Setup

1.5 Basics Of ARS Discrimination

Figure 7 illustrates the clear difference between the acoustic spectra of a solid and a liquid filled munition. The upper graph shows the spectrum of an M105 TNT-filled munition. It displays the characteristics of a solid munition, a small number of very wide resonance peaks. If you tap this munition lightly, you hear a thud. In contrast, the spectrum at the bottom is from a GB-filled 155mm munition. It displays the characteristics of a liquid-filled munition, i.e., a large number of very sharp resonance peaks. If you tap this munition lightly, you hear a ringing sound. This example clearly shows the difference in acoustic spectra of two very different items.

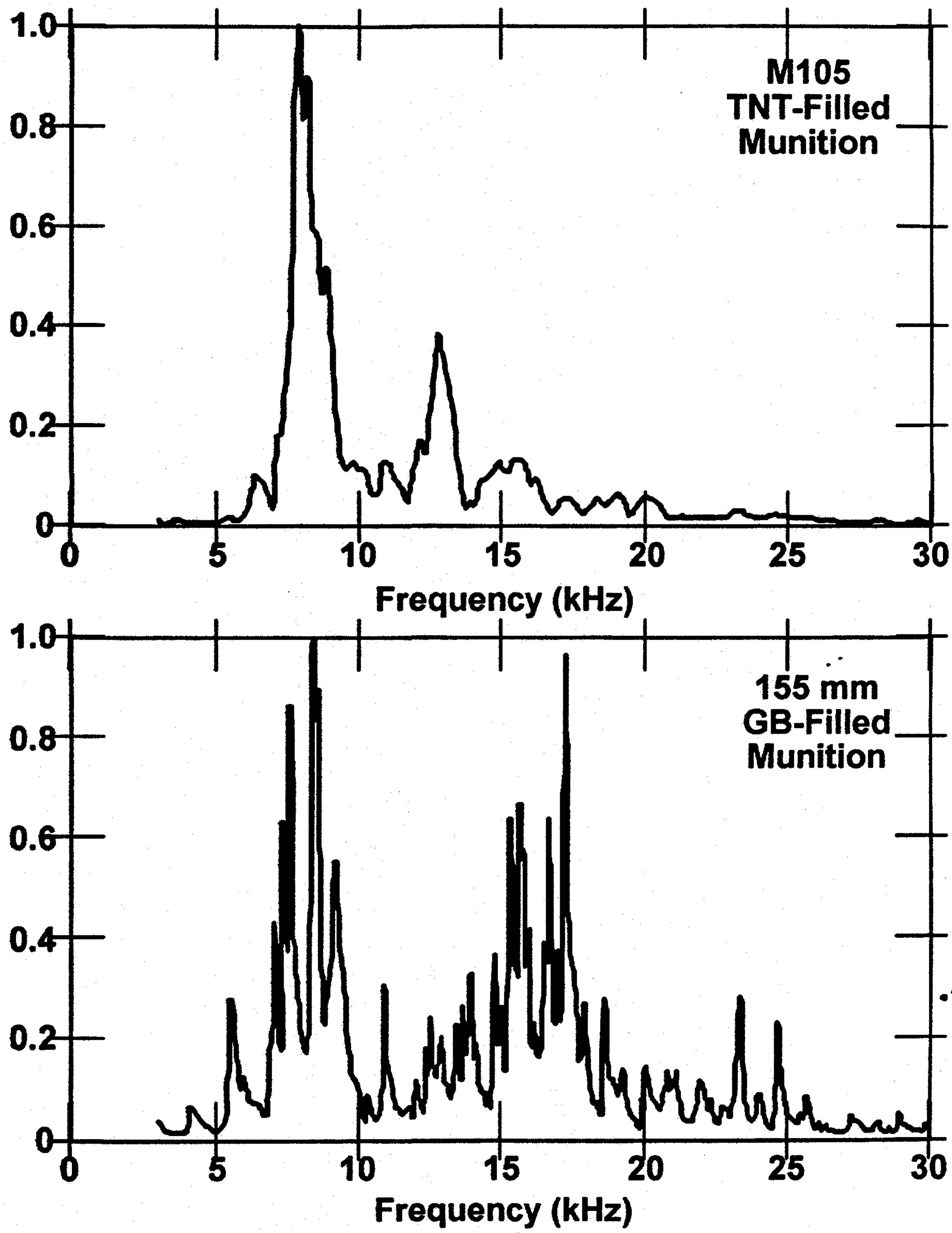


Figure 7. Solid (a) vs. Liquid (b) Filled Munition

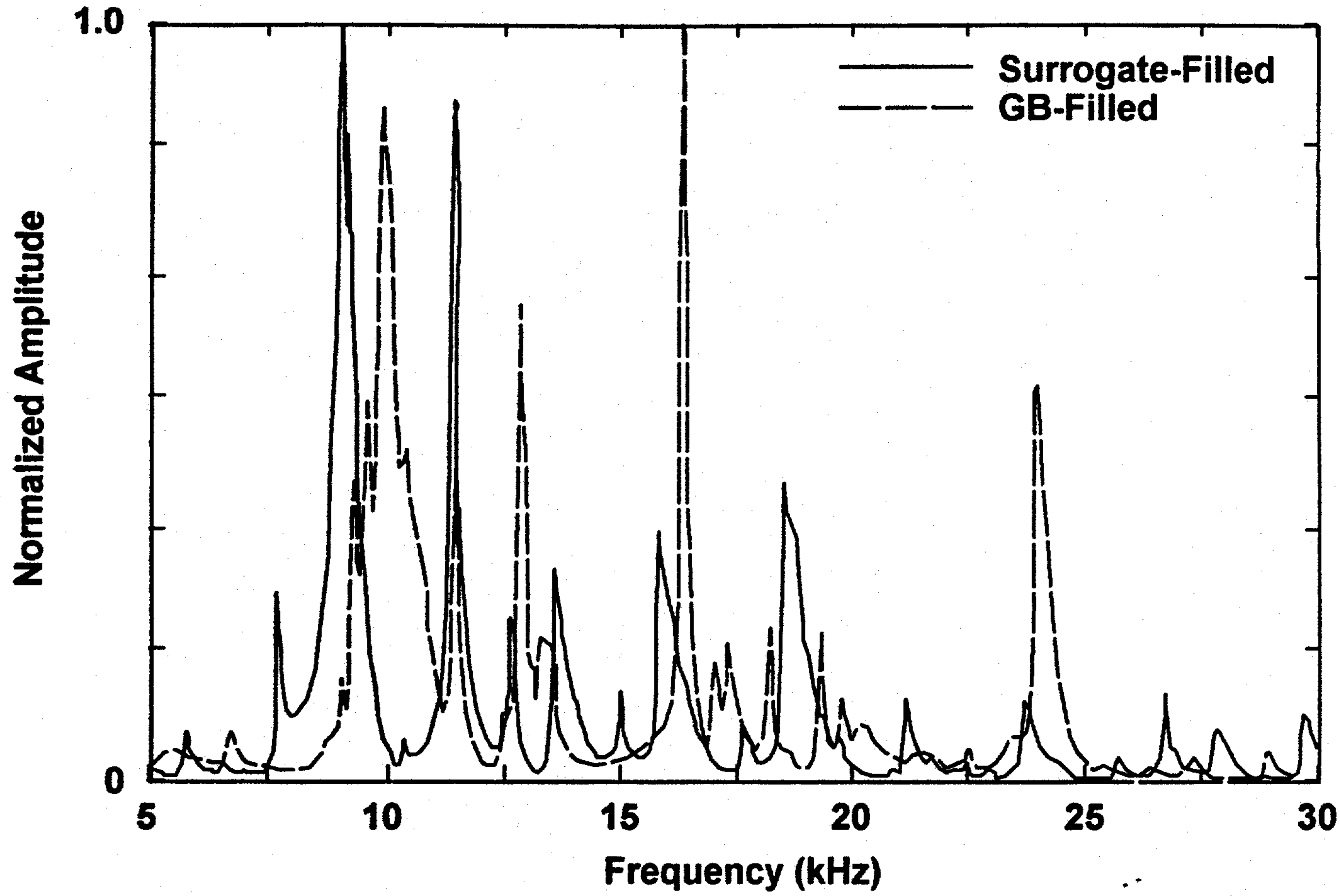


Figure 8. Distinguishability of Fill Types - GB vs. Surrogate

Figure 8 shows the spectra of two items that are more similar, two liquid-filled 155mm munitions. The dotted spectra is from a GB-filled munition, while the solid spectra is from a munition filled with ethylene glycol, a surrogate material. Although both spectra have similar numbers of peaks with similar sharpness, the peak locations are significantly different. The differing locations of these peaks provide a basis for discriminating between these two munitions, even though they differ only in their internal fill material. The shell casings and structure are nominally the same.

Resonance peak locations provide the basis for an acoustic signature of a munition, as shown in Figure 9. A munition is classified by comparing its signature to a prerecorded library of signature templates. In the library, each template corresponds to a different munition type. If a suitable match is found in the library, then the unknown munition has been classified. For example, the signature of a 155mm munition with unknown fill might be compared with library templates of 155mm munitions containing GB, VX, and TNT. If the signature matches one of the templates, then the fill type has been classified. Alternatively, if a number of munitions have been declared to be of a single class, then a sample of the items can be used to generate a template. The template can then be used to verify the similarity of the remainder of the items.

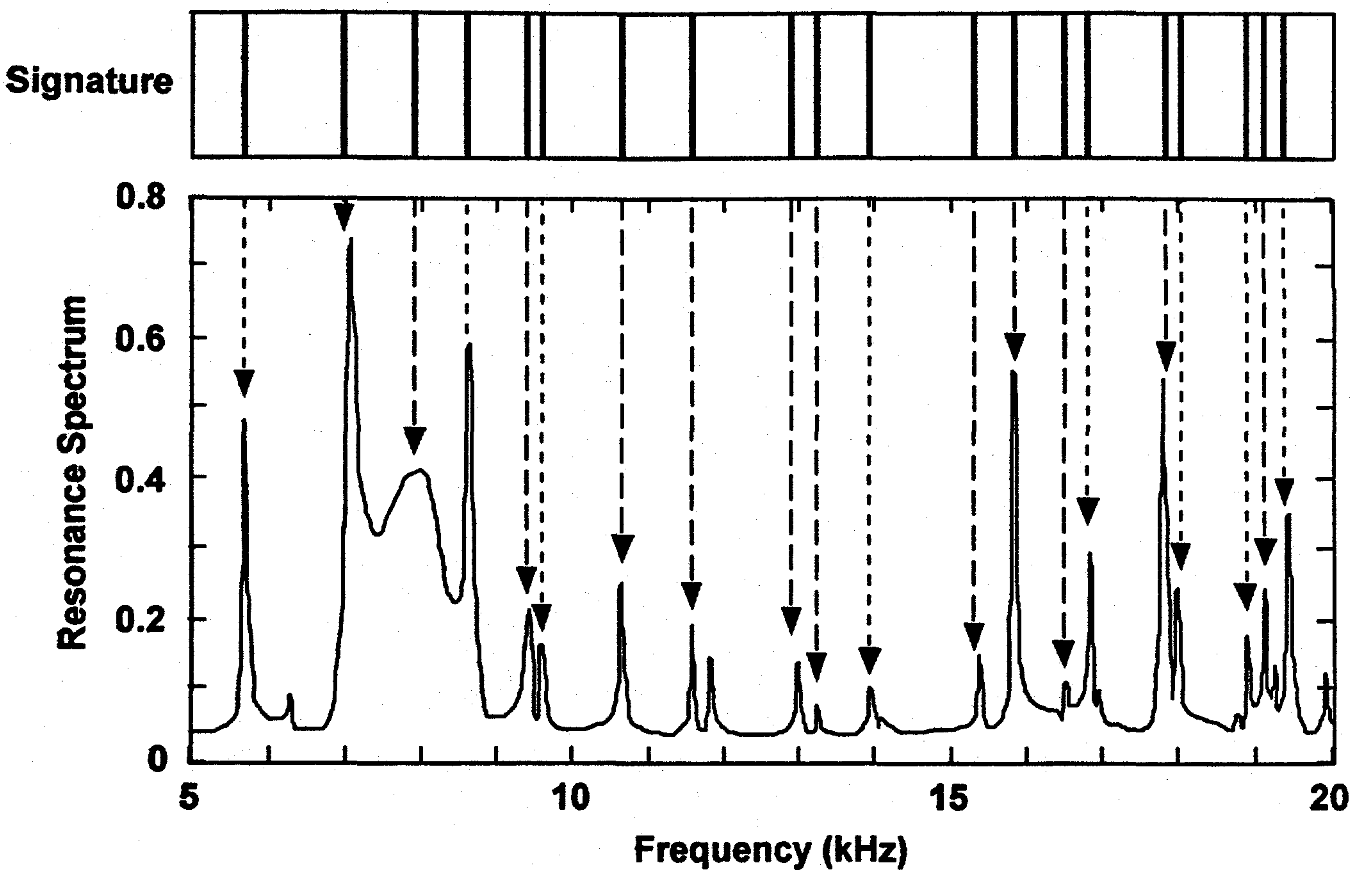


Figure 9. Acoustic Signature

1.6 ARS CW Classification Premise

Figure 10 summarizes the central concept of ARS chemical munition classification. The technique is based on three premises: first, that a given munition possesses a set of well-defined and reproducible resonant frequencies, i.e., its acoustic spectrum; second, that a subset of these resonant frequencies can be excited and detected (the specific subset will depend on the manner of excitation and measurement); and third, that munitions of the same kind and fill type have nominally identical sets of resonant frequencies. Variations will occur only on a finer scale, depending on the type and condition of the munition.

Based on these three premises, unknown munitions are classified by finding the best match of their measured resonant frequencies to a set of reference templates. The basic steps in the ARS classification process are to first build a library of reference templates, then to compare unknown munitions to these templates.

To build a template, we begin with a set of exemplars, generally eight to twelve munitions that adequately represent the munition type. The condition of these munitions should match, as closely as possible, the conditions of the unknown munitions to be identified. For example, they should be of the same age and should have been stored under the same conditions. Likewise, they should be measured in the same manner as the unknown munitions. ARS measurements are taken at several locations on each of the exemplars. This provides a set of spectra that captures the finer scale variability among munitions and among measurement locations. The resonant peaks are extracted from each measurement. The peaks from the different measurements are then grouped or clustered to identify like resonant peaks. From each of these clusters, a feature is identified. In Figure 10, these features are represented by bars, where the center of the bar represents the average resonant frequency, and its width represents the expected variability. A template for a munition type consists of a set of these features, each representing an individual resonance frequency.

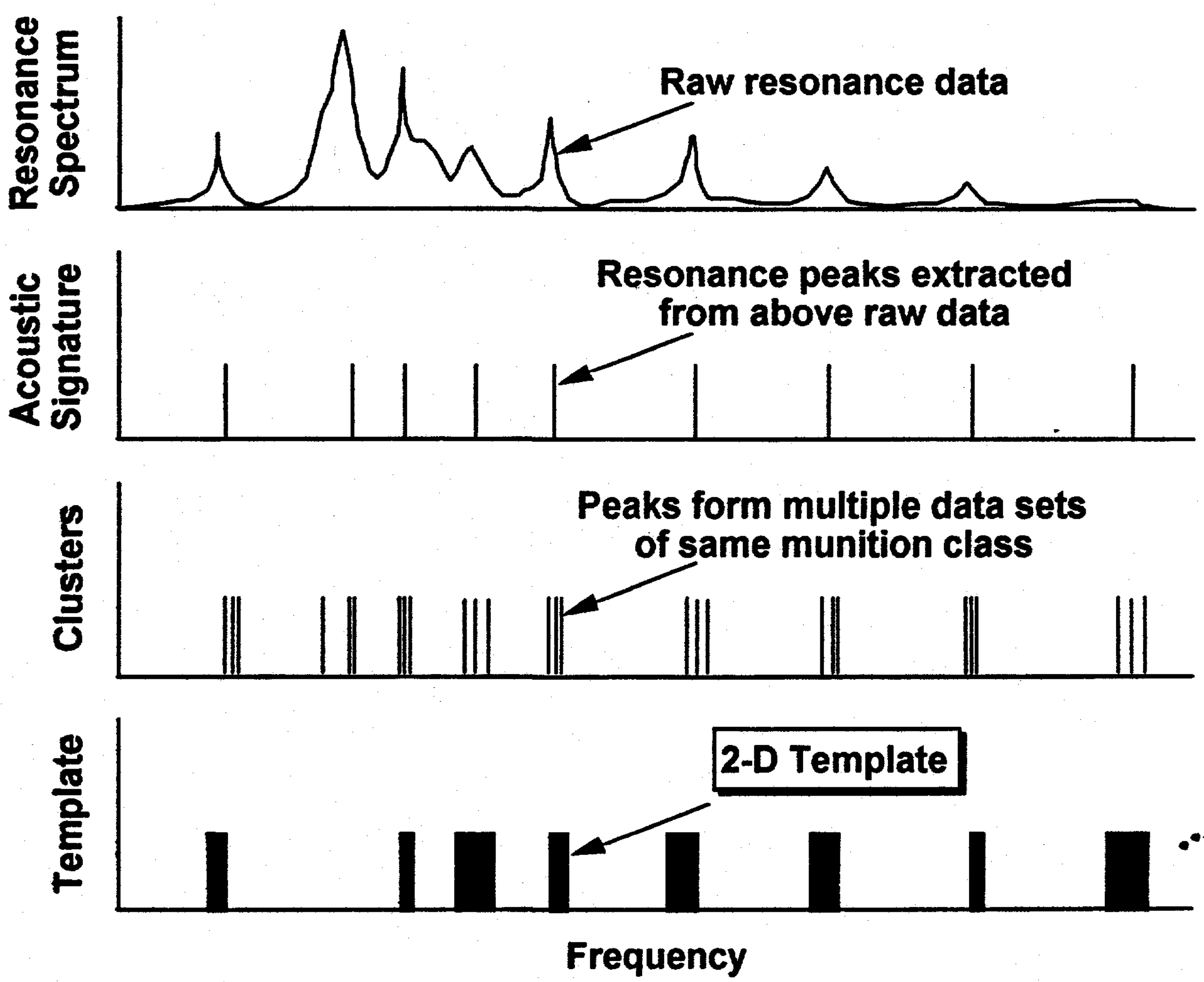


Figure 10. Template Generation

The spectra of unknown munitions are matched to a template by the simple correlation process illustrated in Figure 11. First the peaks are extracted from the spectrum. Then the peak locations are compared with each template. The match is scored by computing the percentage of template bins that contain peaks. The munition is classified by the best matching template, subject to a minimum score requirement. If the munition does not match any of the library templates, then it is labeled as unknown.

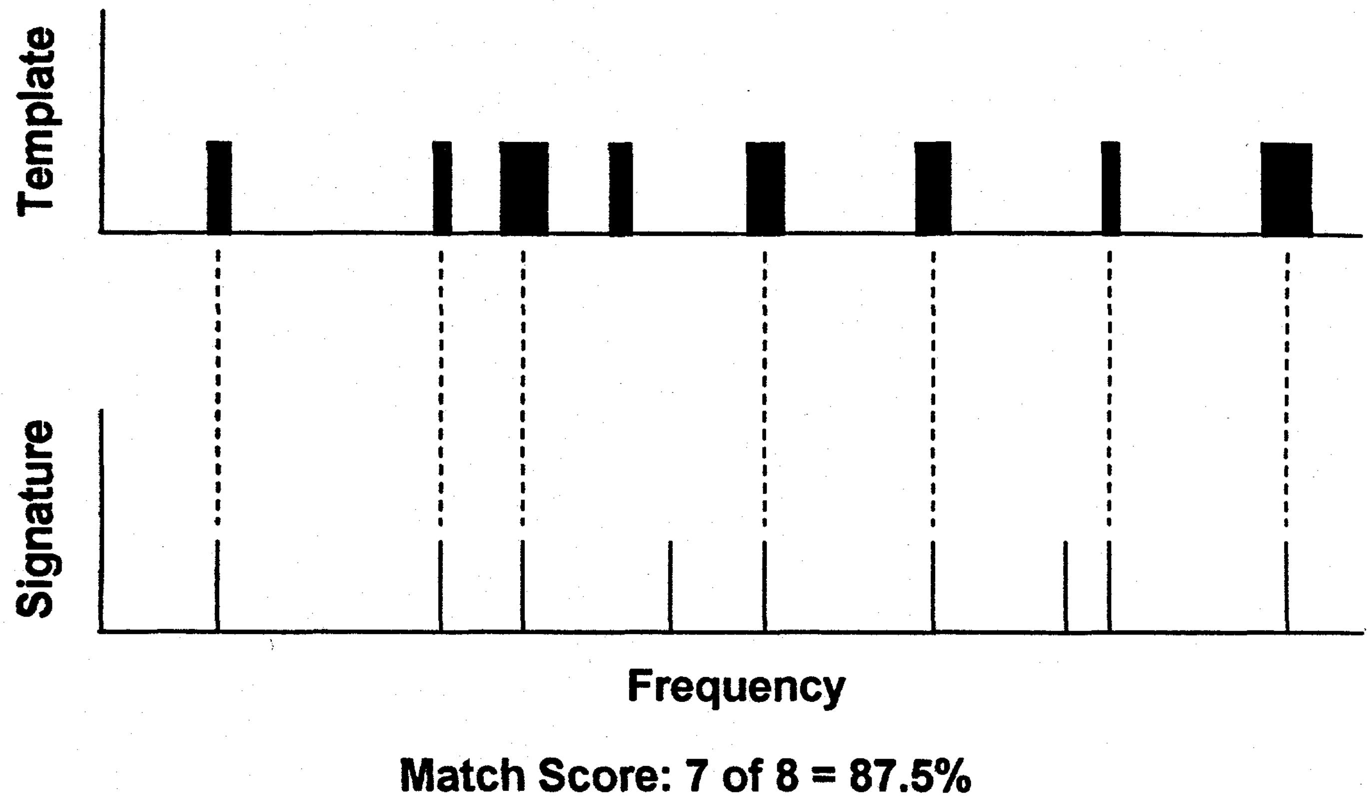


Figure 11. Template Matching

1.7 ARS Field Experience

ARS prototype systems have been field tested on CW munitions in two exercises at the Tooele Army Depot in May 1991 and August 1992. In these exercises the ARS systems were tested on the wide variety of CW munitions and bulk storage containers listed in Figure 12. Although ARS provided valuable information on all classes of items, we found it to be most useful on CW munitions, such as 155mm artillery shells. The smaller size of the munitions makes it easier to excite their body resonances. In addition, the large number of munitions typically found at storage sites makes munitions an attractive candidate for the fast-screening capability of the ARS technique.

Item	Type	Qty Tested
1	105-mm GB	51
2	1-ton GB	49
3	155-mm GB (low purity)	22
4	155-mm GB (high purity)	28
5	MC-1 bomb GB	68
6	1-ton mustard	58
7	155-mm mustard	39
8	155-mm HE M483A1 (ICM)	34
9	M107 HE	45
10	155-mm VX	44
11	155-mm WP	61
12	8-inch VX	24
13	M106 TNT	23
14	Spray tank VX+empty	50
15	155-mm empty	8
16	155-mm surrogate GB (property)	15
17	155-mm surrogate H (property)	17
18	155-mm surrogate VX (property)	17
19	155-mm surrogate GB (nuclear)	15
20	155-mm surrogate H (nuclear)	15
21	155-mm surrogate VX (nuclear)	15
22	155-mm surrogate sand	8
23	1-ton surrogate	22
	Total Number of Measurements:	728

Figure 12. Items Tested at Tooele, August 1992

We generally found the ARS measurements to be very repeatable across different munitions of the same type. Figure 13 shows ARS measurements from six different 105mm GB-filled shells. Although the resonance amplitudes vary slightly from shell to shell, the basic resonance frequencies do not. We also found that the ARS measurements were relatively insensitive to storage conditions. This example shows ARS measurements from two different 155mm HE-filled shells, one measured in a pallet of shells and one measured as a stand-alone item.

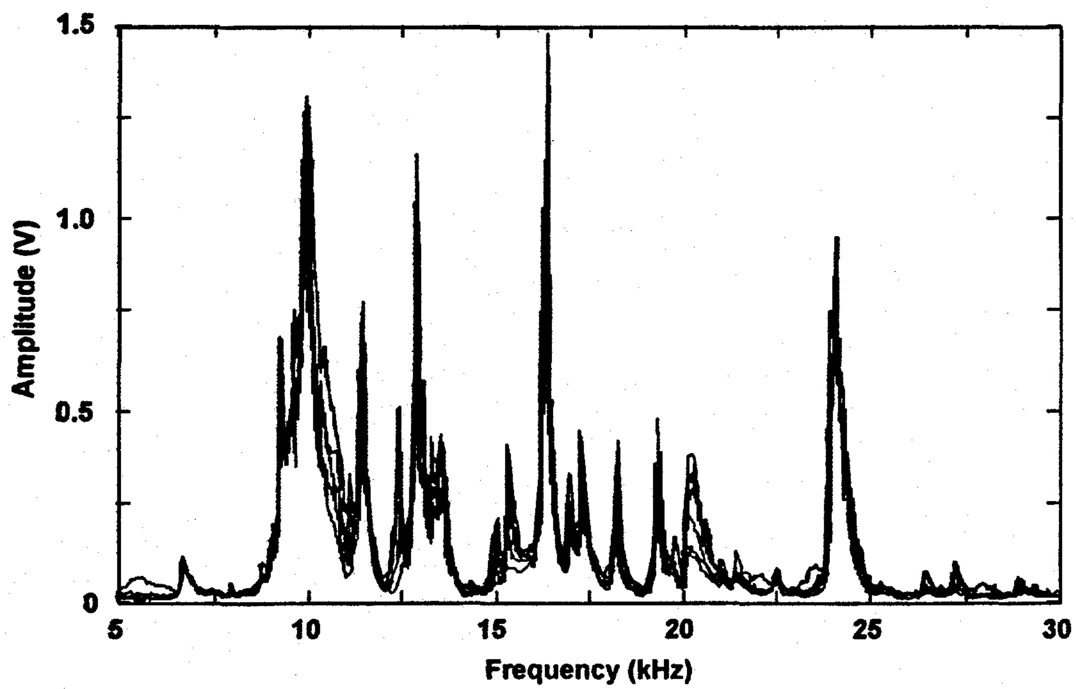


Figure 13. Repeatability Example

There are also detectable difference in the ARS measurements of munitions with different chemical fills. Figure 14 shows the frequency shifts between a 155mm shell filled with VX and a similar one filled with GB.

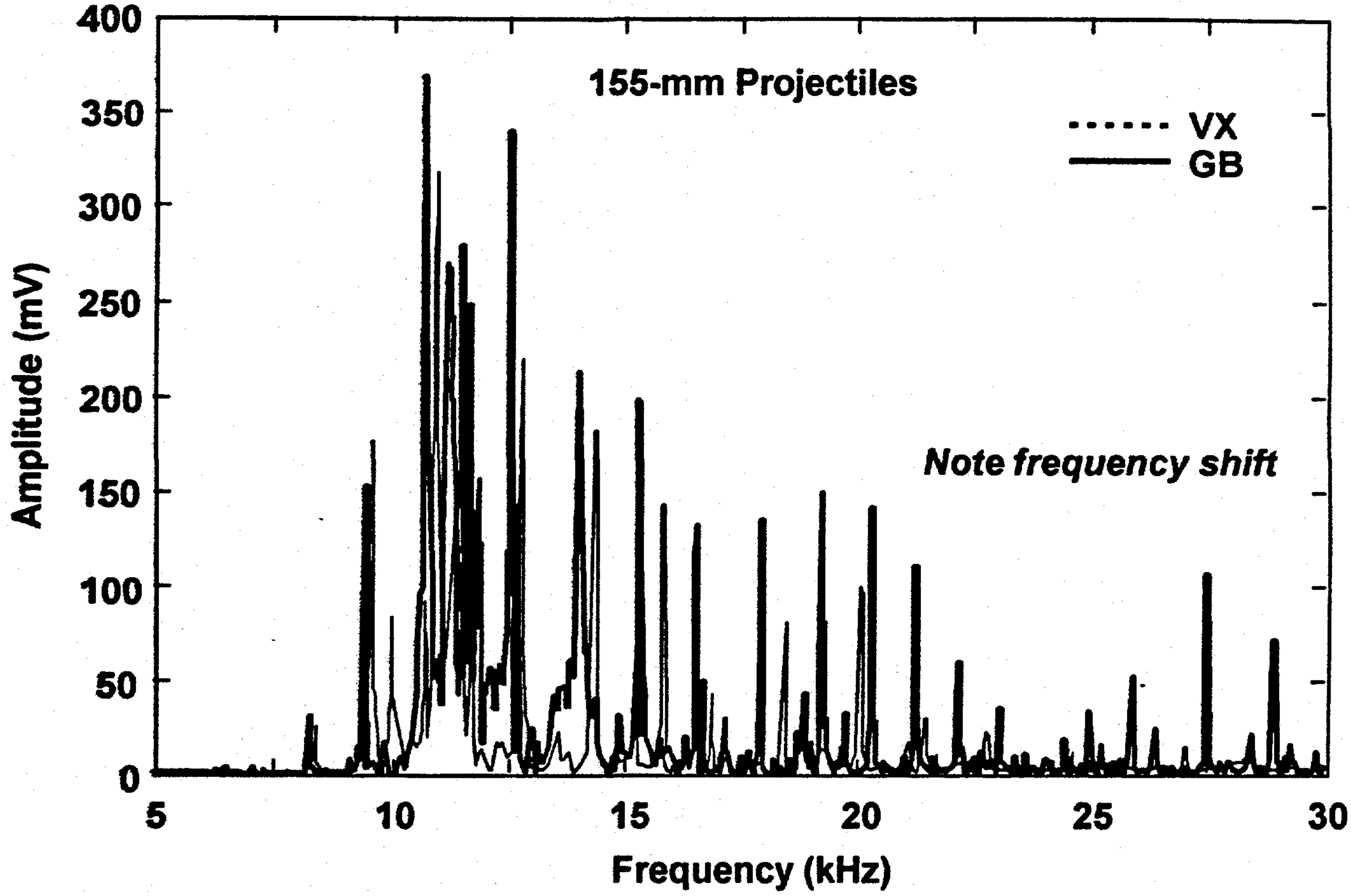


Figure 14. Liquid Fill Example

As a proof-of-principle exercise, we classified the 155mm CW shells (i.e., GB, VX, TNT, and white phosphorus) measured at Tooele. Library templates were developed for each munition type and then each measurement was compared to all of the templates. The results, shown in Figure 15, were consistently good, i.e., correct classification.

Agent Type	Number of Incorrect Categorization	Number of Samples (Tested)
Mustard	0	31
GB	0	46
VX	0	28
TNT	0	15
White Phosphorus	0	23

Figure 15. Tooele Classification Results

Chapter 2: ARS Hardware

2.1 ARS System Hardware

The ARS field instrument proposed for use by the OPCW for the CWC consists of the three basic hardware components shown in Figure 16. These components are a transducer assembly and cable, a digital synthesizer and analyzer, and a notepad computer.

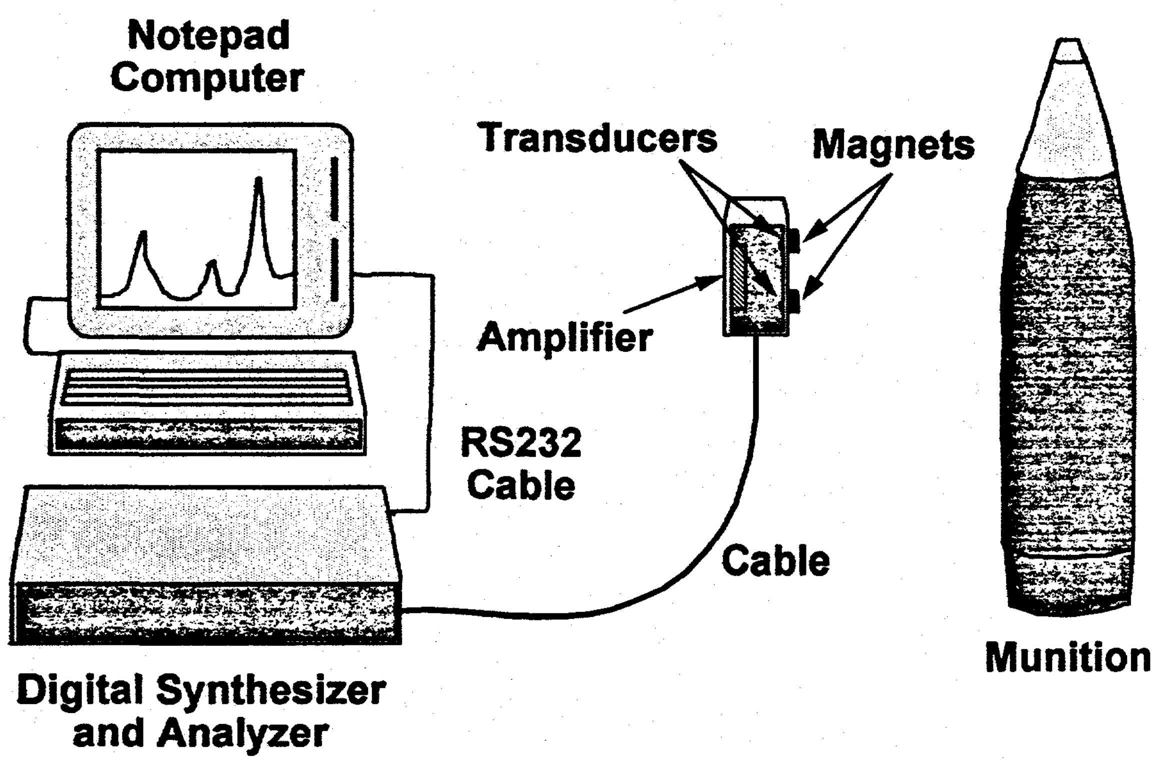


Figure 16. ARS System Hardware Drawing

The three components consist of the following:

- Transducer Assembly
  - Two piezoelectric transducers
  - Magnetic attachments
  - In-line amplifier & 10' or 50' cables

- Digital Synthesizer & Analyzer
  - Digital frequency synthesis
  - Homodyne processing and filtering
  - Small, light, low power instrument
  - Internal battery operation

- Notepad Computer
    - Toshiba T200 - 486 based PC
    - Operator interface, control, & data analysis
    - Removable data storage (PCMCIA Hard Disk)
    - Small, light, low power PC
    - Internal battery operation
    - Standalone mode

The transducer assembly contains two piezoelectric transducers, one to excite the munition and the other to measure its response. Glued to each transducer are neodymium-iron-boron magnets used to attach the transducers to the munition. The signals from the receiving transducer are amplified by a small in-line amplifier that can drive a 50-ft cable. The components are all housed in a light aluminum frame for ease of handling.

The digital frequency synthesizer and analyzer generates the swept sine wave drive signal and measures the response signal. Homodyne processing is used to eliminate interference outside the measurement band. The response is digitized and sent to the notebook computer. This small, lightweight analyzer runs on an internal rechargeable battery. The battery life is 4 to 6 hours, depending on the number of scans taken. The internal battery can be recharged in about 2 hours.

The final component, the notebook computer, is a commercial 486-based Toshiba T200. The computer provides the operator interface, measurement control, data analysis, and data storage. All data is stored on a removable PCMCIA 105MB hard disk. The unit is small and lightweight, and runs on internal rechargeable batteries. Each battery provides 4 to 6 hours of operation. The batteries are removable and can be changed in the field provided fully charged batteries are available. The internal battery can be recharged in about 2 hours.

2.2 Hardware Overview

The equipment provided with the Acoustic Resonance Spectroscopy Instrument provides for a number of different configurations in order to provide the maximum flexibility to the field operators. The equipment provided consists of the following items:

A. DSA300 Data Acquisition Module
B. Toshiba T200 Computer (Notepad)
    B1. Keyboard (Optional)
    B2. PCMCIA Hard Disk
    B3. Stylus (Pen)
    B4. Floppy Disk (External)
    B5. Cables for Floppy Disk & Printer Port
C. Sensor Cables (DSA300 to Sensor Heads)
D. Sensor Heads (SHD300)
E. PC TO DSA Serial Cable (PC-DSA)
F. Soft Pouch (Single Person Data Collection)

G. Spare Battery for DSA300
H. Spare Battery for Notepad Computer (Li-Ion)
I. Battery Charger for DSA300
J. Battery Charger for Notepad Computer
K. AC Plug Adapters (U.S. to European)

In the simplest configuration, only items "A", "B", "C", "D", and "E" are required for data collection. The rest of the items provide flexibility in battery life, battery charging, use of the computer for report writing and other tasks beyond data collection.

The soft pouch (item "F") is intended to simplify single-person operation of the ARS300 system for field data collection. The pouch holds the DSA300, the T200 Computer, and the cables and sensor head. When the system will be used while wearing gloves and mask, it is advisable to configure the system (i.e. wire up the interconnections) before "suiting up".

The chargers for both the T200 and DSA300 are 100 - 240 VAC auto-sensing. The AC plug provided is a USA 115VAC, 3-prong standard plug. In order to use these chargers on AC power systems around the world, a "plug converter" is required. While some plug converters are provided with the system, it is recommended that plug converters (Qty 2 per system) specific to the country of intended use be acquired prior to a field inspection.

> Note: With flexibility comes potential confusion, therefore the following sections will attempt to clarify the various hardware configurations that are possible with this set of equipment.

2.3 Hardware Configuration

2.3.1 Field Configuration

The minimum configuration for data collection consists of the DSA300 (Item "A") and the Notepad Computer (Item "B") in addition to the sensor and serial cables (Items "C&E") and sensor heads (Item "D"). The limiting factor in this configuration is the length of time that the Notepad's internal battery will power the computer (4 to 6 hours).

When the computer alerts the Operator of a low battery condition, the following procedure should be followed:

* Complete the operation currently under way, i.e., complete a scan, save data, add comments, etc.
* Turn power off after exiting the ARS program
* Remove the laptop's internal battery, and insert a fully charged internal battery.
* Turn computer back on and start the ARS program.
* Continue with the data collection operation.

You can continue in this manner, changing laptop internal batteries (assuming you have fully charged batteries available) until you reach the limit of the DSA300's internal battery (4 to 6 hours of normal operation). Note: You may wish to change out both the DSA300 battery and the Computer battery at the same time to avoid work interruptions.

2.3.2 Base Configuration

The maximum configuration for data collection consists of the DSA300 (Item "A"), the Notepad Computer (Item "B"), the sensor and serial cables (Item "C&E"), the sensor heads (Item "D"), the Computer keyboard (Item "J"), and the Computer External Floppy Disk (Item "K"). This configuration is suitable for entering "Site Specific" information, but not for field use (i.e. when scanning munitions).

2.3.3 Battery Charging Configuration

There are two battery chargers necessary for system operation. One charger (Item "H") provides power for the DSA300. The second charger (Item "I") charges the computer's internal battery. Note that the DSA300 and the Computer can be charged while operating, but this lengthens the time to reach a full charge.

See Appendix B3 for schematics showing the charging interconnections for both the DSA300 and the T200 computer.

2.4 ARS System Software

A critical part of the ARS system is the custom software that runs on the notepad computer. This software runs under the Microsoft Windows for Pen Computing Environment with the Win32s extension and provides a graphical user interface. Field functions can all be activated using the "pen" without the keyboard or with single keystrokes if the keyboard is attached. This makes it possible to operate the equipment while wearing protective gear. The operator interface is tailored to the anticipated inspection procedures. Measurements and munition types are all organized by inspection site. Prior to the inspection, a site database is set up and logistical information is entered. Munition types are defined, based on the list of declared items for the site.

During the inspection, the system is first used to record signatures from exemplar items for each munition type. From these data, templates are automatically generated and stored. The system is then used to measure and record signatures from munitions at the site. Munitions are classified in real time, as the measurements are made. Questionable items can then be noted and set aside for additional analysis.

The system stores each signature that it measures. These data can be viewed and printed out. Data can also be re-analyzed and compared with different sets of library templates.

The ARS software consists of the following:

Operating system - Microsoft Windows 3.1 with the Win32s extension and DOS, alternately Windows NT or 95.

Windows-based custom user interface

- Pen input of field functions (w/o keyboard)
- Single key operation of field functions (w/ keyboard)

User interface tailored to anticipated inspection procedures

- Measure and record signatures for verified examples of declared items
- Construct templates for each class of declared items
- Measure and record signatures and compare to template of declared class
- Differentiate between solid and liquid munitions without previous training sets

Post-measurement analysis capabilities

- View and print data
- Compare signatures to multiple templates

Data Storage

- Automatic file name generation
- User selectable "write-to-floppy" setting
- Data written only to removable storage media

In the field configuration (without keyboard), some fields, particularly the "Comment" field can be filled-in using the hand-writing recognition software provided by the operating system. Hand-writing recognition is not yet a well-developed technology. It is therefore recommended that hand-written comments be kept very brief. It is also recommended that the operator use block letters instead of script.

For more information, including how to train the hand-writing recognition engine, see the Windows for Pen Computing documentation.

Chapter 3: Site Inspection Scenario

3.1 Field Operation

A field inspection scenario is based on a two-stage process. The first stage consists of establishing a set of items that will form the "known set" from which a template will be generated. The "known set" can be assembled by randomly selecting 24 to 32 items and either:

* Assume all items are as declared, or
* Drill & tap and chemically analyze samples from each item, or
* Use PINS or some other NDE technique to verify the contents.

Once the "known set" has been determined, the ARS hardware can be used to develop a template that the system will then use as a basis for comparison. The second stage consists of scanning unknown items using the ARS hardware to determine if they match the templates created from the "known-set" of munitions.

3.2 Site Inspection Scenario

The ARS software program is based on the following site inspection scenario.

- When an inspection team arrives at a site to be inspected, the team either has, or is provided with the Site Name, ARS Hardware Operators, Munition Types to be inspected, etc. This information is referred to here as "Site Setup Information."

- The first data collection task involves collecting data to be used as a template for each munition type. It is recommended that at least 24-32 munitions be used in creating a template. If possible, the munitions should be selected at random from the entire population to be tested, and if multiple lots of munitions are present, every lot should be represented in the template set.

- Once enough data files have been collected to create a template, the operator should proceed to the create template menu item. The actual template creation is done by selecting data files to be incorporated into a template. If no files exist when the "Create Template" menu item is selected, an error message will prompt the operator to collect data in order to create a template.

- Once a template exists, the "Collect Data" menu item is designed to simplify data collection on as many munitions as the operator wishes to examine. Each time a data file is collected, the software will provide a comparison against all available templates. In addition, for 155 mm. munitions, the software will automatically differentiate between liquid and solid munitions without prior training.

- The "View and Analyze" menu selection is intended for use as an off-line operation. This menu selection allows the operator to review data files collected earlier. It also allows comparisons to be made between the data file and the other templates stored within the computer. An additional function of "View and Analyze" is to allow printing of each individual data file to a compatible printer.

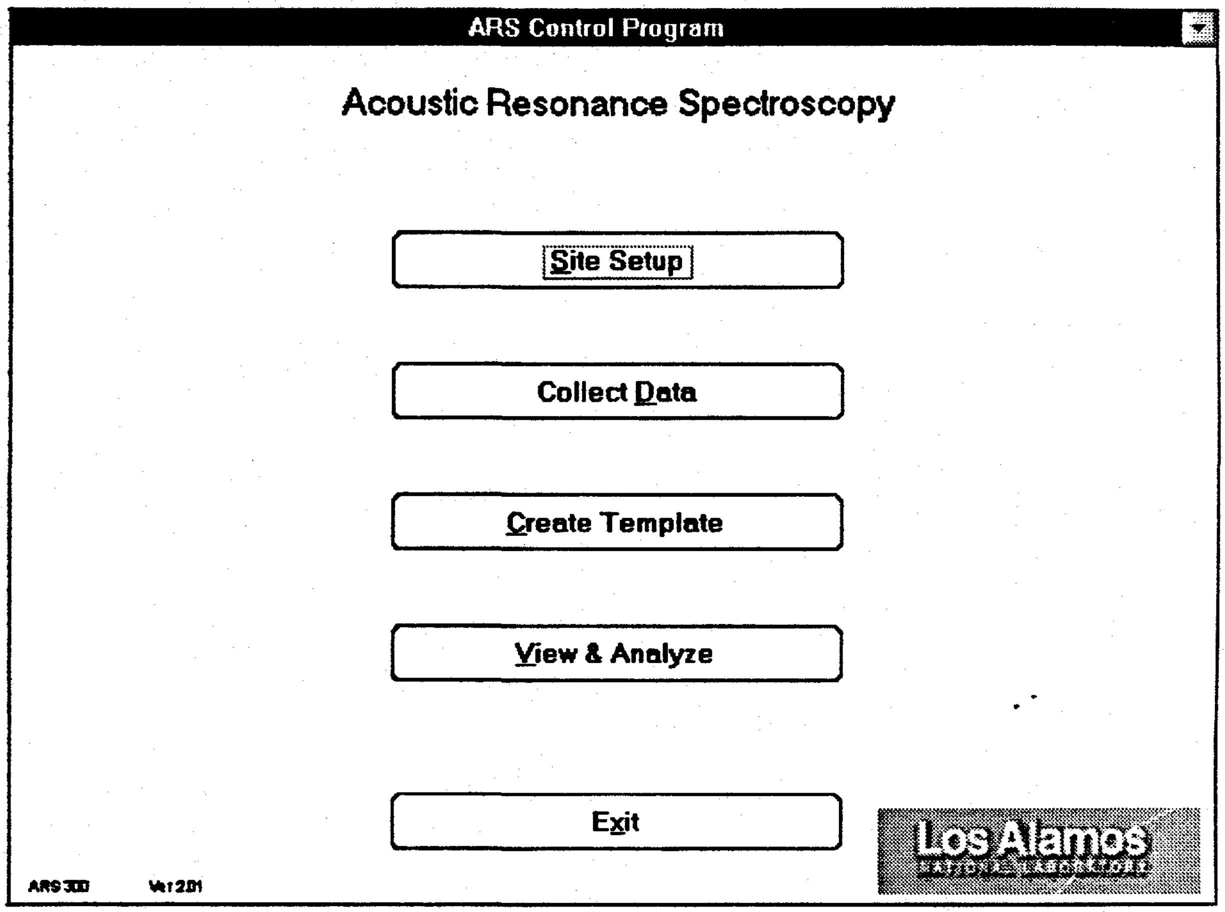


Figure 17. Opening Screen for ARS Program

Figure 17 shows the opening ARS screen. Note that the sequence of events flows from "Site Setup," to "Collect Data," to "Create Template," then back to "Collect Data." The "View & Analyze" selection is drawn last because it serves an off-line function, as described above. The underscored letters indicate the keyboard selection that will activate that function.

3.3 Software Operation

The ARS version 2.01 system software uses DOS and Windows for Pen Computing with the Win32s extension as its operating environment. In addition, a separate version of the ARS software will run on Windows NT or 95 (the Setup program will install the correct version). The ARS software user interface behaves as a Windows program and conforms to Windows conventions, except that user inputs that could reasonably occur while the user is in full personal protective clothing are designed to operate from a "pen" as opposed to a keyboard. This manual assumes the user has a reasonable knowledge of Windows programs and PC compatible computer operation.

When a sample is acoustically scanned, the algorithm evaluates that scan by comparing it against all available templates instead of against just one template. The result of this evaluation is to indicate which template most closely matches the scan.

If it is enabled, the software will also evaluate the fill material of 155 mm. munitions as either solid or liquid without the need to create templates. If the munition is not clearly either a solid or a liquid, the software will return "indeterminate". When this occurs, it is recommended that the user perform additional scans at different points on the munition to resolve the "indeterminate" reading. Also, if the munition is identified by the user as being a size other than 155 mm., the software will return "indeterminate." The limitation to 155 mm. munitions results from a lack of data on other munition sizes. It is hoped that, in the future, this limitation will be removed.

3.4 System Setup

Remove the DSA300, cables, sensor heads, and Notepad computer from their packing cases and interconnect the cables according to Section 2.3.1 (field configuration) or 2.3.2 (base configuration). Turn computer power on by pressing the power switch and holding it momentarily (power can be turned off (toggle style) with exactly the same action). The DSA300 power can be switched on now or just before starting the ARS program. While using the ARS software, do not turn off or unplug the DSA300. If the software loses communication with the DSA300, simply exit the ARS software and restart it to reestablish communication.

When the system boots up, it will boot directly into the Windows operating environment. Double click (tap the pen twice) on the ARS icon within the ARS program group in standard Windows fashion. If the DSA300 has not been turned on, an error message "Unable to connect to DSA300, please check wiring" will appear. Click on "OK" (or hit return) to bypass this message. The next screen is the top level ARS program menu.

In all cases, the standard Windows convention is followed (when using a keyboard) except as follows:

- In all cases, the pen works like a mouse in a standard Windows application. This is the recommended way of selecting and activating functions within the ARS program, even when the keyboard is attached.

- In each selection, when a letter in the selection is underlined, the Windows convention is to hold down the "ALT" key and press the underlined letter.

  Within the ARS program, this convention works in all cases except in those instances when the operator might be expected to be wearing full personal protection clothing. In those instances pressing the underlined key without the "ALT" key will activate the function.

- In all cases, moving from field to field is done using the Tab key and selecting items within a field is done by using the cursor control keys.

Chapter 4: Software Navigation

4.1 Site Setup

Selecting "Site Setup" by pressing "S" or by clicking with the mouse brings up a "Site Specification" box (Figure 18). This box shows the Directory and Site Name last used, as well as buttons for "OK," "Edit," and "Select." If the Directory and Site Name are the desired selection, press Return to proceed. If not, click on the Select button or press Tab to move to the Select button, then press Return (Figure 19).

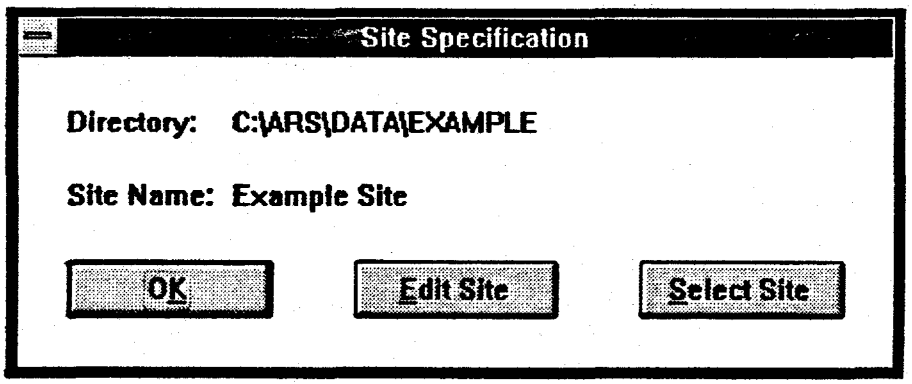


Figure 18. Site Specification Screen

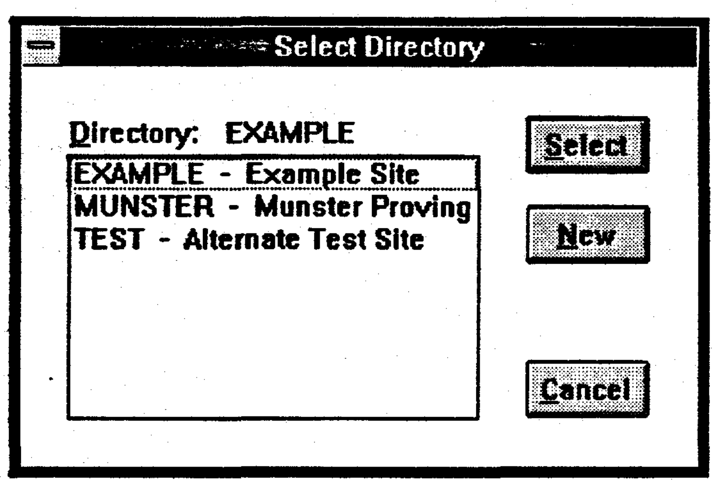


Figure 19. Select Directory Screen

If the directory you wish to select is already listed in the directory box, use the Tab key, the pen, or press the underlined letter "D," followed by the cursor control keys to highlight the selection you want. Then press Return.

If the directory you want is not listed (i.e., if this is a new site to be set up), tap the pen on the "New" button. Alternatively, press Tab to move to the button "New," then press Return (Figure 20). This will bring up a "New Directory Name" box and "Site Name" box. As always, the Tab key will move you from one field to the next. Note that the directory name is limited to 8 characters and must conform to standard DOS directory names. When complete, press the OK key to return to the previous screen.

> *Note: If you accidentally enter more than 8 characters, the system will truncate the name to create the directory.*

Select the new site just entered and press Return or tap the "Select" button. This will select the new site and return you to the previous screen (Site Specification). In this box, tap the "Edit" button or use the Tab key to move to the Edit button to add additional information about that site, then press Return (Figure 18).

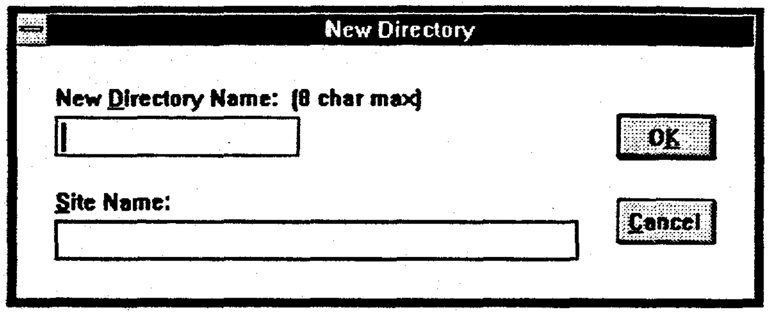


Figure 20. New Directory Dialog Box

Selecting Edit will bring up the "Setup Information" box. Using the Tab key to navigate from field to field, press the Add and Delete buttons (as appropriate) to add information to the Operators and Munition Types boxes. Note that the OTHER munition type is already in the field and cannot be deleted (Figure 21). Add all the munitions that will be scanned at the site.

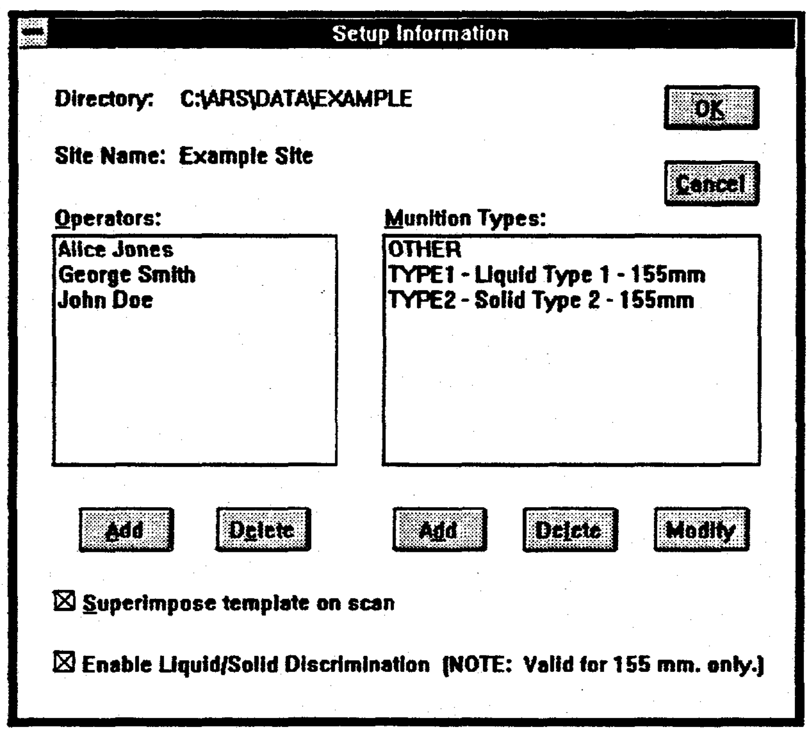


Figure 21. Setup Information Dialog Box

Checking the "Superimpose template on scan" box superimpose the applicable template on the scan response plot after the evaluation has been completed. The template will appear as a "bar code," with the bars matching a number of peaks in the scan response.

Checking the "Enable Liquid/Solid Discrimination" box causes the program to follow the normal template matching algorithm with a Liquid/Solid discrimination algorithm. This is valid only for 155 mm. munitions at the present time.

If the "Add" or "Modify" munition buttons are chosen, the Add Munition dialog box will be shown (Figure 22). This dialog allows each munition to be evaluated to be entered and assigned a directory for data storage. In addition, the munition size can be selected for use in Liquid/Solid discrimination. In the current release, only 155mm. munitions are evaluated by the Liquid/Solid blind (non-template based) algorithm. Other munition sizes can be selected, but will return "Indeterminate" when evaluated. The munition size will be displayed along with the name of the munition throughout the program. When modifying munitions, the user cannot change the directory name.

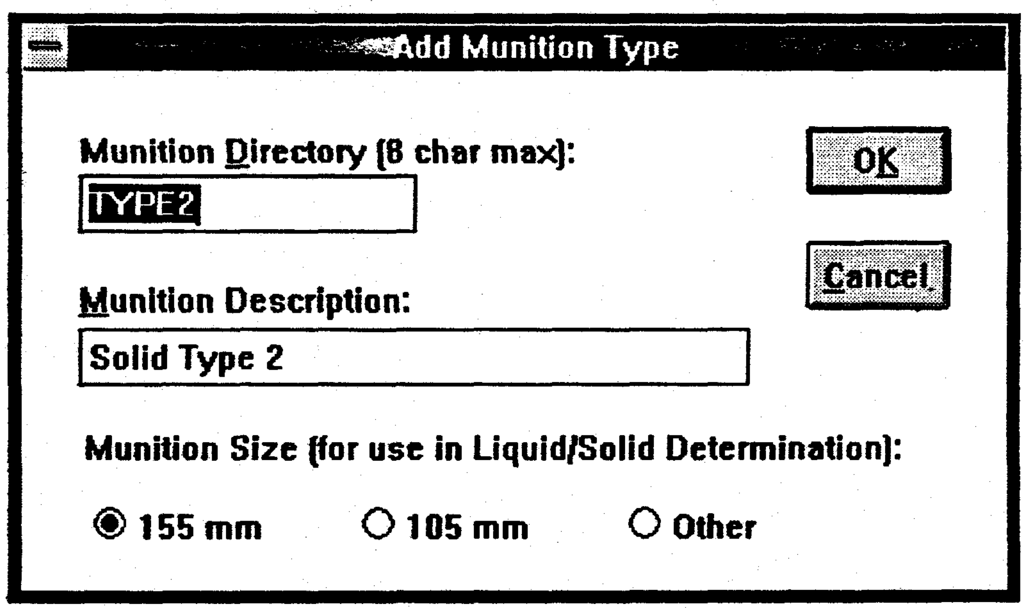


Figure 22. Add Munition Dialog

> *Note: Previous versions of the ARS software did not include munition size data, so any data files created previously will be evaluated as "Other." This can be corrected by returning to the Setup Information dialog box (Figure 21) and modifying the munition types. If no size information is listed after the munition description in the list box, the data set was created with a previous version of the software and should be modified to include size data.*

When you have filled in the information in the Setup Information screen, select OK to return to the previous screen. In this Site Specification box, tap the "OK" button or use the Tab key to move to OK, and press Return to return to the previous screen.

4.2 Collect Data (Template Generation)

Because no "templates" have been created for munitions at this site, the first data collection activity is performed to create a template. Selecting the "Collect Data" button will bring up the screen necessary for data collection (Figure 23).

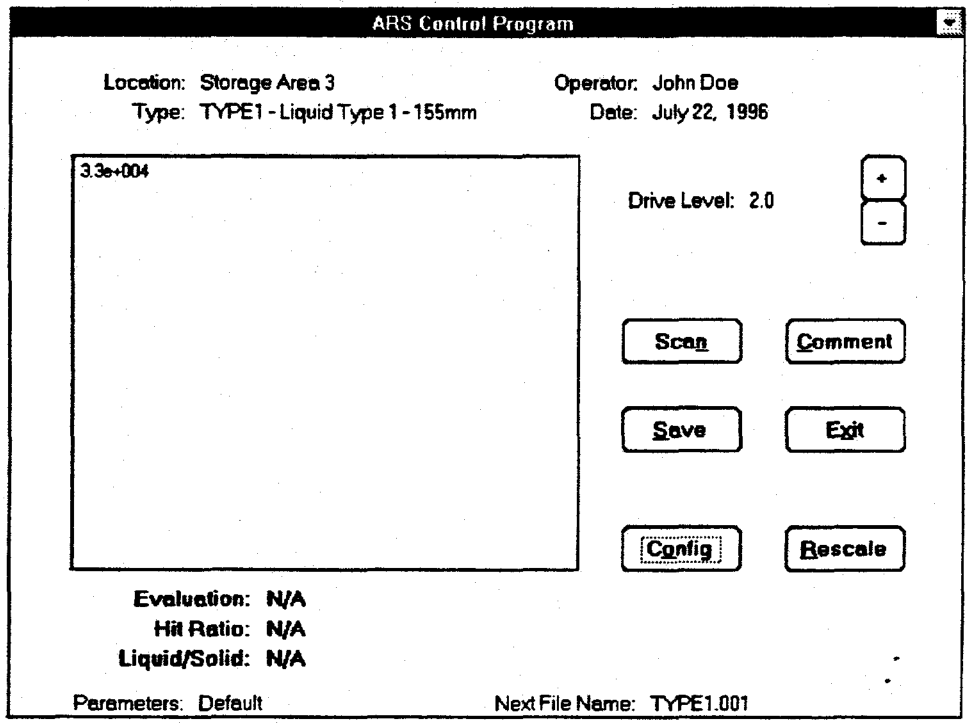


Figure 23. Data Collection Screen

At this stage, it is necessary to configure the information associated with this particular data collection instance (i.e., name of operator taking data and building name or number). Select "Config" to bring up the configuration screen (Figure 24).

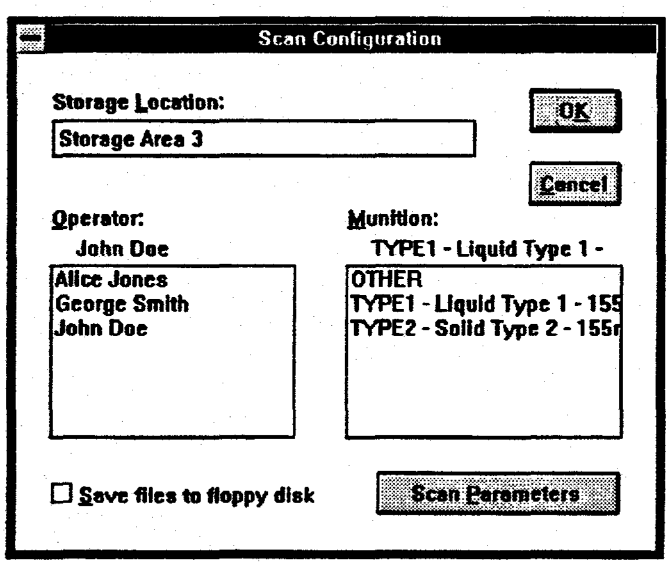


Figure 24. Configuration Screen for Data Collection

Using the "Standard Navigation Keys" (Tab key, Cursor control, Pen) enter the Building Description and select the "Operator Name" and "Munition Type" for this particular data collection session.

Note the "Save files to floppy disk" box. If this box is not checked, the files will be saved only to the removable hard disk, not to the floppy disk. If this is the case, transferring files to floppies will have to be done at the DOS prompt level or by using the Windows File Manager as a separate operation outside of the ARS program. If you check the box for "Save files to floppy disk," the saving to floppy operation will occur at the same time that the data is written to the hard disk.

> *Note: Saving data to floppy disk slows down the overall operation and requires that you have a formatted floppy disk in the floppy drive. It also requires that the external floppy be connected to the computer which is not the recommended field configuration.*

Selecting the "Scan Parameters" button will bring up a box that allows you to modify the start frequency, stop frequency, and frequency increment. This box will display the expected length of time for a single scan. It also allows you to reset the scan parameters to their default value (Figure 25).

> *Note: If you change the scan parameters, a file will result that has different parameters from files created previously. This will result in files that cannot be used together. We recommend that the default values be used, except in special circumstances. At the very least, all munitions of a given size should use the same scan parameters.*

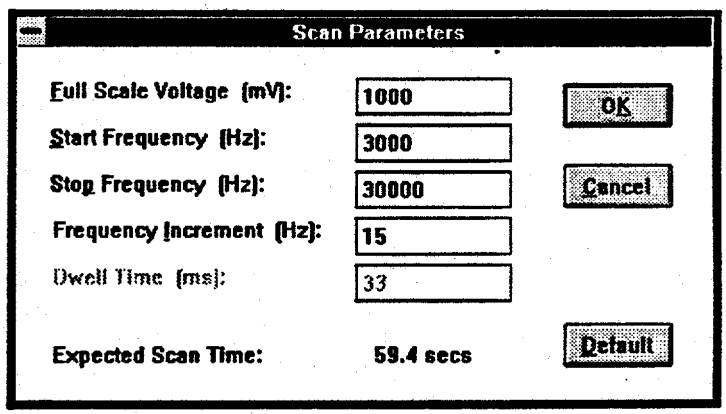


Figure 25. Modifying Scan Parameters

> *Note: Changing the default values so a new set of values appears as the default requires that the ARS.CFG file in the ARS subdirectory be edited by a knowledgeable individual. If the default values in ARS.CFG are changed, be advised that the product of the frequency increment and the dwell time must be 500. If this is not the case, the ARS program will display a "modified" parameter indication, even though the operator selects the default values.*

Selecting OK will return you to the previous menu with the selected values for Building, Operator, and Munition Type displayed at the top of the screen. At the bottom of the screen, you will see the Parameters indicated as default or modified.

Notice the Drive Level indicated as well as boxes with a "+" and a "-". Pressing the "+" or "-" keys will increase or decrease the drive level in 0.5-volt increments, except when the level is below 1.0 volt, at which time the "+" and "-" keys will increase or decrease the drive level in 0.1-volt increments. We recommend that you adjust the drive level until the maximum return signal is between 50% and 75% but does not clip (as evidenced by square topped response peaks). The computer will indicate a signal saturated condition as an aid to the operator in setting the proper drive level.

> *Note: Collecting data with saturated drive levels results in invalid templates, which will later result in invalid comparisons against the invalid templates.*

Once all information on this screen is as desired, run a scan and save it. Repeat the scan acquisition for all munitions that will be used to generate a template. Exit from this screen and return to the top-level menu, then go to the template generation screen.

> *Note: If you continue taking scans, the scan files will be saved without an evaluation (i.e., a comparison against a valid template) because no template yet exists. It is necessary to backtrack through the top-level menu in order to create a template before taking data for "production" purposes. Identifying the fill material as a liquid or a solid can take place at this time, however, since the Liquid/Solid discrimination algorithm does not require a template.*

In the lower right-hand corner is a field named "Next filename." The extension to this filename is a number that automatically increments as new files are saved. The asterisk following the filename indicates that the previous file has been saved. This is useful in cases where the scan appears inadequate (noisy, low return signal, etc.) and multiple scans are taken.

The "Evaluation" and "Hit Ratio" in each case will not be applicable because no templates exist. The "Liquid/Solid" evalutation will show indeterminate unless a munition size of 155 mm. has been specified and the liquid/solid determination has been enabled in the site setup. It is highly recommended that at least 24-32 munitions be scanned to create a template. The more scans used to create a template, the more accurate the template. Also, the munitions scanned should represent a good random sample from the entire group to be tested.

Exit from the data collection (for template generation) screen and return to the top-level menu.

4.3 Create Template

From the top-level menu, select "Create Template" to process the template generation. In this screen, you will see a "Selection" box with the current selection shown above the box and a list of available scans appropriate to that selection (Figure 26).

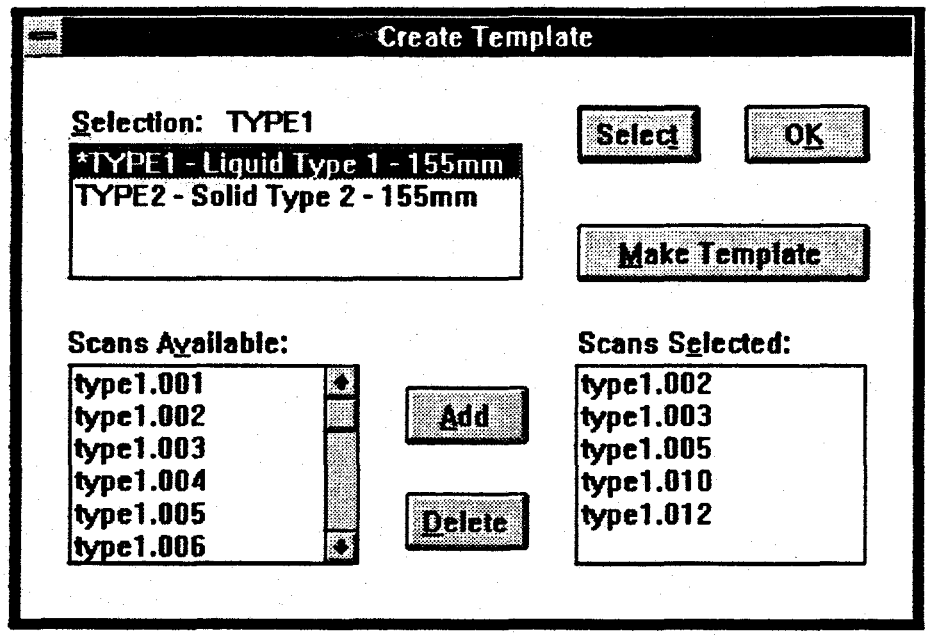


Figure 26. Template Creation Screen

Use the pen to select the desired item or alternatively use the *Tab* key to move to the desired field and use the cursor control keys to highlight the desired selection from the list. Use the *Tab* key to move to the "ADD" button, then press *Return* (or double-tap the scan file). This adds the individual file to the list of "Scans Selected." Scans can be deleted from this list by following a similar procedure using the "Scans Selected" list and the "Delete" button.

Once you have selected all the files to be included in that template, move to the "Make Template" button and activate it. The template creation may take several minutes; therefore, an "Abort" box is available that allows you to abort the operation. The "Abort" box also informs the operator of the file name being processed.

> *Note: An error message appears if one or more of the selected files has incompatible parameters. If this happens, the template creation is aborted. Delete the incompatible file from the list of "Selected Files" and press the "Create Template" button again.*

If no errors occur, a message will indicate that a template has been created and what type of munition the template applies to. Exit from this screen back to the top-level menu by selecting the "Exit" button.

4.4 Collect Data "Production"

At this point, a template or templates have been created for munitions at that site. The creation of templates can be done for an individual munition type, followed by data collection for "production" purposes or several templates can be created for different munitions types. Selecting the "Collect Data" button will bring up the screen necessary for data collection (Figure 27).

Note: Since scan evaluations are made against all available templates, having only one template available means that all scans will match that template. The only difference will be in the "hit ratio" displayed after an evaluation.

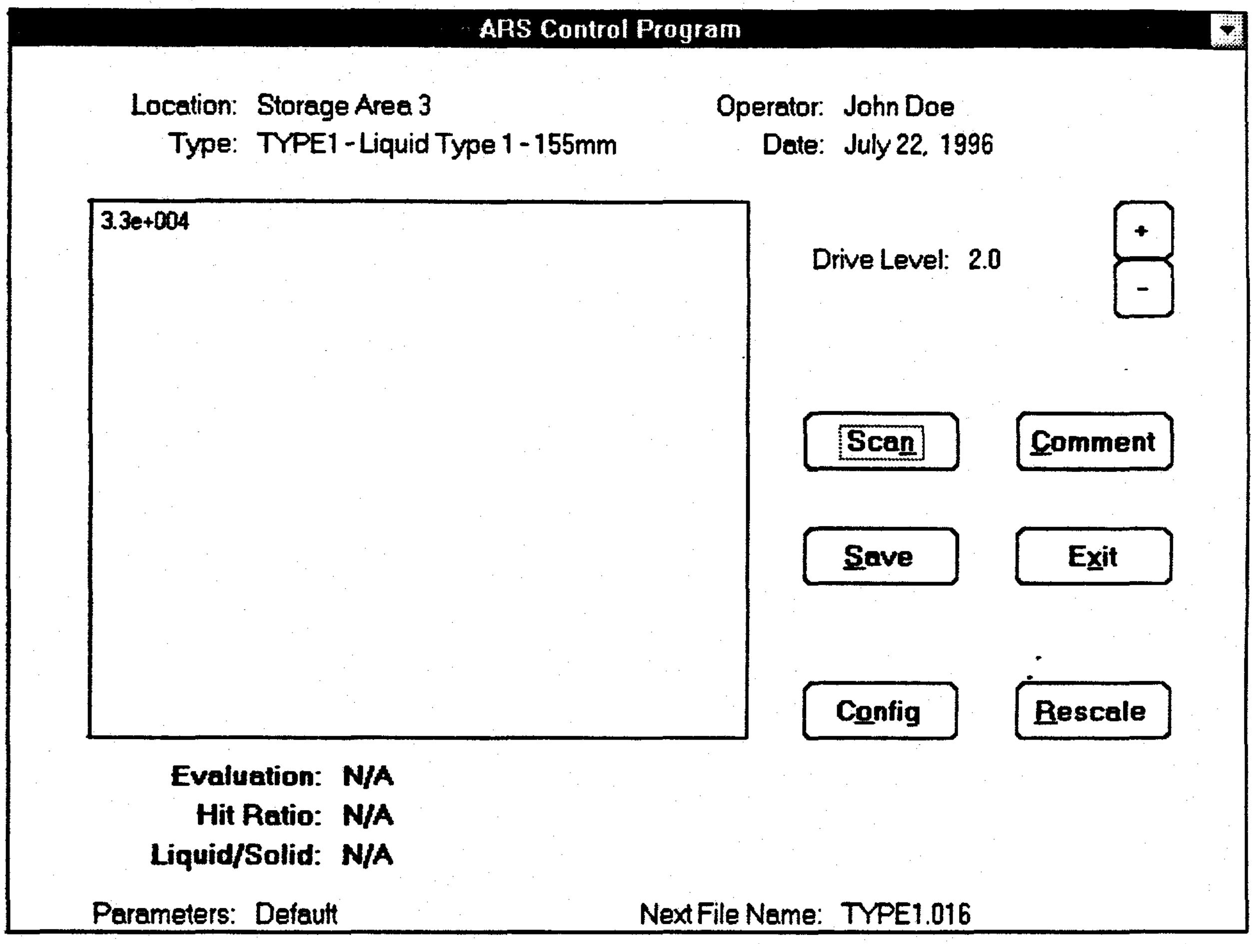


Figure 27. Data Collection Screen

At this stage, it is necessary to Configure the information associated with this particular data collection instance (i.e., Operator taking data, building name , and munition type). Select "Config" to bring up the configuration screen.

Note: If nothing has changed (i.e., building, operator, or munition) from the time the template was created, the default values will be appropriate and you can go directly to the "Collect Data" button. If changes have occurred, configuration will be necessary.

Using the "Standard Navigation Keys" (Tab key, Cursor control, Mouse) enter the Building Description and select the "Operator Name" and "Munition Type" for this particular data collection session.

Note the "Save files to floppy disk" box. If this box is not checked, the files will be saved to the hard disk only. If this is the case, files will have to be transferred to floppies at the DOS prompt level as a separate operation outside the ARS program. If you check the box for Save files to floppy disk, the saving to floppy operation will occur at the same time that the data is written to the hard disk.

> *Note: This slows down the overall operation and it requires that you have an empty formatted floppy disk in the appropriate drive.*

Selecting the Scan Parameters button will bring up a box that allows you to modify the start frequency, stop frequency, and frequency increment. This box will display the expected length of time for a single scan. It also allows you to reset the scan parameters to their default value.

> *Note: Changing the scan parameters between the template and the data files to be collected is not advisable. No valid comparison can be made in such a case.*

Selecting OK will return you to the previous menu with the selected values for Building, Operator, and Munition Type displayed at the top of the screen. At the bottom of the screen, you will see the Parameters indicated as default or modified. If the parameters are modified, at the very least the modified values should agree with those used in the template scans.

You will also notice the Drive Level indicated as well as boxes with a "+" and a "-". Pressing the "+" or "-" keys will increase or decrease the drive level in 0.5-volt increments. The default drive level is taken from the files that created the template. This value should be adequate unless you are taking data on a particularly dirty munition.

> *Note: If you adjust the drive level for a particular munition, the new drive level will remain in effect for the next munition. It is important that the operator look for an overdrive condition, resulting in signal saturation, on each scan. A saturated signal can result in an erroneous evaluation.*

Once all information on this screen is as desired, run a scan. Assuming the return signal looks "reasonable", save it and repeat the scan acquisition for all the munitions of interest. Exit from this screen and return to the top level menu when finished or when other factors cause you to stop the data acquisition.

If the Notepad computer starts beeping (indicating a low battery condition), follow the instructions given in Section 2.3.1.

When the data collection is complete, exit from the data collection screen and return to the top level menu.

4.5 View & Analyze

The "View & Analyze" menu selection is intended mainly for off-line (no DSA300) processing of data. When you select this option from the top level menu, you go into a screen that looks similar to the collecting data screen. The primary difference is in the selection of buttons available to the operator (Figure 28).

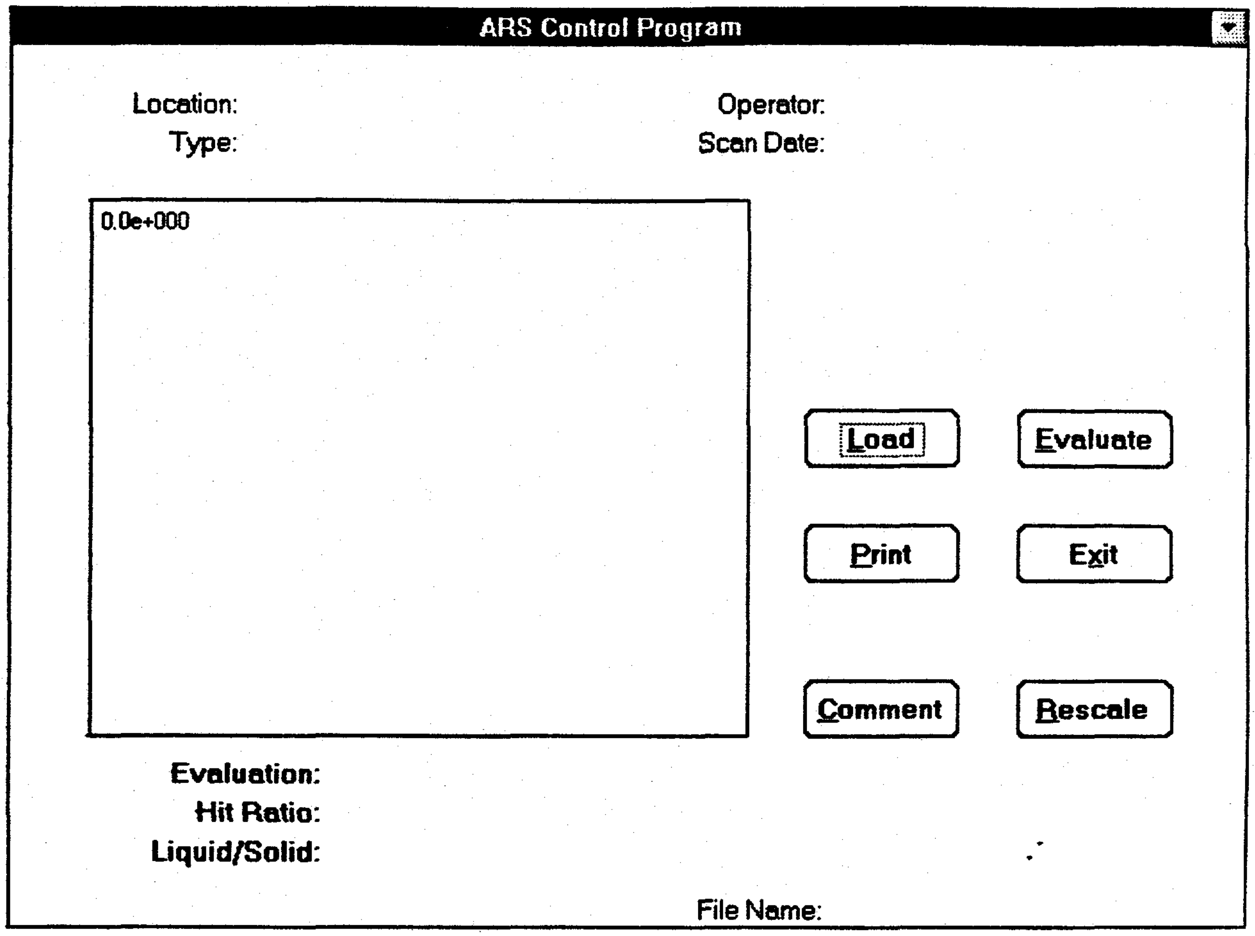


Figure 28. Viewing and Analyzing Files Off-Line

Selecting the "Load" button brings up the "Load Data File" box. The selection list offers a choice of the various munition types available for analysis. Use the pen or the *Tab* and cursor control keys and the "Select" button as before to enter the "Selection" box and select one of the file types. If data files are available for that selection, a list of those files will appear in the "Files" box. Once you have highlighted one of the data files, use the Tab key to move and activate the "Load" button.

All of the relevant information saved in that file is displayed including the scan. To see any comments that may have been entered at the time of the scan, select the "Comment" button. The "Rescale" button shows a more detailed view of the plot, but it hides all the other information except an "Exit" button.

When you select the "Evaluate" button, the scan on the screen will be compared with all available templates. The "Evaluation" and "Hit Ratio" lines at the bottom show how this particular file evaluates.

The "Print" button will print a copy of the plot, in addition to all the pertinent information associated with that particular file. The print function prints to the default Windows printer.

4.6 Exiting The ARS Program

Once you are finished with the ARS program, exit the program by tapping the "Exit" button at the top level menu. This will bring you back to the Windows Program Manager screen. To exit Windows, double tap the control bar or press "ALT" + "F" then "X" to exit Windows. When the message prompt asks if you want to exit Windows, press "Return".

> *Note: Wait until the screen returns to the DOS prompt before turning power off. The power to the DSA300 can be turned off at any time after exiting the ARS program.*

Appendix A: Configuration File and Command Switches

A.1 ARS Program Configuration File

The configuration file (ARS.CFG) resides in the ARS subdirectory of the computer's hard disk. This file is used to set all the default parameters used by the ARS program. The most common parameters to change are the start and stop frequency and the frequency increment. There are several other parameters such as drive level, full scale voltage, etc that can be changed. It is ***strongly recommended*** that only start and stop frequency, frequency increment, and drive level be changed for field use (and then only by knowledgeable operators). Changing other parameters could result in severe degradation of the function of the ARS program.

ARS Configuration File Listing

Directive	Default Value	Description
ROOT=D:\ARS\DATA	D:\ARS\DATA	Default data root directory (required)
STARTF;3000	3000	Sweep start frequency (Hz)
STOPF;30000	30000	Sweep stop frequency (Hz)
INCR;15	15	Sweep step frequency increment (Hz)
DWELL;33	33	Sweep frequency dwell time (ms)
DRIVE;20	20	Sweep drive voltage (2.0 volts)
PORT;COM1	COM1	Serial port for DSA300
FLOPPY;A:	A:	Floppy drive port

***Note:** None of the values listed below should be changed except under direction from the software developer.*

GRAPH;32767	32767	Graph plot range
FLTCLST;30	30	NFLATCLUSTER
MAXCLST;100	100	MAXCLUSTER
VCUTOFF;4	4	VARCUTOFF
VFACTOR;3	3	VARFACTOR
WINFRAC;150	150	WINFRAC
WININC;0.1	0.1	WININC
WINSIZ;8	8	MAXWINDOW
WSCL;1.6	1.6	WSCALE
NQSELECT;100	100	NQSELECT
#DEBUG;1	1	Debug mode switch
NEELC;1	1	Down scale constant
FSCALE;1000	1000	Full scale voltage (mv)
MATCH;0	0	Minimum match level (MATCH / 1000)
FEATFRAC;0.80	0.80	Minimum attendance level for cluster

Note: If you change the scan parameters, a message will indicate that an incompatible file will result. This is true if you attempt to compare two files (i.e., a file against a template) scanned with different parameter settings. We recommend that the default values be used, except in special circumstances. At the very least, all munitions of a given size should use the same scan parameters.

Note: Changing the default values so a new set of values appears as the default requires that the ARS.CFG file in the ARS subdirectory be edited by a knowledgeable individual. If the default values in ARS.CFG are changed, be advised that the product of the frequency increment and the dwell time must be 500. If this is not the case, the ARS program will display a "modified" parameter indication, even though the operator selects the default values.

A series of config file directives allow the internal statistics for the liquid/solid discrimination algorithm to be altered. When the directives are not present in the config file, the default values are used. Each set of statistics consists of two covariant matrices, four mean values, and an error factor arranged as follows:

Small munitions (used for 105mm. and Other settings):

Solid covariant matrix:

SS00=2187.41	SS01=-3.9361
SS10=-3.9361	SS11=0.2268

SSAW=663.731 Small solid average width
SSAR=1.47126 Small solid average ratio

Liquid covariant matrix:

SL00=440.43	SL01=-2.613
SL10=-2.613	SL11=0.6438

SLAW=485.619 Small liquid average width
SLAR=1.586 Small liquid average ratio

SERR=-1 Small munition error factor (negative number causes "Indeterminate" result for all data.)

Large munitions (used for 155mm.):

Solid covariant matrix:

LS00=3987.1	LS01=-0.501871
LS10=-0.501871	LS11=0.021594

LSAW=508.9750 Large solid average width
LSAR=0.4740 Large solid average ratio

Liquid covariant matrix:

LL00=402.5702	LL01=-1.9325
LL10=-1.9325	LL11=0.0986

LLAW=311.8413 Large liquid average width
LLAR=0.7649 Large liquid average ratio

LERR=4.0 Large munition error factor (negative number causes "Indeterminate" result for all data.)

A.2 Command Switches

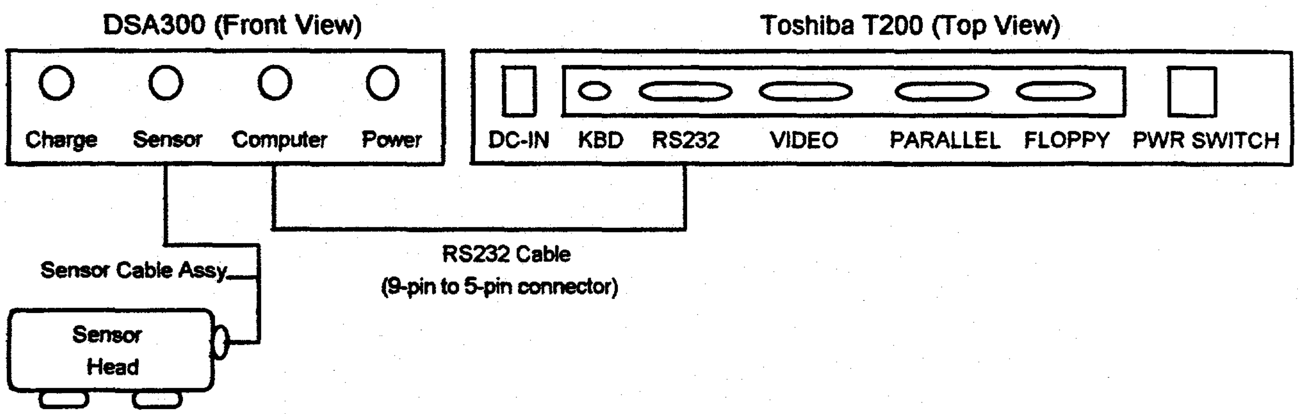
The ARS program behavior can be altered for special situations by using command switches when executing the program. These switches can cause dramatic program changes and should not be adjusted by the user. The switches are listed here for reference, and, with the exception of '-n,' are not supported and may yield unexpected results. The switches are not case sensitive.

Switch	Function
-n	Disables the DSA check on startup. This is used to allow processing of data on a desktop computer without receiving the "Cannot connect to DSA" message on startup. This switch is automatically set by the setup program if requested.
-a	Sets the DSA into autoscale mode.
-e	Expert mode switch. Allows dwell time to be modified, templates to be built from multiple directories, and file names to be pasted into template listbox by right-clicking on the dialog box border.
-r	Repeat mode. Causes the evaluate button in View and Analyze to evaluate all files in the selected data directory and save the results in a data file.
-p	Displays lines where the program has identified a peak.

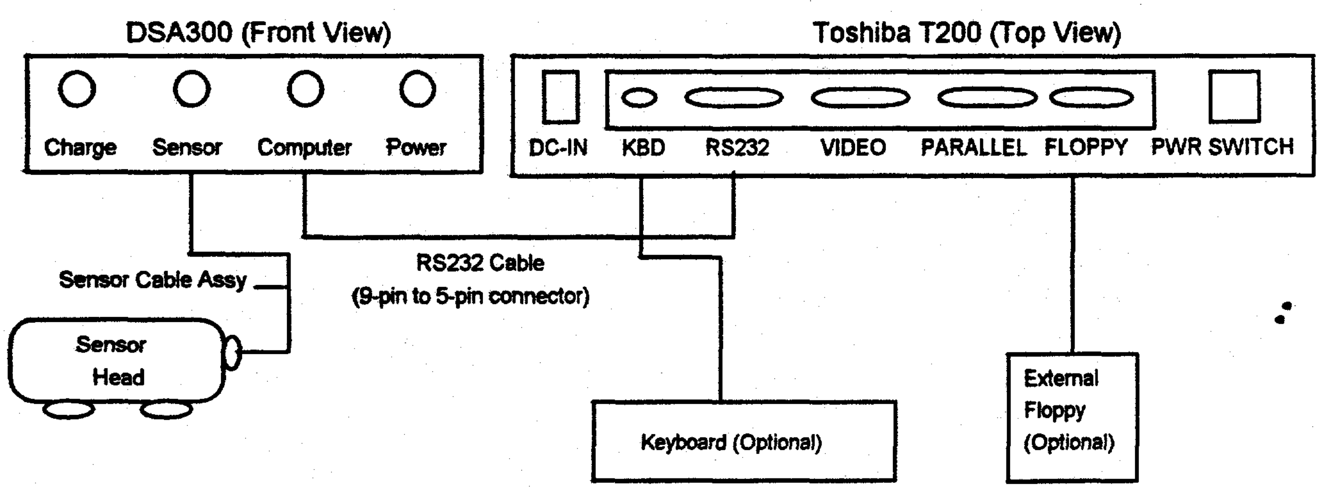
Appendix B: Interconnection Wiring Diagrams

INTERCONNECTION WIRING

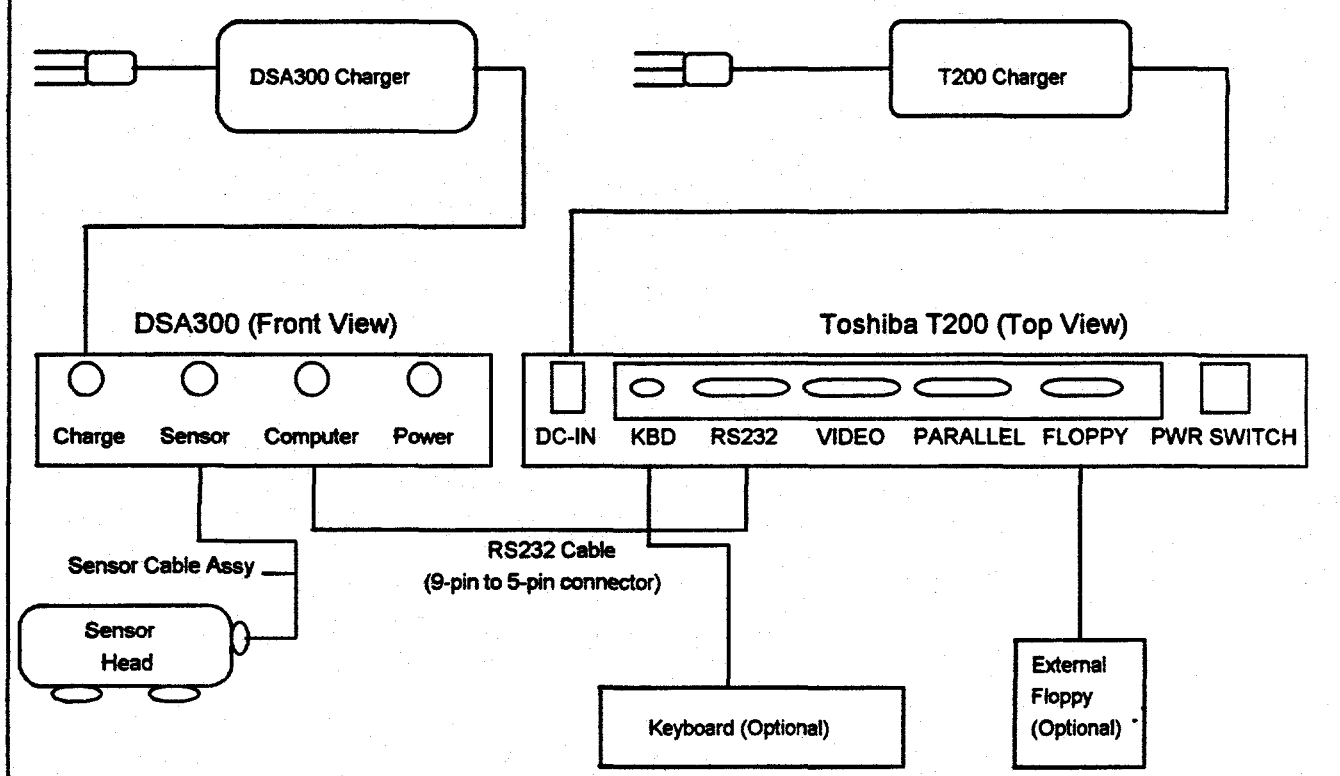
B.1 Field Configuration



B.2 Base Configuration



B.3 Charging Interconnection Wiring



Note: (1) Both the DSA300 and the Toshiba T200 can be operated while charging. The front panel "charge" light on the DSA300 will turn off when fully charged and the T200 charge light will turn green when fully charged.

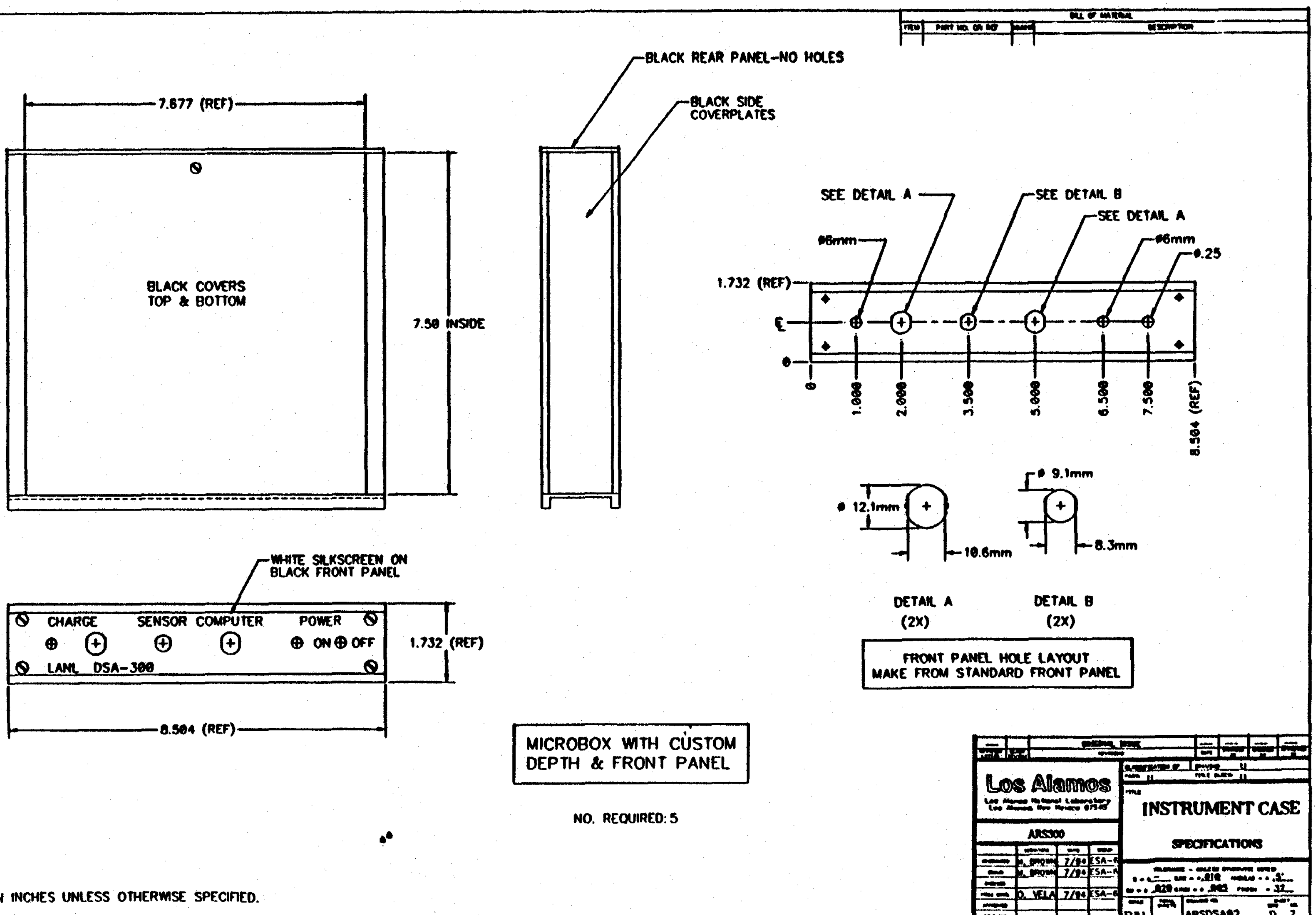
Appendix C: Component List

Acoustic Resonance Spectroscopy (ARS300 System)

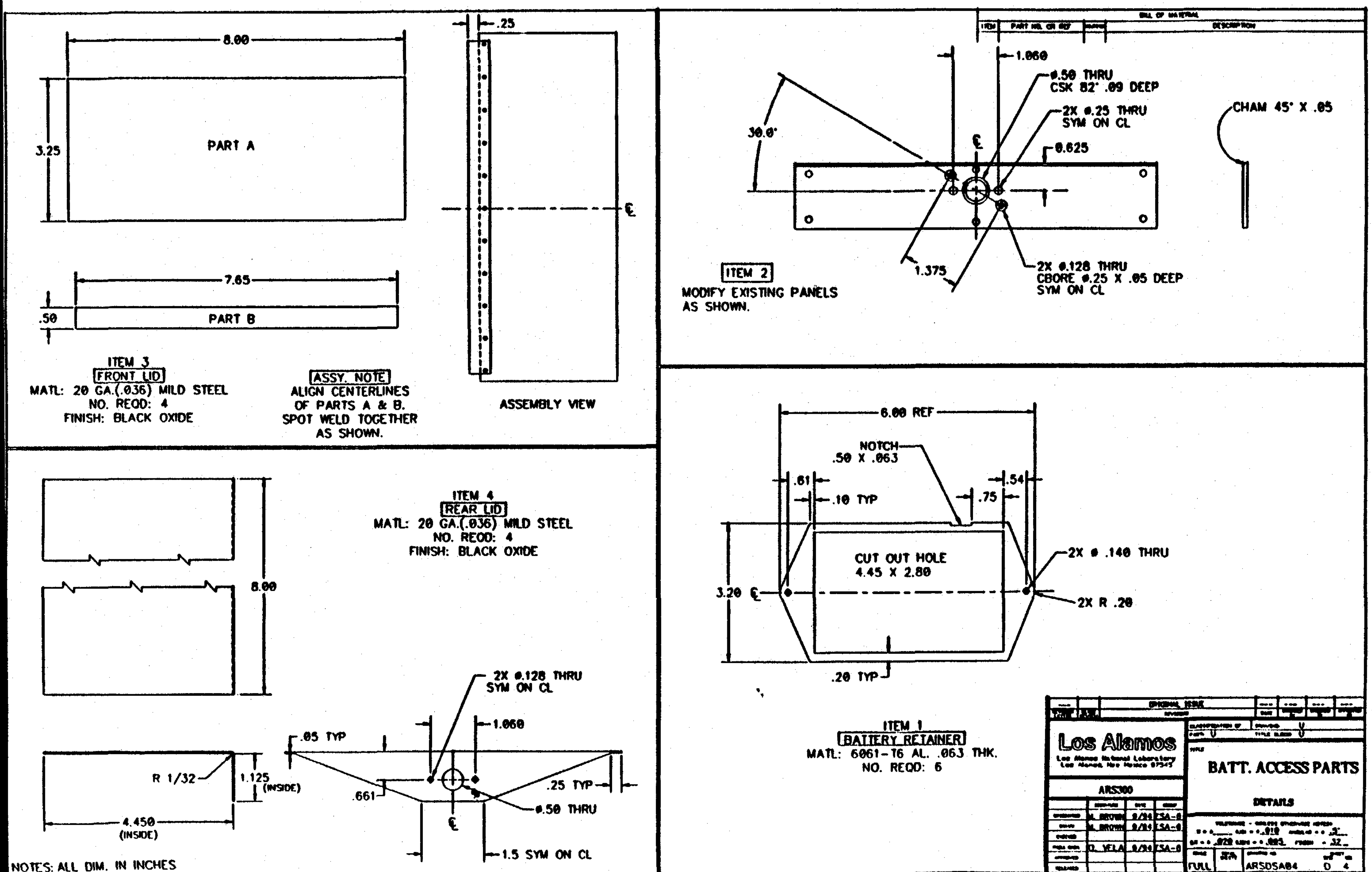
ITEM	QTY	DESCRIPTION
DSA300	1	Data Acquisition System (Modified per LANL specifications) Mfg: Neel Electronics Inc. 12 Silent Knoll Laguna Niquel, CA (714) 495-3216
Sensor Heads (SHD300)	2	Transducer Heads for DSA300 (Built to LANL specifications) Mfg: Neel Electronics Inc. 12 Silent Knoll Laguna Niquel, CA (714) 495-3216 Components: Panametrics Transducers 221 Crescent St. Waltham, MA 02254 (617) 899-2740 Model: Videoscan V103-RM; 1.0 MHz; 0.5" Transducer Magnets Edmund Scientific Co. 101 E. Gloucester Pike Barrington, NJ 08007 (609) 547-8880 Model: Nd-Fe-B; 1/2" dia.; 1/8" thick; Stk. # F35,105 In-line Amplifier (Built to LANL Specifications) Neel Electronics Inc. 12 Silent Knoll Laguna Niquel, CA (714) 495-3216 Sensor Housing (Custom Built to LANL Specification)
Sensor Cable (SC300-50)	1	Cables (50' Length) for DSA300 to Sensor Heads (Custom Built to LANL Specifications)
Sensor Cable (SC300-10)	1	Cables (10' Length) for DSA300 to Sensor Heads (Custom Built to LANL Specifications)

PC-DSA Cable	1	Serial Cable from PC to DSA300 Custom Built by LANL Components: LEMO Connector (P/N: FGG.1B.305.CLAD-72Z) Serial AT Style 9-pin Cable (Radio Shack or Equivalent)
Computer	1	Laptop Computers for Data Processing Mfg: Toshiba Corp. DynaPad T200 Pen (Monochrome) Laptop Add-On & Accessories Memory Module (8M) Extra Battery AC Charger
DSA300 Charger	1	Charger for DSA300 Mfg: Custom Built by LANL Components: LEMO Connector (P/N: FFA.1S.302.CLAC52) International Power Sources, Inc. (Model #: PUP30-12-B2) AC Power Cord (Detachable)
DSA300 Case	1	Soft Carrying Case for DSA300, Computer, Sensors, & Cables Mfg: HER Electronics 6201 Copper NE Albuquerque, NM (505) 265-7843 P/N: ARS300 Carrying Case
Transport Case	1	Transport Case for Complete ARS300 System Mfg: HER Electronics 6201 Copper NE Albuquerque, NM (505) 265-7843 P/N: ST1714-10F-LP Size: 17 3/4 x 14 1/2 x 10

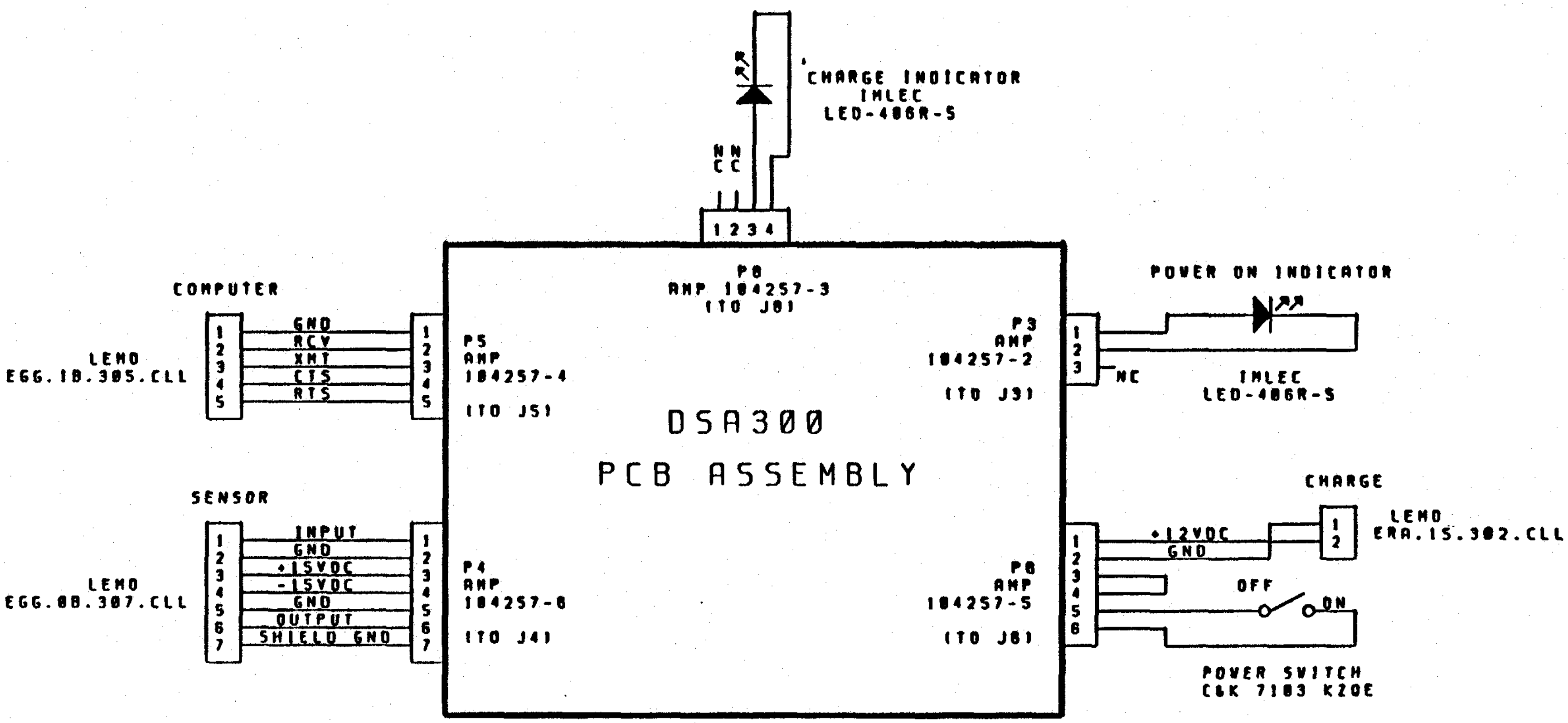
Appendix D: Drawings



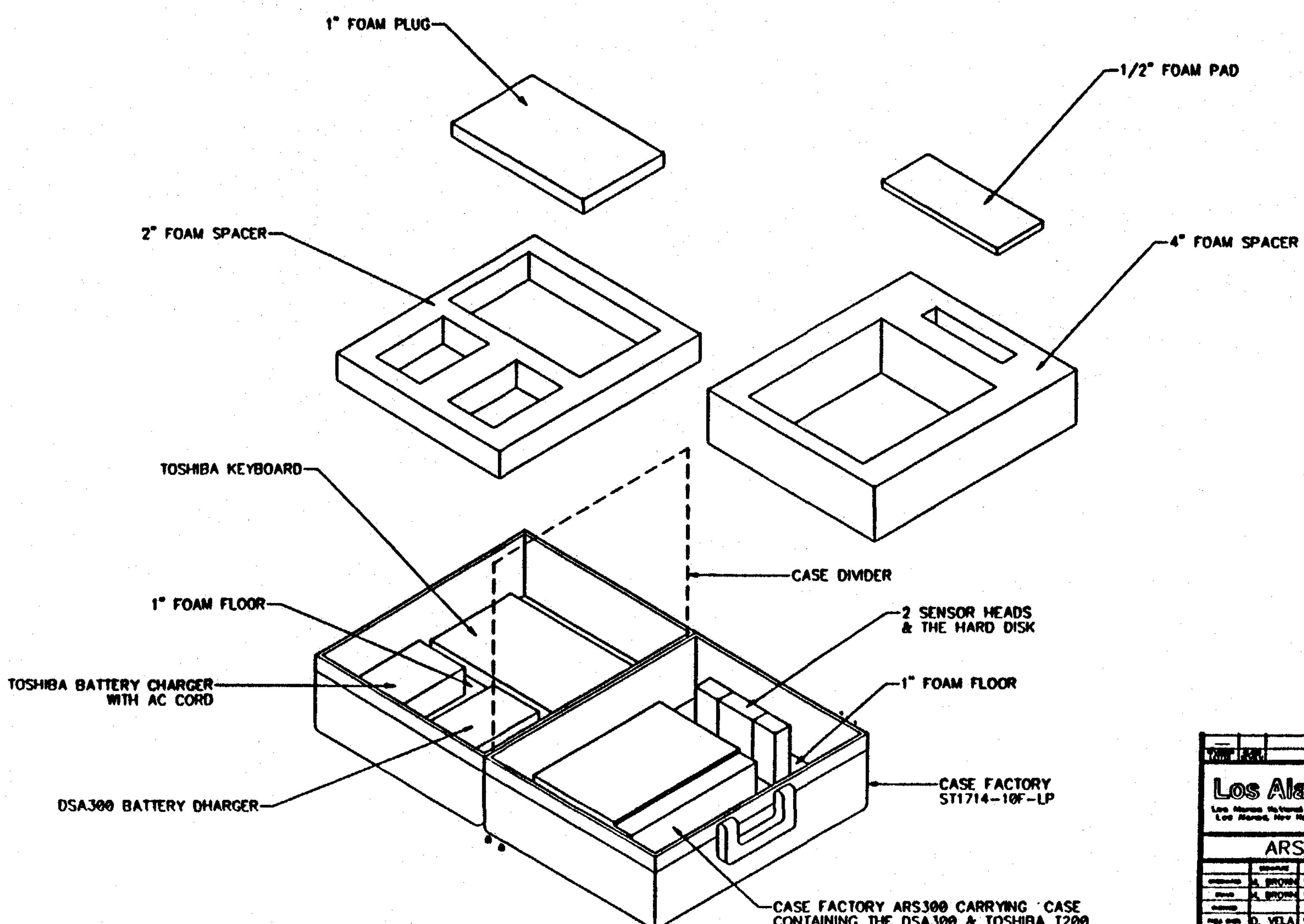
1. DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED.
NOTES:



8.00
3.25
PART A
7.65
.50
PART B
ITEM 3
FRONT LID
MATL: 20 GA.(.036) MILD STEEL
NO. REQD: 4
FINISH: BLACK OXIDE
ASSY. NOTE
ALIGN CENTERLINES
OF PARTS A & B.
SPOT WELD TOGETHER
AS SHOWN.
.25
ASSEMBLY VIEW
1.060
ø.50 THRU
CSK 82° .09 DEEP
2X ø.25 THRU
SYM ON CL
0.625
30.0°
1.375
2X ø.128 THRU
CBORE ø.25 X .05 DEEP
SYM ON CL
CHAM 45° X .05
ITEM 2
MODIFY EXISTING PANELS
AS SHOWN.
BILL OF MATERIAL
ITEM
PART NO. OR REF
DESCRIPTION
ITEM 4
REAR LID
MATL: 20 GA.(.036) MILD STEEL
NO. REQD: 4
FINISH: BLACK OXIDE
8.00
2X ø.128 THRU
SYM ON CL
.05 TYP
1.060
R 1/32
1.125
(INSIDE)
.661
.25 TYP
ø.50 THRU
4.450
(INSIDE)
1.5 SYM ON CL
NOTES: ALL DIM. IN INCHES
6.00 REF
NOTCH
.50 X .063
.61
.54
.10 TYP
.75
CUT OUT HOLE
4.45 X 2.80
2X ø .140 THRU
3.20
2X R .20
.20 TYP
ITEM 1
BATTERY RETAINER
MATL: 6061-T6 AL. .063 THK.
NO. REQD: 6
ORIGINAL ISSUE
Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545
ARS300
BATT. ACCESS PARTS
DETAILS
M. BROWN 8/94 ESA-8
M. BROWN 8/94 ESA-8
D. VELA 8/94 ESA-8
FULL
ARSDSA84
D 4



LOS ALAMOS NATIONAL LABORATORY LOS ALAMOS, NEW MEXICO 87545 ORIGINATED BY: D. VELA GROUP: ESA-MT DRAWN BY: M. BROWN GROUP: ESA-MT		
Title DSA300 WIRING DIAGRAM		
Size A	Document Number ARS\DSA300WD.SCH	REV 0
Date: December 7, 1994	Sheet 1 of 1	



ITEM	PART NO. OR REF		DESCRIPTION

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ARS

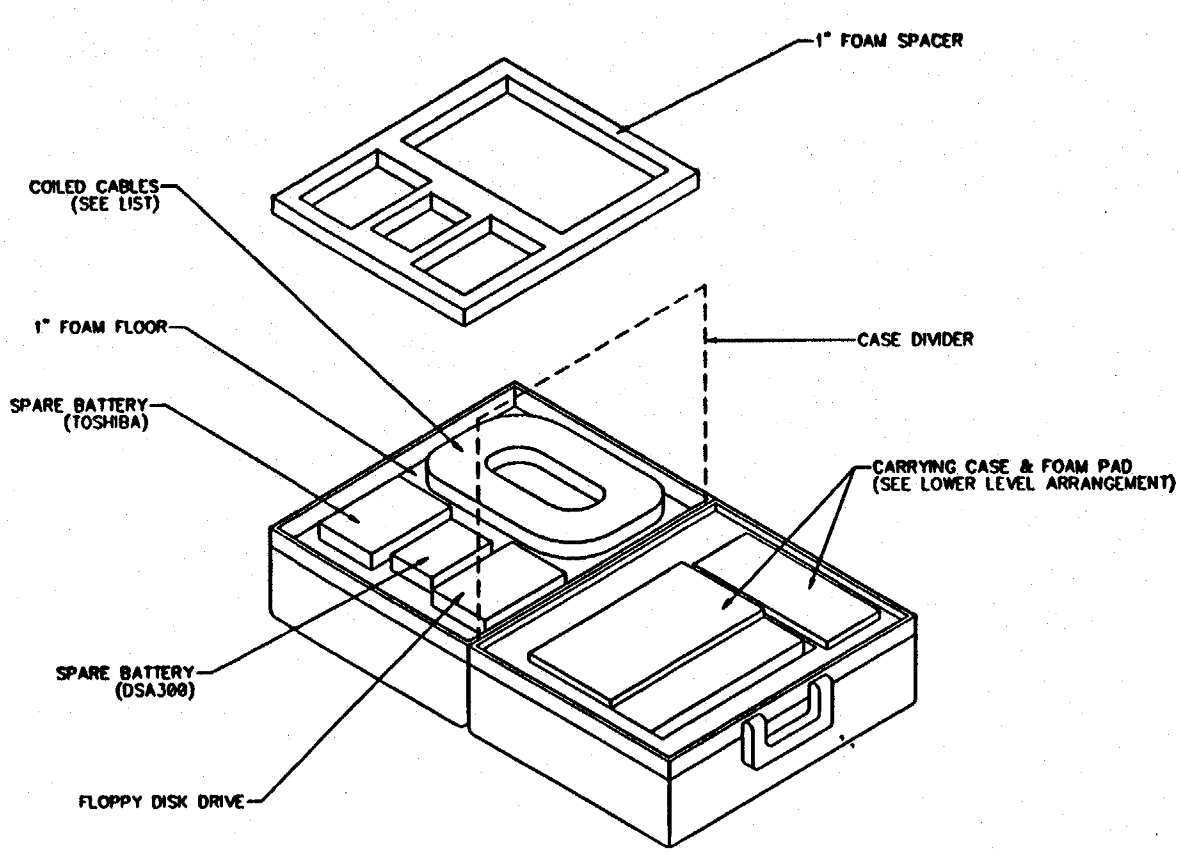
TRANSPORT CASE

LOWER LEVEL PACKING ARRANGEMENT

	SIGNATURE	DATE	GROUP
	A. BROWN	10/94	ESA-6
	A. BROWN	10/94	ESA-6
	D. VELA	10/94	ESA-6

Scale NA — ARSDSA05 — D 5

NOTES:



CABLE LIST

* (2) SENSOR CABLES
* DSA SERIAL CABLE
* PARALLEL PORT CABLE
* FLOPPY CABLE
* AC CORD
* AC 220V ADAPTER

BILL OF MATERIAL

ITEM	PART NO. OR REF	QUANTITY	DESCRIPTION

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ARS

TRANSPORT CASE

UPPER LEVEL PACKING ARRANGEMENT

	M. BROWN	10/94	CSA-8
	M. BROWN	10/94	CSA-8
	D. VELA	10/94	CSA-8

NA | ARSDSA06 | D | 6

NOTES: