SAVIAC
Shock and Vibration Information Analysis Center
Current Awareness
March 2004

Introduction to Air Blast Measurements

Part I

Editor's Note: This is the first in a series of articles high-lighting one of this year's featured commercial organizations, PCB Piezotronics. This article was written by Patrick Walter, PhD, of PCB.

An explosion in air is a process by which a rapid release of energy generates a pressure wave of finite amplitude. The energy source can be anything that generates a violent reaction when initiated. This includes: chemical or nuclear materials, gases (high pressure gas-storage vessels, steam boilers), or electricity (spark gap, rapid vaporization of a metal). The properties of air will cause the front of this pressure wave to "shock up" or steepen as the front moves. The result is a shock front moving supersonically, i.e., faster that the sound speed of the air ahead of it, with discontinuities in pressure, density, and particle velocity across the front.

Unlike acoustic waves that move at sonic velocity, produce no finite change in particle velocity, and don't "shock up," air blast is a nonlinear process involving nonlinear equations of motion. Air blast can be encountered in freely expanding shocks in air or, if obstacles enclose the energy source, in directed shocks and contained shocks. Examples of all three are shown next in Figure 1.

A near-ideal explosion that is generated by a spherically symmetric source, and that occurs in a still, homogeneous atmosphere, would result in a pressure-time history similar to the one illustrated in Figure 2. The pressure is at ambient until the air blast arrives. At this time it instantaneously rises to its peak side-on overpressure, decays back to ambient, drops to a partial vacuum, and eventually returns to ambient.

Figure 1 - Examples of Freely Expanding, Directed, and Contained Air Blasts

Figure 1a - Free Air Blast

Figure 1b - Directed Air Blast (Shocktube)

Figure 1c - Contained Air Blast

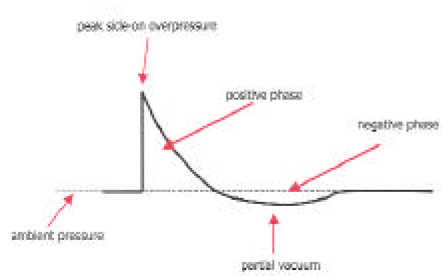

Figure 2: Ideal Side-On Pressure Record Attributable to a Spherical Symmetric Source in a Homogeneous Medium

Deviations from this ideal waveform are to be expected. Rarefaction waves occur at the contact surface between the explosion products and air; these waves result in modification of the positive shock phase.

For caged explosives, any fragment that is generated may have an associated momentum adequate for it to outrun the blast-wave velocity and produce disturbances before the wave's arrival. Ground effects due to dust or heat-reflecting surfaces may form a precursor wave.

Additionally, if the blast wave has low specific energy, it may travel a significant distance before "shocking up." The interaction of blast waves with a solid object can result in reflections from the object or cause the waves to reflect from as well as diffract around the object.

Figure 3 shows the reflection of strong shock waves from a reflective surface. I1, I2, and I3 represent the expanding shock wave, while the "R" contours represent the respective reflections from the surface. When I1 just touches the surface S, a reflection occurs that is more than two times I1. As the shock wave continues to move outward, the intersection of each I and its corresponding R lies on the dashed line. The incident and reflected shocks coalesce to form a Mach stem. As the shock expands, the Mach stem grows, eventually encompassing the 2-shock system above it.

As the blast wave propagates to greater distances from its source, its magnitude lessens and it decreases in velocity until it propagates at the speed of sound. Theoretically, acoustical laws could then apply, but meteorolog

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Call For Papers

75th Shock and Vibration Symposium
October 17-22, 2004
The Cavalier
Virginia Beach, VA

Planning for the 75th Shock and Vibration Symposium is underway. NSWC/Dahlgren Division is the Government Featured Organization and Northrop Grumman Newport News and PCB Piezotronics are the Commercial Featured Organizations. The Cavalier Hotel in Virginia Beach is the location.

The Shock & Vibration Symposium is the oldest continuously held meeting dealing specifically with the shock and vibratory response of air, sea, space, and ground vehicles and structures and blast effects. The Symposium was established as a mechanism for the exchange of information among Government activities, private industry, and academia on current work and new developments. Presentations on work in progress are encouraged. Separate sessions are held for presentation of classified or limited-distribution material.

Presentations in the following subject areas are welcomed:

901D Case Studies
Active Vibration Control
Air Blast
Anti-Terrorist Technologies
Ballistic Shock
Biodynamics
Blast Design
Blast Effects
Combined Environments
Computational Structural Dynamics
COTS
Crash Dynamics
Damage Identification
Damping
Data Analysis
Dynamic Analysis Methods
Dynamic Measurement

Dynamic Scale Modeling
Dynamic Testing
Environmental Databases
Finite Element Analysis
Fluid-Structure Interaction
Ground Shock
Homeland Defense
Impact/Penetration Mechanics
Infrastructure Protection
Instrumentation
Isolation Systems
Large Structures
Live Fire Testing
Machinery Diagnostics
Machinery Vibration
Material Dynamic Properties
Modal Analysis and Testing

Product Announcement/Facility Description
Pyrotechnic Shock
Seismic Shock
Shock Characterization
Shock Hardening
Shock Qualification by Extension
Shock Response Spectrum
Shock Test/Equipment Failure Modes
Simulation Methods
Specifications and Standards
Structural Hardening
System Identification
Test Criteria
Test Tailoring
Underwater Shock Testing
Vibroacoustics

Two categories of presentations will be accepted: full papers, suitable for publication in the Symposium Proceedings; and short discussion topics, consisting of viewgraphs with no written paper. Full papers will have a 15 minute technical presentation time plus 5 minutes for questions, while short discussion topics will have a 10 minute presentation time with no question period.

Presentations will be accepted on the basis of their abstracts, which must be submitted by June 3, 2004. You are encouraged to submit online at www.saviac.org, click on 75th S&V Symposium Abstract Submittal. The Program Committee will review the abstracts during the July Program Committee meeting and authors will be notified of acceptance by July 16, 2004. The full paper presentations must meet the following standards: They must be previously unpublished and unpresented, must be appropriate to community interests and must not be overtly commercial, except for papers in the Product/Facility session. Standards for short discussion topics are similar except that they may include previously presented or published material.

The Proceedings will be published on CD-ROM.
The paper due-date is October 8, 2004.
Questions should be directed to Joel Leifer, 301.596.0100 or joel.leifer@saviac.org.

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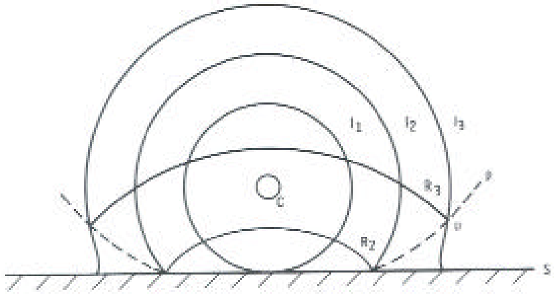

Figure 3 - Strong Shock Wave Interaction With a Reflective Surface

PCB 137A Pencil Probe

PCB 134A Blast Probe

Figure 4 - PCB Blast Pressure Transducers

ical conditions tend to control its properties at long distances.

The development of predictive codes and analytical techniques for the strength and directional characteristics of blast-waves is highly dependent on experimental measurements. Robust blast-pressure transducers were not always available to make these measurements; they had to be developed.

Much of the early development of these blast-pressure transducers occurred at government laboratories such as the Ballistic Research Laboratory (BRL - United States) and Royal Armament Research and Development Establishment (RARDE - United Kingdom) in the 1950s and 1960s. Among the early commercial pressure transducer developers were Atlantic Research Corporation, Kaman Nuclear Corporation, Kistler Instrument Corporation (where some of its founders subsequently formed PCB), and Shaevitz-Bytrex Corporation.

To characterize the time signature of a blast-pressure event, transducers are required for two types of measurements. Side-on transducers are those that record free field pressure at varying distances from the blast source. Their design must minimize interference with the flow behind the shock front. Reflected-pressure transducers are used for measuring pressures reflected at normal or oblique incidence from a rigid surface. Flow and diffraction effects are no longer important. This type of transducer must be mounted so that its sensing surface is flush with the reflecting surface for the shock front.

One of the notable pioneers in this field was Mr. Ben Granath who originally worked at BRL and subsequently founded Susquehanna Instruments, a development company for blast transducers. This company is now a part of PCB Piezotronics. Photographs of two transducers, which resulted from Mr. Granath's work, are provided as Figure 4.

In Figure 4, the transducer on the left, the pencil probe, is obviously intended for side-on pressures. Its piezoelectric sensing element is built into the housing. The geometry of the contained piezoelectric element, as well as the velocity of the shock front of the blast wave passing over it, control its rise time of 1-4 sec. This transducer covers a pressure range extending to 1000 psi. The transducer in the right portion of this figure works on the principle of a pressure bar. Its sensing element is tourmaline, which is interfaced to an internal bar. The bar is acoustically impedance-matched to the tourmaline, resulting in a 1.5-MHz resonant frequency for the transducer. This model transducer is used for reflected pressure measurements to 20,000 psi.

A limitation of the early piezoelectric transducers developed by the government labs and/or industry was the influence of the cable on their signal. In hazardous tests, such as those involving explosives, cable lengths of 100s to 1,000s of feet are typical. When these cable lengths were employed with charge-sensing circuits, a variety of deleterious effects would result; the principal problems were:

(1) noise generated within the cable due to triboelectric effects,

(2) the high cost of special noise-treated cables to eliminate the above effects, and

(3) a charge sensing amplifier's noise level, which increases in propor-

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Free
Summer Shock & Vibration Seminar

SAVIAC invites you to attend a FREE seminar on Shock & Vibration. The course will be held on Wednesday, June 30, 2004 at The Cavalier Hotel in Virginia Beach, VA, the day before the 75th Shock & Vibration Symposium Program Committee Meeting. SAVIAC and the featured experts in their disciplines have organized this seminar to introduce you to the SAVIAC community, while providing a valuable educational experience.

Agenda

8:00 - 8:30	Registration & Continental Breakfast	
8:30 - 8:45	Introduction to SAVIAC	Joel Leifer, SAVIAC
8:45 - 9:00	Using SAVIAC to Address Your S&V Problems	Joel Leifer, SAVIAC
9:00 - 10:00	MIL-S-901 Requirements/Approval Process	Kurt Hartsough, NSWC/Carderock
10:00 - 10:15	Break	
10:15 - 10:45	TBD	TBD
10:45 - 11:15	TBD	TBD
11:15 - 11:45	Shock Response Spectrum	Tim Edwards, NSWC/Dahlgren
11:45 - 1:00	Lunch (no host)	
1:00 - 1:30	TBD	TBD
1:30 - 2:00	Blast Pressure Measurements	Pat Walter, PCB Piezotronics
2:00 - 2:30	Aluminized Explosive Modeling	Eric Rinehart, Defense Threat Reduction Agency
2:30 - 3:00	Overview of Hazard Assessment Testing (HAT) per MIL-STD-2105	Jamie Howell, NSWC/Dahlgren
3:00 - 3:15	Break	
3:15 - 3:45	Seakeeping & Slam Effects on Combatant Craft	Tim Coats, NSWC/Carderock
3:45 - 4:15	Transportation Vibration	Skip Connon, US Army Aberdeen Test Center
4:15 - 4:45	TBD	TBD
4:45 - 5:00	Wrap-up & Questions	All

Please forward this invitation to anyone you know who may be interested in attending this program.

The seminar is free, but you must register to attend. You may register online at **www.saviac.org/75th_Symposium/seminar_registration_form.htm**, or RSVP to Lauren Yancey, (703) 892-0060 or **lauren.yancey@saviac.org** to assure your space and note packet. SAVIAC reserves the right to substitute topics and/or instructors when necessary. This schedule is subject to change. For more information about SAVIAC, or for a list of area hotels and directions to The Naval Surface Warfare Center Panama City, please visit our website at www.saviac.org.

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tion to cable capacitance, i.e., cable length.

All of the aforementioned problems have subsequently been solved with integral-electronics piezoelectric (IEPE) transducers. PCB Piezotronic's equivalent registered trademark, which predates the IEPE designator, is "ICP." The IEPE configuration converts the transducer's output to low impedance, thus eliminating triboelectric effects, and it also permits the use of a variety of inexpensive 2-wire cable systems,

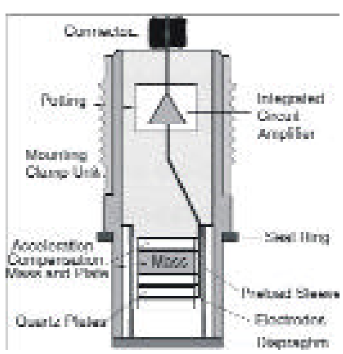

Figure 5 - ICP Pressure Transducer

none of which require noise treatment. In addition, if a typical 20-milliamp current is used to power the transducer, the high-frequency response of the transducer is maintained over very long cable runs. Figure 5 shows a cross-sectional view of a pressure transducer in an IEPE or ICP configuration.

Author's note: This article introduced the topic of blast pressure measurement and provided background on it. Subsequent articles will deal with other unique challenges associated with this discipline.

WANTED

Ballistic Shock Analyst/Structural Analyst/Structural Dynamicist

Description: A senior structural analyst/structural dynamicist is needed to perform analysis and design functions related to the survivability of lightweight ground vehicle, components, and crew which may be subjected to weapon- induced shock loading. The position supports the long-term vehicle protection research program being executed at the Weapons & Materials Research Directorate (WMRD) of the U.S. Army Research Laboratory. The duties of the position are to be performed principally at Adelphi, MD, which is located in the metropolitan Washington DC area, with occasional travel to the WMRD situated at the Aberdeen Proving Ground area, some 65 miles from Adelphi. The duties are focused on two areas, shock characterization and shock protection. Because of the breadth and skills required to perform the work up to 2 individuals may be recruited to meet the ongoing research needs.

The work involves shock and structural analysis of lightweight combat vehicle systems and components, leading to their increased survivability to shock loading. The loading originates from the engaging kinetic or chemical weapons, such as high-velocity projectiles/penetrators, fragments, and blast energy. The analysis generally mandates the development and verification of sophisticated physics-based high frequency ("=10 KHz) structural models of complex vehicular configurations comprising multi-layer material architecture (metallic, ceramic, composite etc) using FEA tools such as Dyna, Abaqus, Ansys, etc. Proficiency in the use of native code and/or advanced pre, and post processors, such as Hypermesh, is required to efficiently construct models of the structure from CAD files (e.g., Pro-E) and/or to interpret and manage computational results. Model(s) will often be experimentally verified and updated, with the analyst involved in the development of the live fire test plan of the test article (vehicle, surrogate structure, panel, component, etc), as well as with the interpretation of data. Proficiency with data analysis tools such as MATLAB is required in support of the analysis and verification process outlined above.

Additional duties may involve use of the structural analysis and experimental tools to develop structural and/or material-based mitigation concepts that attenuate shock loading to the vehicle structure, critical component, and crew-thereby enhancing their survivability. This may entail the development of energy/impulse-based absorbing concepts or means that could be integrated into the vehicle structure, or placed locally to isolate components and crew. Included are passive, semi-active, and passive means to manage, diffuse, and otherwise control stress waves and loads to the allowable survivability/fragility criteria. The development, verification, and use of methods to establish the failure criteria of the component of concern, down to details such as leads of an electronic component, wire bonds, die attach, PWB, soldier joint integrity, acceleration tolerance of humans, etc, are integral to the overall development of shock protection concepts.

Other duties involve presentation of the work products to the technical staff and sponsors, participation and presentations in technical meetings and conferences, development of technical and associated cost proposals and preliminary strategic plans for future research thrusts, preparation of technical reports, as well as occasional travel in support of the work.

Qualification/Preferences

1. 5 years of applied or relevant experience
2. Masters level mechanical/aeronautical/civil engineering degree from an accredited institution
3. Proficiency with large scale elastic-plastic finite codes such as Dyna, Paradyne, Abaqus, Ansys, including use of native or associated pre and post processors such as Hypermesh, etc.
4. Proficiency in the use of blast/impact loading codes such as CONWEP, Blast-X, Dyna, CTH, etc.
5. Proficiency with data analysis tools and techniques such as MATLAB, LABVIEW, and standard digital processing techniques used in analysis of shock & vibration data (FFT, PSD, Modal Analysis) etc.
6. Proficiency with MS office suite software.
7. Proficiency in constructing large scale finite element models (millions of DOF's) and executing parallel processing calculations.
8. Ability to obtain security clearance.
9. Ability to guide and lead members of a small technical team.

Salary: Sr. Analyst- Up to $ 100 K depending on qualification & experience; Bonus. POST-DOC-Up to $ 60K + $ 10 K relocation bonus.

POC: Ami Frydman, ARL, 301 394 2804; Afrydman@arl.army.mil

INDUSTRY NEWS

Multi-purpose 4-20 mA Sensor

A new Series 640B vibration sensor from the IMI Division of PCB Piezotronics offers optional temperature signal. This two wire, loop-powered, current output sensor is available with either top exit or side exit with patented 360-degree swivel mount technology and is able to interface with existing alarm, control, and monitoring systems such as PLC's, DCS's, and SCADA systems. Optional temperature range is from -40 to +185 ºF (-40 to +85 ºC), with the vibration signal offered in peak velocity, rms velocity, and rms acceleration versions. These sensors have improved RF filtering, withstand exposure to harsh industrial environments, and are used for monitoring rotation machinery, gears, bearings, and motors.

For additional information, contact the IMI Division of PCB Piezotronics at 800.959.4464 (toll-free is US and Canada) or 716.684.0003, fax 716.684.3823, e-mail: imi@pcb.com, or visit their website at www.imi-sensors.com.

HI-TECHNIQUES' meDAQ Portable Ethernet Data Acquisition System

The meDAQ Portable Ethernet Data Acquisition System is a high speed, high performance system with many applications in physical research, mechanical product development, and high speed transient testing. Any number of systems are controlled from one computer over the Ethernet interface. The operating software controls up to 500 Channels. Buffer memories reside in the meDAQ for each digitizer. Microprocessors on these memory boards coordinate trigger, timebase, and which data to send to the PC for display. A separate Timebase/Trigger board assures simultaneous clocking on all digitizers and provides a separate path for trigger and channel data. Built-in mathematic and statistic functions for data analysis, macro-programming for quick and easy programs that run an entire test with the press of one button, and report writing functions that result in automated test print-outs.

To download demo software visit http://www.hi-techniques.com/products/medaq.htm.

Accelerometer Resists High Temperatures

Higher performance at elevated temperatures is enabled by the use of new PiezoStar® crystal element employed in a new accelerometer from Kistler Instrument. The exclusive crystal exhibits an unusually low sensitivity variation over the operating temperature range of -54°C to 165°C for improved preciseness. Typical piezoelectric elements react less accurately to temperatures in this range. The 8765A250 is a miniature 6.4 gram accelerometer with a ±250g measurement range and 20mV.g sensitivity. It has a wide frequency response from 1 to 9kHz with only 5% deviation. This triaxial accelerometer operates in the low impedance, voltage mode with Kistler power supply coupler or any industry standard IEPE (Integrated Electronic Piezo Electric) compatible power supply. With center hole mounting, the cable is allowed 360° orientation. Construction features include a welded hermetic and ground isolated enclosure.

For additional information contact Don Beehler at don.beehler@kistler.com

Heavy Truck Wheel Sensor Measures Force and Moments

The RoaDyn™ V6HT from Kistler Instrument installs easily to heavy truck class vehicles without vehicle modification. Ideal for use on a test track or collecting data in a test laboratory, it accurately provides longitudinal, lateral and vertical force information plus the respective moments. The unique design of the sensor produces complete decoupling of the individual forces and moments into components that are essential for meaningful data analysis. Captured data is conditioned at the wheel sensor and transmitted by telemetry to nearby electronics. A rotation-restraining bracket attached to the fender or axel defines the wheel rotation in relation to the vehicle coordinate system by an angle sensor. Electronics inside the vehicle perform an online coordinate transformation. A reference plane can be preselected for the measured moments. The wheel sensor provides analog output data for convenient inputting to a wide range of data acquisition units.

For additional information contact Don Beehler at don.beehler@kistler.com

DIN-Rail Mountable ICP® Sensor to 4 to 20 mA Signal Conditioner

March 8, 2004, Depew, NY - IMI Sensors, a division of PCB Piezotronics, Inc., has released a DIN-rail mountable, ICP® sensor signal conditioner for converting the analog voltage measurement signals of industrial vibration sensors into 4 to 20 mA signals. Model 682A03 provides a choice of rms or peak acceleration, velocity, or displacement output signals as well as a selection of filtering ranges. In addition, the unit converts and delivers a second 4 to 20 mA output signal proportional to temperature to accommodate IMI's vibration sensors with built-in temperature sensors. Additional features include an analog output BNC for dynamic signal analysis and diagnostics, LED indicators for power, input fault, and selected output, and 500 VDC isolation. With this one powerful and versatile instrument, critical machinery vibration can be continuously monitored with PLC, DCS, SCADA, and alarm systems as well as analyzed and diagnosed with portable data collection and acquisition equipment.

For additional information, contact IMI's applications engineering group at (800) 959-4464 in the U. S. and Canada, (716) 684-0003 outside of the U. S., Fax9716) 684-3823, E-mail: imi@pcb.com, or visit our web site at www.imi-sensors.com.

Conference & Short Course Announcements

Be sure to check www.saviac.org for more information on upcoming events.

Aircraft Fire and Explosion Course
BlazeTech
April 6-8, 2004
Woburn, MA

This course provides a unified treatment of fires and explosions in commercial and military aircraft in the context of accidents, terrorist attacks and combat operations. This complex subject is treated through carefully chosen case studies illustrated by videotapes and photographs that are discussed in details to bridge the gap between theory and practice. The course provides an understanding of fundamental and practical considerations in fire and explosion hazards, calculation methods with examples, methodology for accident investigation and damage analysis using recent accidents, approaches to safety/risk analysis, and survivability/vulnerability, numerous opportunities for class discussion, related documentation and references, and certificate of completion (course is equivalent to four Continuing Education Credits). Registration is $1,800.00 ($1,600 if booked before March 15th). For more information please visit www.blazetech.com.

ESTECH 2004 - 50th Annual Technical Meeting and Exposition
IEST
April 25-28, 2004
Las Vegas, Nevada

ESTECH 2004 will provide attendees with opportunities to network and to share new and better ways to improve job performance and safety through products and services. ESTECH 2004, IEST's 50th annual technical meeting and exposition, has a world-wide reputation for presenting a top educational program with tutorials, technical sessions and working group meetings, as well as practical solutions in the state-of-the-art displays on the ESTECH Expo show floor. For more information, and to register, visit http://www.iest.org/estech/estech.htm.

Practical Shock Analysis & Design Short Course
MFPT Society
May 10-14, 2004
Portland, Maine

This course will provide a comprehensive treatment of practical shock design and analysis with special emphasis on applications related to the design of ship structures and equipment for shock loads produced by underwater explosions. Participants in this course will have an opportunity to increase their knowledge and understanding of the analytical and experimental tools that are available for shock design and qualification particularly with respect to requirements that are imposed for shipboard equipment. The lectures will provide a basic review of vibration and shock theory and will present the analytical and experimental methodology in the context of particular design applications. Analytical lectures will emphasize the physical significance of the results. Examples and case histories will be used as illustrations of design approaches; workshop problems that involve class participation will be used to advantage throughout the course. Class members will be encouraged to propose real design problems. The instructors will provide guidance for solutions or the problems may be used as class exercises. Although this course is aimed primarily at shock design applications on ships, the analysis and design techniques presented are equally applicable to problems related to design for seismic loads or blast induced ground shock. Thus, engineers in these related areas may find the course to be useful. For all who participate, the course will provide a comprehensive coverage of shock design practice and a solid basis for further exploration of shock technology. For more information and to download the registration form, visit http://www.saviac.org/Shock%20Course.htm.

21st Transducer Workshop
Vehicular Instrumentation/Transducer Committee of the Range Commanders Council Telemetry Group
June 22-23, 2004
Lexington Park, MD

The Twenty-First Transducer Workshop, sponsored by the Vehicular Instrumentation / Transducer Committee, Telemetry Group, of the Range Commanders Council, will be held June 22-23, 2004 at the J. T. Daugherty Conference Center in Lexington Park, MD. This committee develops and implements standards and procedures for transducer applications. Attendees are working level people who must solve real-life hardware problems and are strongly oriented to the practical approach. Test and project people who attend will benefit from exposure to the true complexity of transducer evaluation, selection, and application.
A block of rooms has been reserved for the workshop at the Fairfield Inn in Lexington Park, MD, with a limited number of rooms available on a first come first serve basis. Since there is also limited seating available at the Transducer Workshop attendees are encouraged to register as early as possible. With your registration please include a $100.00 registration fee payable to the Transducer Workshop, and mail to the Workshop Treasurer by June 1, 2004.

CLEAN UP IN 2004!!

Join SAVIAC's 2004 ListServ and have Current Awareness delivered straight to your Inbox! Every month! Paper-Free and interactive! Click on the articles you want to read, pass the ones you don't. E-mail Lauren Yancey at lauren.yancey@saviac.org to have yourself added to our mailing list.

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In the March 2004 Current Awareness Newsletter

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