An experimental approach to determine load-functions for the impact of fluid-filled projectiles

Dr.-Ing. Nico Herrmann
Dipl.-Ing. Klaus Kreuser
Prof. Dr.-Ing. Lothar Stempniewski
Institute for Reinforced Concrete Structures and Building Materials
University of Karlsruhe (TH)
76128 Karlsruhe, Germany

This paper reports on tests that have been performed at the Institute for Reinforced Concrete Structures and Building Materials at the University of Karlsruhe (TH) with the goal of evaluating the load-time-history of fluid-filled projectiles on a target that can be regarded as almost rigid. In order to gain first results on the shape and the peak-loads of load-functions for projectiles with stiffness and mass distribution similar to the proportions of a commercial aircraft we performed impact tests with different velocities and a projectile mass of about 700 g.

INTRODUCTION

In these days there are a lot of discussions on the safety aspect of vulnerable structures that are of importance for the infrastructure of nations. The reasons for such hazards are of different origins. One point that has been intensively discussed is the consequences of an aircraft-crash. In order to gain knowledge on the shape and the peak-loads of load-functions for projectiles with stiffness and mass distribution similar to the proportions of a commercial aircraft and to check the theoretical models as by Riera [3] or other researchers ([1], [2]) impact tests with different velocities and a projectile mass of about 700 g were performed. As material an aluminum alloy which is common in the aircraft industry was used. The fluid-filling was realized by using tanks either half-filled or full with water or in some cases filled with a substitution mass of expanded clay beads.

An experimental facility has been built up that includes an almost rigid target that can be tilted to various different angles of impact. For the acceleration of the different projectiles an air-pressure gun that is capable of accelerating a projectile of 2.5 kg to a velocity of about 220 m/s has been used. The air-pressure-level can be adjusted up to 100 bars and released at the desired level.

The target set-up has been covered by a wooden box with the inner walls capable of catching fragments and allowing the registration of the fluid distribution directly after the tests. Through some windows the interior of the box could be lightened and a high-speed-camera could be used in order to film the procedure of impacting and the fragmentation of the projectiles. The velocity of the impacting projectiles was measured with the help of a simple construction using glass-rods that were destroyed by the projectile without having an influence on the behavior of it.

The data registration for the load-time-function was realized with piezo-electric force transducers that were mounted between a changeable impact plate and the target construction. The evaluation of the data showed that there are some interpretation problems regarding the impact of the eigenfrequencies of the measuring technique and the target itself on the results of the force-measurements. The evaluation of the data is still ongoing and further tests will be performed to broaden the data basis.

EXPERIMENTAL SET-UP

An already existing air-pressure gun that formerly was used for friction and hard impact tests has been modified for the use with projectiles of a diameter of ~ 70 mm (Figure 1). Therefore a muzzle of this diameter was produced and built to the pressure chamber. A bursting diaphragm is separating the muzzle from the pressurized part and can be destroyed at the desired pressure-level to release the compression energy and to accelerate the projectile brought into the muzzle from the front opening in a position directly before the diaphragm. The perforation needle penetrates the diaphragm when being hit by a pendulum system. The supporting construction for the gun has been built with extremely stiff steel-beams that are mounted on the strong-floor of the laboratory. The maximum pressure that can be used with is 100 bar which lead to a capability of accelerating a mass of 2.5 kg to a velocity of ~ 220 m/s.

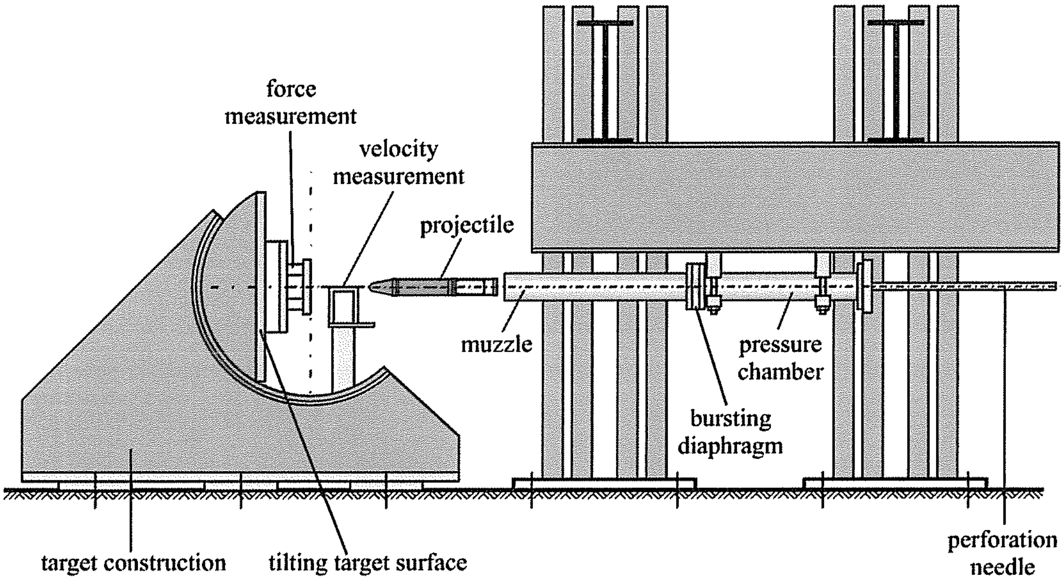


Figure 1 Principle of the experimental set-up

The target has also been made out of steel and has a tilting target surface so that different angles between the main axis (perpendicular) and the target could be adjusted. All angles were regarded as angles with respect to this main axis (e.g. perpendicular means 0°). On the target surface a force measurement platform was mounted in a way that the hitting point always laid in the rotation center of the target. The distance between the opening of the muzzle and the target was 1.9 m. The target has been covered by a wooden box with the inner walls capable of catching fragments and allowing the registration of the fluid distribution directly after the tests.

The projectiles were produced out of an aluminum alloy that is common in the aircraft industry. The geometry of an aircraft has been simplified by considering the aircraft consisting of only three main parts not taking into account the engines and the rear end. The engines were investigated in separated projects regarding the hard impact and the rear end has no significant effect on the load-time-function because of being rather light and soft.

The remaining three parts consist of the front part of the aircraft ("nose"), the body located before the wing zone and the middle section of the body in addition with the wing and tank section. In Figure 2 these three sections (1-2-3) can be seen. For a better evaluation of the fragmentation they were marked with different colors (red-blue-green).As in a real aircraft the stiffness ration for the three sections (1-2-3) was chosen to 1:1:3. Therefore it was decided that the wall thickness of the alloy cylinders should be 0.3 mm for the first two sections and to 1.2 mm for the third section. The last section also contained the fluid tank that could be used full, half-filled or empty. For some tests the tank was filled with a substitution mass of expanded clay beads in order to increase the visibility of the fragmentation in the high-speed-movies.

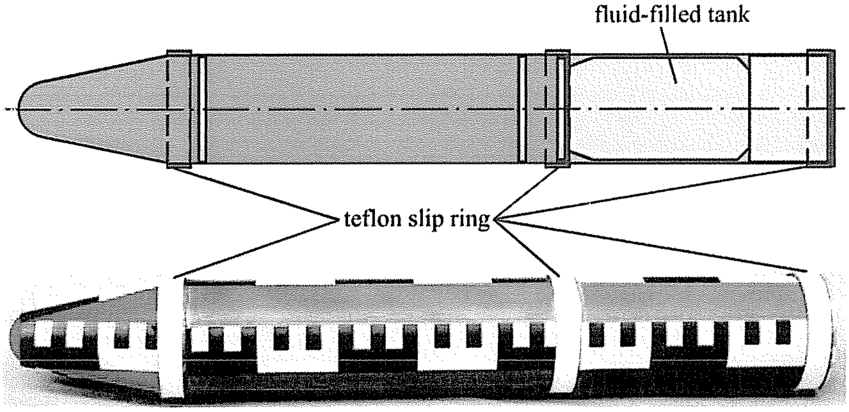


Figure 2 Principle structure of the projectile, section (top) and picture of a real projectile (bottom)

The focus regarding the measurements during the tests laid mainly on two parameters: the velocity v of the projectile and the forces F_X, F_Y and F_Z. For the velocity measurement a simple construction was used. In the main axis a construction was built that held 4 thin glass-rods covered by a conductive silver paste. These rods had a small diameter so that they could be regarded as of no influence to the flying of the projectile. Every single rod was built in a serial resistor circuit in a manner that with the destruction of the rod a voltage could be detected and out of the different arrival times at the rods (located in a distance of 50 mm to each other) the velocity of the projectile could be calculated. The registration of the signals has been performed with a transient recorder with a sampling rate of 100 kHz. For the triggering of the data record the signal of the destruction of the first glass-rod was used.

The detection of the forces has been realized by using a ready-to-use piezo-electric force transducer-system. It was built between the tilting target surface and the plate that has been hit by the projectile in the rotation point of the target construction. With the help of pre-amplifiers the signal could be registered in a transient recorder as well.

EXPERIMENTAL RESULTS

A test series of more than 50 tests with the variation of different parameters was performed. These parameters were the filling of the tank, the velocity of the impact and the angle between the target and the projectile axis. By choosing different pressure-levels the velocity could be adjusted within a range of +/- 10 m/s. Two different velocities were desired: “slow” and “fast”. For both velocities tests with impact angles of 0°, 30° and 60° to the main axis were performed. The following table 1 gives an overview on the variations of the parameters.

velocity [m/s]	angle [°]	full	half-filled	empty	substitution mass
slow	0	X	X		
slow	30				X
slow	60				X
fast	0	X	X	X	X
fast	30	X			X
fast	60				X

Table 1 Parameter variations within the test series

The following figure 3 shows the picture sequence of a typical impact of a half-filled projectile at a slow velocity. It can be seen that the third section is only slightly damaged. Despite of the only slightly destroyed section 3 the fluid is forming a cloud which would be dangerous in the case of having a real fuel.

Figure 3 Picture sequence (frame rate 4000 frames/s) of a perpendicular impact (α = 0°) of a projectile with half-filled tank at a slow velocity

A typical load-time-history for the perpendicular impact ($\alpha = 0$) is given in figure 4. F_Z is the measured force in the main axis of the set-up. It can easily be seen that the signal is overlaid by some different high frequencies. By using low-pass filters most of these frequencies can be filtered out..

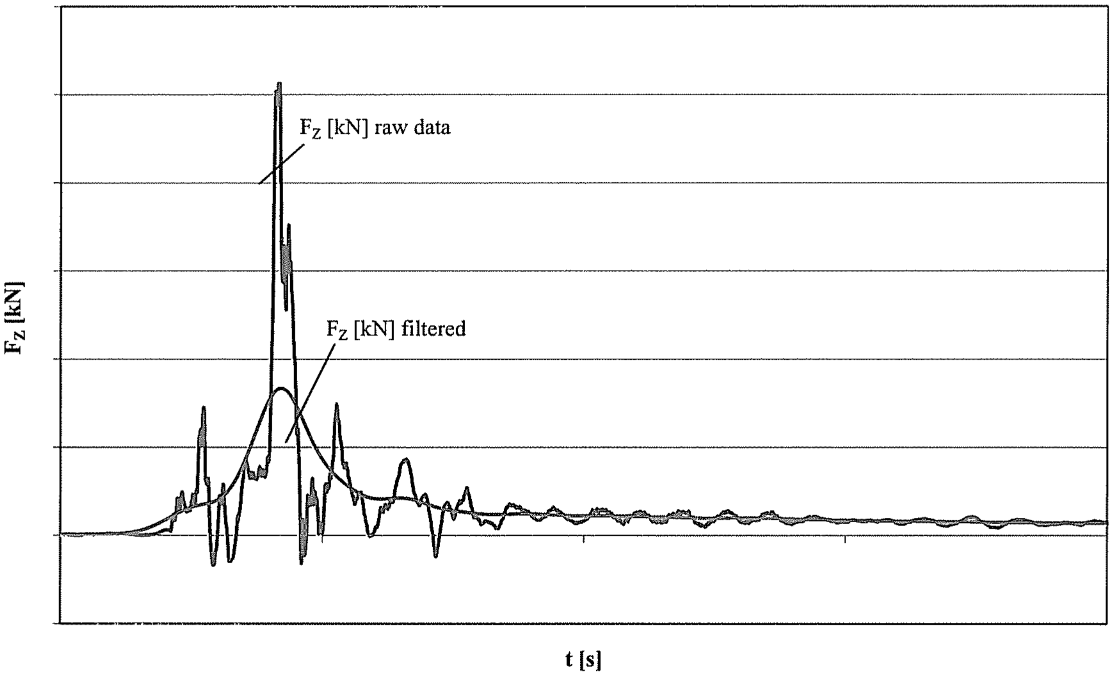


Figure 4 Load-time history F_Z as raw and filtered data in principle

As shown in table 1 also tests with different impact-angles were performed, most of them by using a substitution mass in order to have the best visibility regarding the effects which or important during the impact. Figure 5 shows an example for a 30°-impact and figure 5 a 60°-impact. It can be seen that at 30° the projectile began to slide along the target but was still heavily damaged. At the 60°-impact the effect of sliding increased and the fragments were still more or less connected to each other after the collision but the tank was destroyed anyway.

Figure 5 Picture of an impact of a projectile filled with substitution mass and $\alpha = 30°$

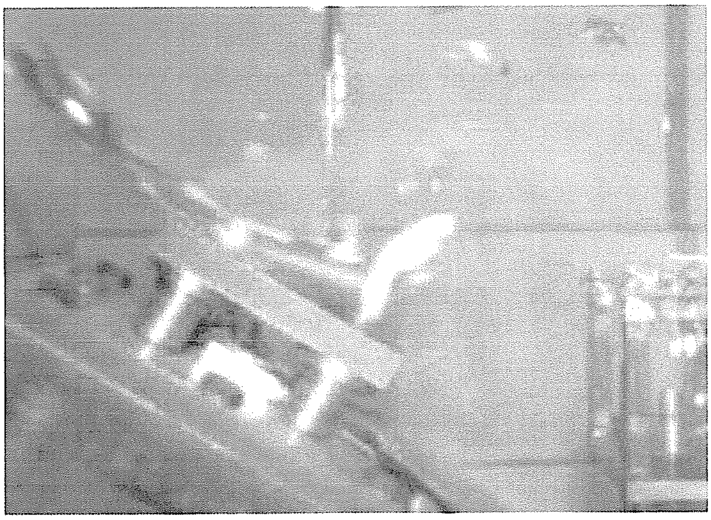


Figure 6 Picture of an impact of a projectile filled with substitution mass and $\alpha = 60°$

In order to evaluate the exact impact of the target vibration or the eigenfrequencies of the force measurement pendulum tests were performed. Therefore a steel pendulum of 2.1 kg was swung against the target to produce a well defined hard impact and to measure the reaction of the target system including the measuring platform. The set-up for the pendulum test is shown in figure 7. The pendulum can be seen after destroying the glass-rods shortly before impacting the measuring platform. After the single impact the pendulum was fixed again to avoid any disturbance of the registered force signal.

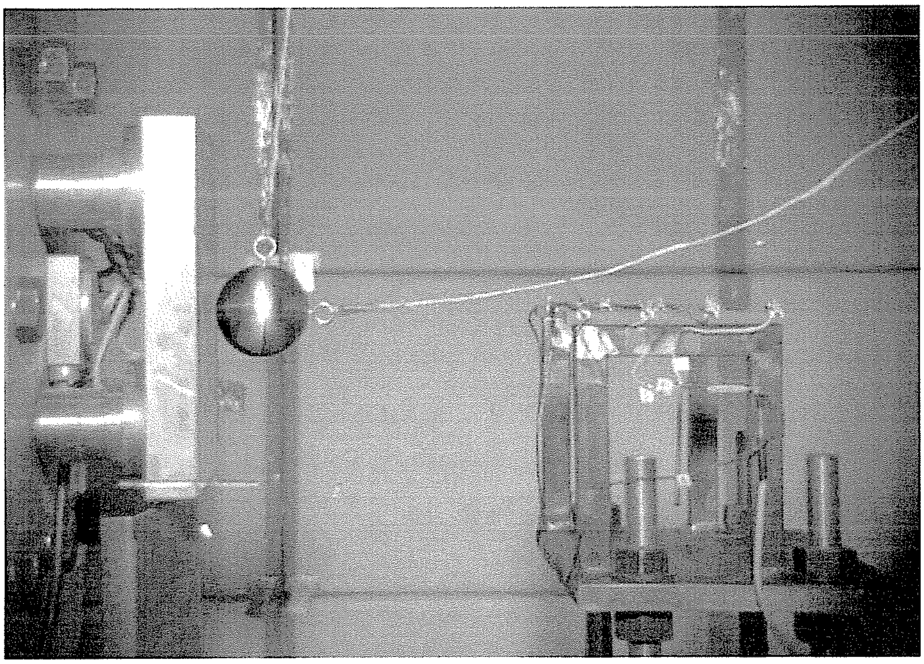


Figure 7 Picture of the perpendicular impact of the pendulum to evaluate the vibrations of the target system

The force measurement results for a 0°-pendulum test are shown in figure 8. The two upper curves show the forces F_X and F_Y within the plane of the target surface. It can easily be seen that these two curves have a basic frequency that is quite of the same value.

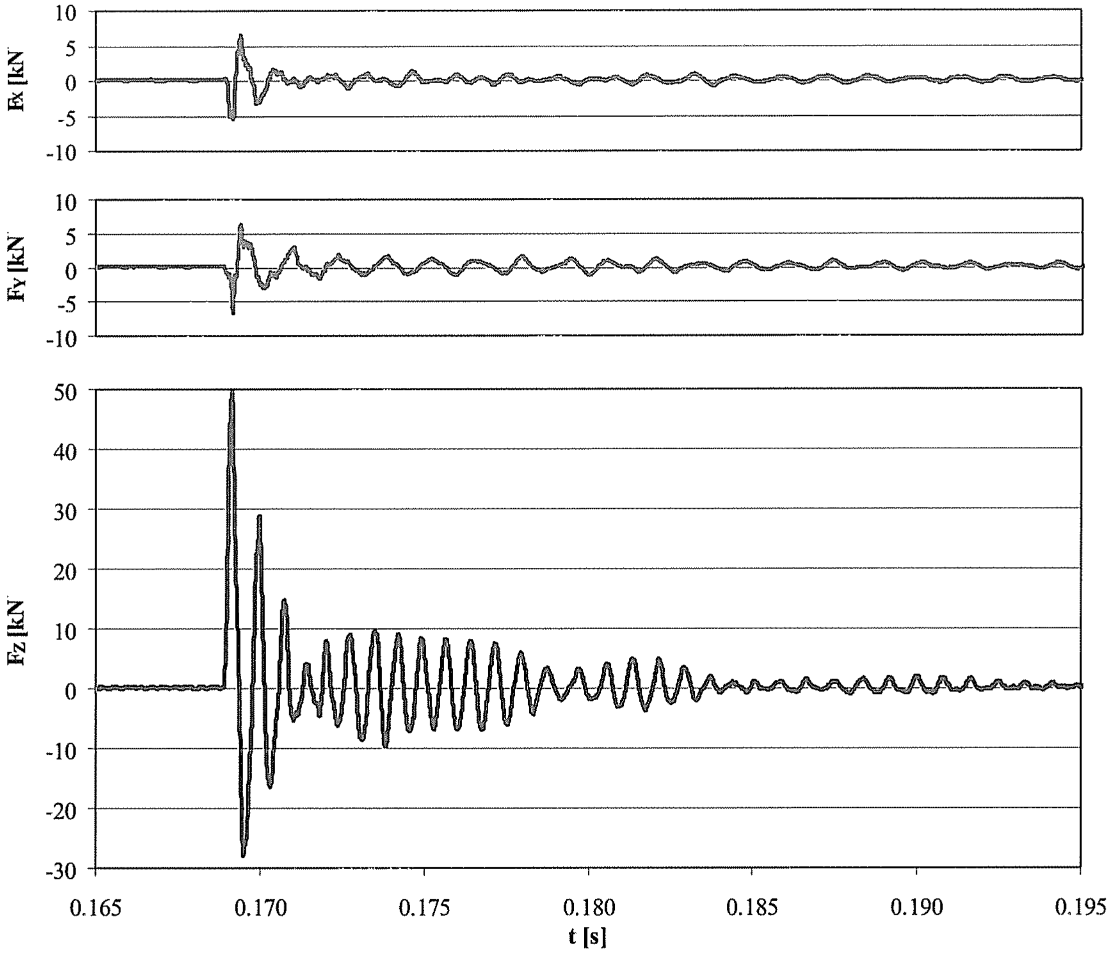


Figure 8 Force measurements in all three directions during a 0°-pendulum test

The important main axis force F_Z can be seen in the third diagram of figure 8. As expected the value is approximately 10-times larger and therefore a different vertical axis is used. The basic frequency seems to be higher than in the other direction but in addition to this it is overlaid by another frequency being responsible for the pulsating of the registered signal.

For the analysis of the eigenfrequencies a Fourier-transformation was performed and the resulting spectra is shown in figure 9. As discussed above F_X and F_Y are overlaid by the same basic frequency of ~ 740 Hz. No other frequencies are of any importance for these two directions. For the F_Z-direction three different frequencies lying next to each other are of importance. The values of these frequencies are 1150 Hz, 1250 Hz and 1390 Hz which explains the pulsating of the signal and effects the use of low pass filters (see figure 4). The evaluation of many of the test results is still ongoing.

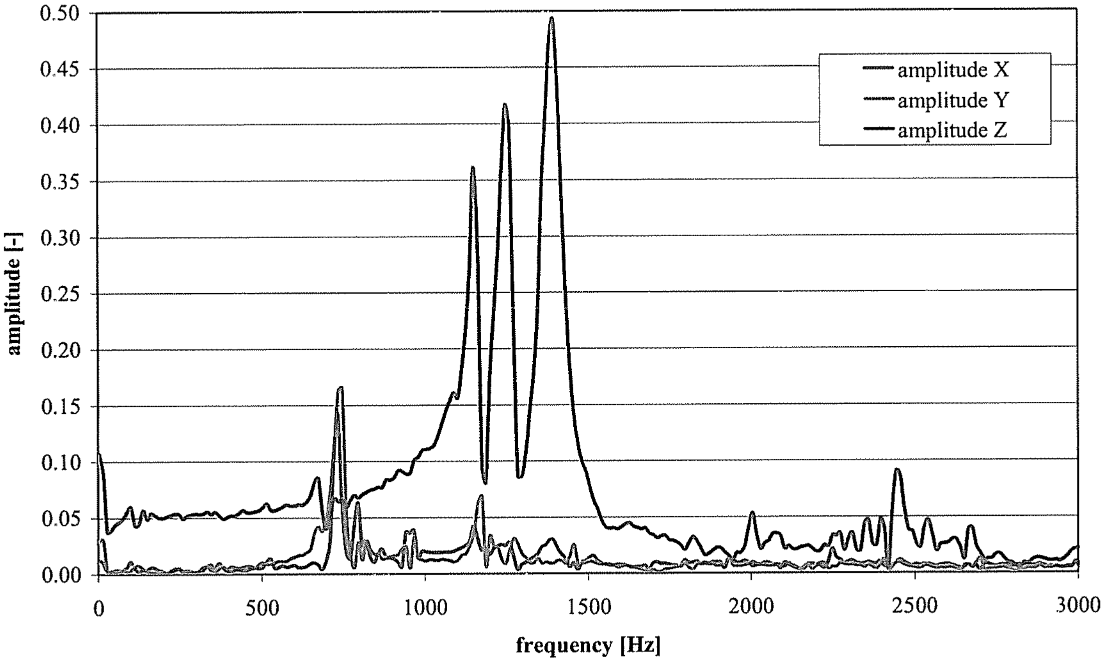


Figure 9 Spectra of the eigenfrequencies of the combination of the target and the measuring platform

CONCLUSION

A test set-up for a series of impact tests with fluid-filled projectiles is presented in this paper. The variation of different parameters and some first results are described. As the evaluation of the data is not possible without the knowledge of the vibration characteristics of the whole set-up pendulum tests in order to investigate the eigenfrequencies of the system were performed and their results are discussed. All the results presented in this paper are first interpretations of the raw data. For a better interpretation and understanding of all the phenomena occurring in these tests a further series with an alternative target is planned as well as theoretical and numerical studies.

ACKNOWLEDGEMENT

The work was performed in cooperation with the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH and sponsored by the German Ministry of Economics and Labour.

REFERENCES

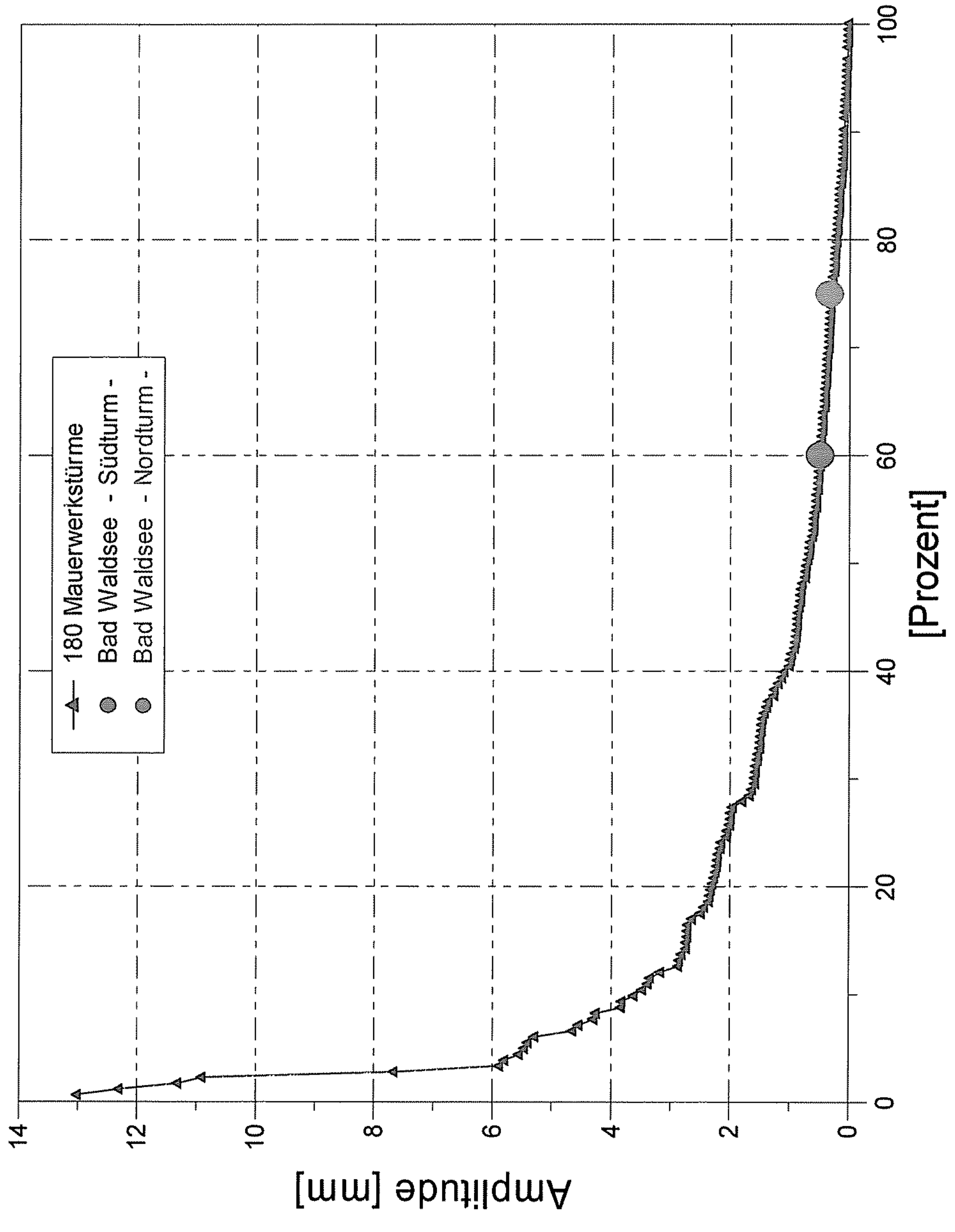
[1] Holsapple, K.E.; "The Scaling of Impact Phenomena", International Journal of Impact Engineering Vol. 5; pp 343-356;1987

[2] Lorenz, H.; "Aircraft Impact Design", Power Engineering; 1970

[3] Riera, J.D.; "On the Stress Analysis of Structures Subjected to Aircraft Impact Forces", Nuclear Engineering and Design 8; pp 415-426; 1968

Mauerwerkstürme Stand 06.04.2005

Amplituden in Läuterichtung



analysis is made on the work done on SDOF structures by the excitation force. Since work is equal to the change in the energy of a system, this quantity is closely related to failure models based on strain energy such as the Von Mesis criterion. This paper explores a method for characterizing shock motion based on the input energy. The input energy spectrum has attractive properties which include intuitive physical significance, insensitivity to system parameters such as damping, the ability to distinguish between realistic shocks and chirps, and a close relation to accepted material failure models.

PERFORATION/PENETRATION

An Experimental Approach to Determine Load-functions for the Impact of Fluid-filled Projectiles

Dr Nico Hermann, Klaus Kreuker, Prof. Lothar Stempniewski, University of Karlsruhe

We report on a series of tests that has been performed at our institute with the goal of evaluating the load-time-history of fluid-filled projectiles on a target that can be regarded as almost rigid. An air-pressure gun has been used that is capable of accelerating a projectile of 2.5 kg to a velocity of about 220 m/s. The air-pressure-level can be adjusted up to 100 bars.

In order to gain first results on the shape and the peak-loads of load-functions for projectiles with stiffness and mass distribution similar to the proportions of a commercial aircraft we performed impact tests with velocities in the range of 130 m/s to 190 m/s and a projectile mass of about 700 g. As material we used an aluminum alloy which is common in the aircraft industry. The fluid-filling was realized by using tanks either half-filled or full with water or in some cases filled with a substitution mass of expanded clay beads.

The whole test set-up will be presented and its capabilities will be described. The measurement technique for the load and the velocity registration will be shown. Some showcase results from first and still ongoing data interpretations will be given as well as a discussion on the difficulties of evaluating the load-time-signal out of the raw data that is always overlaid by vibrations due to the eigenfrequencies of the target and the measurement device itself.

Perforation of Metal Plates: Laboratory Experiments and Numerical Simulations

Dr. Leonard Schwer, Schwer Engineering and Consulting Services, Dr. Kurt Hacker, Dr. Kenneth Poe, Naval Explosive Ordnance Disposal Technology Division

The Naval Explosive Ordnance Disposal Technology Division has a requirement to establish a modeling capability to simulate render safe procedures for unexploded ordnance. To aid in establishing this capability, the Navy has initiated a research and development program that includes modeling studies, research on applicable impact related material parameters, and comparison of the modeling results with experimental results. This paper presents a summary of the progress during the first six months of this

SAVIAC
Shock and Vibration Information Analysis Center

Abstracts

76th Shock & Vibration Symposium

DEFENSE THREAT REDUCTION AGENCY
UNITED STATES OF AMERICA

US Army Corps of Engineers®
Engineer Research and Development Center

WEIDLINGER ASSOCIATES® INC
CONSULTING ENGINEERS

MSC SOFTWARE®

October 30 - November 3, 2005
Destin, Florida

Table of Contents

TEST CRITERIA

Derivation of MALD Ground Test Vibration Requirements from Captive Carriage Flight Tests 1

Pat Willems Raytheon Missile Systems, Scott Fling, JE Sverdrup *1*

Development of Rail Impact Test Criteria for Cushioned Draft Gear Rail Cars 1

Stanley Poynor, Wayne Clay, Jeff Kirk, Lockheed Martin Missiles & Fire Control *1*

On the Use of Linear Accelerometers in Six-DOF Laboratory Motion Replication: A Unified Time-Domain Analysis 2

Dr. Norman Fitz-Coy University of Florida, Dr. Michael Hale, Redstone Technical Test Center *2*

Utilization of Vehicle Test Course Speed Distributions to Refine Methods of Vehicle Scenario Derivation for Laboratory Vibration Test Schedule (LVTS) Development 2

Jesse Porter, US Army Redstone Technical Test Center, Michael Barry, US Army Aberdeen Test Center *2*

Methodology for Determining Ballistic Shock Damage to Internal Components Mounted within Combat Vehicles 3

Jennifer Akers, Michael Gillich, Ed Fioravante, U.S. Army Research Laboratory *3*

Earthquake Hazard Analysis and Dynamic Site Response Evaluation for Design of Tower Buildings in Dubai, UAE 4

Prof Azm Al-Homoud, American University of Sharjah *4*

HARDENING OF ELECTRONICS & STRUCTURES TO HIGH-G EFFECTS INDUCED BY GUN LAUNCH AND BALLISTIC SHOCK

Finite Element Modeling of Electronic Components in Projectiles 5

Dr. Mohamed Trabia, Dr. Brendan O'Toole, Dr. Samaan Ladkany, Dr. Mostafiz Chowdhury, University of Nevada, Las Vegas *5*

Optimization of Joint Design for Side Panel of A Military Vehicle for Shock Reduction 6

Dr. Mohamed Trabia, Dr. Brendan O'Toole, Dr. Samaan Ladkany, Dr. Jinhua Huang, University of Nevada, Las Vegas *6*

Protection of Military Vehicle Occupants from Mine Blast Using an Air Bladder Seat Shock Isolation System 6

Dr. Douglas Reynolds, Dr. Brian Landsberger, Chris Ransel, Tarek Deeb, University of Nevada Las Vegas *6*

Simulation and Measurement of Shock Transmission Across Joints 7

Dr. Brendan O'Toole, Dr. Samaan Ladkany, Masoud Feghhi, Karthik Doppola, University of Nevada Las Vegas *7*

TEST FACILITIES I

US Army Centrifuge: Critical Capability for the Future 7

Wipaji Vanadit-Ellis, US Army Engineering Research and Development Center *7*

Magneto-Inductive Remote Activation Munitions System 8

Dr. Jon Windham, Dr. James Cargile, US Army Engineer Research & Development Center, Richard Andrejkovics, Picatinny Arsenal, Paul Wrathal, Magneto-Inductive Systems Ltd *8*

Simultaneous Multi-Axis Mechanical Shock Simulations 8

Dr. Vesta Bateman, Lawrence Carlson, Sandia National Laboratories *8*

Design and Evaluation of Multi-Axis High-Frequency Vibration Shaker Systems 8

Dr Georg Mauer, Brinda Venkatesh, University of Nevada, Las Vegas *8*

Structural Damage Detection and Localization by Non-linear Acoustic Spectroscopy 9

Dr. Gerard Vanderborck, Thales Underwater Systems, Dr. Bernard Rousselet, Nice University *9*

TEST FACILITIES II

Design of a Shock Test Machine for Encanistered Missiles 10

Dr. Jon Yagla, Naval Surface Warfare Center Dahlgren Division *10*

Calibration and Qualification of the WOX-MSTM Encanistered Missile Shock Test Machine 10
Dr. Jon Yagla, Naval Surface Warfare Center Dahlgren Division *10*
Development of a Test System to Replicate the Shock Profiles Through Small Arms Accessories 11
Nigel Linden, Re Test Equipment, Inc. *11*
Littoral Warfare Environment 12
Robert McHugh, U.S. Army Aberdeen Test Center *12*
Using a Six Ton Pile Driver to Mimic Firing Pressures of Large Caliber Cannon –Softly 12
Dr. Eric Kathe, John Keating, Lawrence Kelley, Dr. Andrew Littlefield, US Army RDECOM/Benet Labs *12*

TRAINING I

Basics of Acoustics: Generation, Description, Instrumentation, & Measurement 12
Richard Peppin, Scantek, Inc. *12*
Using The Pseudo Velocity Shock Spectrum For Shock Damage Potential, Part 1 12
Dr. Howard Gaberson, MFPT Society/SAVIAC *12*
Using The Pseudo Velocity Shock Spectrum For Shock Damage Potential, Part 2 13
Dr. Howard Gaberson, MFPT Society/SAVIAC *13*

DOCK SHOCK – AN ALTERNATIVE SHIP SHOCK TEST CONCEPT (LIMITED)

Cavity Dynamics and the Development of a Non-Explosive Ship Shock Testing System 14
Dr. Georges Chahine, Dynaflow, Inc. *14*
DockShock: An Introduction to the DockShock Concept 14
Dr. Russel Miller, Roger Bagbey, Erv Pettersen, Dr. Christopher Mairs, Anteon Corporation *14*
DockShock: Predicting Target Response 15
Dr. Russel Miller, Dr. Christopher Mairs, Anteon Corporation *15*
DockShock: System Design Considerations 16
John Tullai, Christian Whitney, Anteon Corporation *16*
An Electromagnetic Transducer for Generating High Pressure, Underwater Pulses 17
Dr. Michael Raleigh, Dr. James Galambos, BAE Systems Advanced Technologies, Inc. *17*

ALTERNATE SHIP SHOCK TESTING SYSTEMS – AIR GUNS (LIMITED)

Non- Explosive Shock Testing Requirements and Aspirations: The US Navy and OSD LFT&E Perspective 17
Frederick A. Costanzo, Carderock Division, Naval Surface Warfare Center *17*
Non- Explosive Shock Testing Requirements And Aspirations: The United Kingdom Ministry Of Defence Perspective 17
Barry Knott, Ministry of Defence (UK) *17*
Overview of The Development Of Seismic Airgun Techniques For Non-Explosive Shock Testing 18
Phillip Thompson, Weidlinger Associates Ltd *18*
High Frequency Airgun Signature Characterisation And Shock Barge Testing Using Airgun Arrays 18
Gavin Colliar, Weidlinger Associates Ltd *18*
SBIR Phase I Review: Non Explosive Shock Testing Using Airguns 19
Dr Raymond Daddazio PE, Weidlinger Associates Inc. *19*
Large Structure Modal Testing Using Seismic Airgun Excitation Techniques 19
Phillip Thompson, Weidlinger Associates Ltd *19*

VIBRATION (LIMITED)

Comparing the Measured Response of an AN/ALQ-99 Tactical Jamming System Pod to the Input Motions During a Vibration Study 19
James Wilcoski, Jonathon Trovillion, US Army Engineer Research and Development Center, Construction Engineering *19*
Validation of FEM predictions of Vibration Levels to support CVN Design 20

Kevin Arden, Northrop Grumman Newport News *20*
USE OF VIBRATION MEASUREMENTS AND FEM PREDICTIONS TO EVALUATE LOCATION OF ISLAND STRUCTURE FOR NEW CVN DESIGN 20
Davis Hill, Jason Hartmann, Northrop Grumman Newport News *20*
VIBRATION MEASUREMENTS PERFORMED ON CARRIER SEA TRIALS TO SUPPORT CVN DESIGN 21
James Gardner, Northrop Grumman Newport News *21*

FINITE ELEMENT MODELING (LIMITED)

FINITE ELEMENT MODELING OF CLOSE ENCOUNTERS WITH UNDERWATER EXPLOSIONS 21
Dr. Gale Mulligan, General Dynamics Electric Boat Corporation *21*
A COMPARISON OF LS-DYNA COMPOSITE FAILURE MODELS IN A DYNAMIC ENVIRONMENT 22
Bill Gregory, Christopher Key, Dr. Iam Lua and Dr. Richard Cobb, Anteon Corp *22*
DYNAMIC RESPONSE AND FAILURE PREDICTION OF COMPOSITE HAT STIFFENERS 22
Bill Gregory, Dr. Richard Cobb, Dr. Jim Lua, Joshua Gorfain, Anteon Corp *22*
FINITE ELEMENT ANALYSIS IN SUPPORT OF MIL-S-901D SHOCK TESTING OF THE AN/SPQ-9B ANTENNA GROUP 23
Andrew Lotz, Northrop Grumman Newport News *23*
STRUCTURAL OPTIMIZATION OF NON-LINE-OF-SIGHT CANNON (NLOS-C) TURRET 23
Dr. Nam Ngo, Vincent Whelan, Dr. Brian Bauman, Ed Alexander, BAE Systems *23*

SHOCK RESPONSE

DERIVATION OF THE RAMP INVARIANT FILTER FOR SHOCK RESPONSE SPECTRUM CALCULATIONS 23
David Smallwood, Consultant *23*
APPLYING FUZZY STRUCTURE THEORY TO SHOCK RESPONSE PREDICTIONS 24
Carina Ting, Thomas Littlewood, Dr. Russel Miller and Jeffrey O'Brien, Anteon Corporation *24*
A TECHNIQUE FOR THE IDENTIFICATION OF THE OPTIMUM INPUTS FOR A VIBRATION OR ACOUSTIC TEST24
Jerome Cap, Melissa C de Baca, Sandia National Laboratories, David Smallwood, Compa Industries *24*
ON THE COMPARISON OF TEST SPECIFICATION AND MEASURED FIELD DATA 24
Professor Kjell Ahlin, Blekinge Institute of Technology *24*
MODAL EXPRESSIONS FOR RELATIVE DISPLACEMENTS UNDERLYING PSEUDO-VELOCITY SHOCK-RESPONSE SPECTRA, FOR IDEALIZED REMOTE SHOCK LOADINGS: DERIVATION AND VERIFICATION 25
Dr. R. David Hampton, U.S. Military Academy *25*
ANALYTICAL KINEMATIC EXPRESSIONS FOR PSEUDO-VELOCITY SHOCK RESPONSE SPECTRA OF GENERALLY DAMPED LINEAR SYSTEMS 25
Dr. R. David Hampton, Colonel Kip P. Nygren, Captain Jared Erickson, U.S. Military Academy; Ting H. Li, U.S. Army Research Laboratory *25*
USING WORK AND ENERGY TO CHARACTERIZE MECHANICAL SHOCK 25
Timothy Edwards, Sandia National Laboratories *25*

PERFORATION/PENETRATION

AN EXPERIMENTAL APPROACH TO DETERMINE LOAD-FUNCTIONS FOR THE IMPACT OF FLUID-FILLED PROJECTILES 26
Dr Nico Hermann, Klaus Kreuker, Prof. Lothar Stempniewski, University of Karlsruhe *26*
PERFORATION OF METAL PLATES: LABORATORY EXPERIMENTS AND NUMERICAL SIMULATIONS 26
Dr. Leonard Schwer, Schwer Engineering and Consulting Services, Dr. Kurt Hacker, Dr. Kenneth Poe, Naval Explosive Ordnance Disposal Technology Division *26*
NUMERICAL SIMULATIONS OF INVERSE PLANAR IMPACT TESTS ON SAND 27
Dr. Leo Laine, ANKER-ZEMER Engineering AS *27*
NUMERICAL INVESTIGATION ON THE IMPACT STRENGTH OF BACK PLATES OF WELDOX STEEL, PURE COPPER, 2024-T3 ALUMINUM ALLOY, TI-6AL-4V TITANIUM ALLOY AND SOME COMPOSITES 27
Rengas Venkataraman, Dr. Abdalla Elbella, Potluri Krishna, Bradley University *27*
THE CHARACTERISTIC OF BLADE FORMATION/CUTTING PROCESS OF LINEAR SHAPED CHARGES (LSCs) 28
Seokbin Lim, Braden Lusk, Dr. Paul Worsey, Rock Mechanics & Explosives Research Center *28*
PROJECTILE DECELERATION FOR PERFORATION THROUGH LAYERS OF UN-REINFORCED CONCRETE TARGETS 28

Jeff Averett, Dr. Donald Cargile, US Army Engineer Research and Development Center, John Foster, Dr. Vincent Luk, Sandia National Laboratories *28*

NUMERICAL METHODS

EXTENSION OF INFINITE ELEMENTS AND ABSORBING BOUNDARY CONDITIONS TO EIGENANALYSIS OF SUBMERGED STRUCTURES 29
Dr. Jeffrey Cipolla, ABAQUS, Inc *29*
CROSS ORTHOGONALITY CHECK-OUT OF SUPERELEMENTS 29
Fred Russell, General Dynamics/Electric Boat *29*
UNDERSTANDING AND USING THE SPECTRAL DENSITY MATRIX 29
Dr. Marcos Underwood, Tony Keller, Spectral Dynamics, Inc. *29*
A COMPREHENSIVE APPROACH FOR TREATING CLOSELY SPACED MODES IN THE DYNAMIC DESIGN ANALYSIS METHOD 30
Dr. David Winkler, David Woyak, ABAQUS Inc. *30*
CUMULATIVE ERROR DUE TO INTEGRATION PROCEDURE IN PROGRESSIVE COLLAPSE ANALYSIS 30
Dr. Hyung Jin Choi, Karagozian & Case *30*

TRAINING II

TUTORIAL ON BALLISTIC SHOCK IN ARMORED VEHICLES 31
W. Scott Walton, U.S. ARMY Aberdeen Test Center, Ami Frydman, US Army Research Lab *31*
METAL FATIGUE I 31
Dr. Rudy Scavuzzo, University of Akron *31*
METAL FATIGUE II 32
Dr. Rudy Scavuzzo, University of Akron *32*
CENTRIFUGE TECHNOLOGY 32
Dr. Mike Sharp, Dr. Joe Koester, US Army Engineer Research & Development Center *32*

DD(X) UNDEX (LIMITED)

DD(X) MACHINERY AND ELECTRONICS SHOCK MITIGATED RAFTING: DESIGN CONCEPTS 32
Dr. Russ Miller, Vince Godino, Skip Dixon, Jeff O'Brien, Anteon Corp. *32*
MODELING, SIMULATION AND VALIDATION OF GOLDWHIP FOR DD(X) 33
Sean Murphy, Northrop Grumman Ship Systems *33*
DD(X) UNDEX HULL WHIPPING TEST: A MODELING AND SIMULATION COMPARISON OF LARGE CHARGE AND SMALL CHARGE SHOCK TRIAL SCENARIOS 33
Derek Skahen, T&E Solutions; Joel Myers, Northrop Grumman Ship Systems; Steve Rutgerson, NSWC/CD *33*
DD(X) UNDEX HULL WHIPPING TEST: AN EVALUATION OF M&S TOOLS FOR ABOVE DESIGN LEVEL ANALYSES 33
Sean Murphy, Dr. Erwin Moyer, Northrop Grumman Ship Systems *33*
TUTORIAL- PPD 802-7651312 SHOCK (HIGH-IMPACT AND LOW-IMPACT) TESTING, DD(X) SHIPBOARD 33
D Shawn McPartland, Anteon *33*
DD(X) MACHINERY AND ELECTRONICS SHOCK MITIGATION RAFTING: EQUIPMENT TESTING AND MODELING 33
Jeff O'Brien, Brendan Woolrich, Vince Godino, Dr. Russ Miller, Anteon Corporation *33*
DD(X) MACHINERY AND ELECTRONICS SHOCK MITIGATION RAFTING: DEVICE ALGORITHM DEVELOPMENT 34
Jeff O'Brien, Brendan Woolrich, Vince Godino, Dr. Russ Miller, Anteon Corporation *34*
DD(X) MACHINERY AND ELECTRONICS SHOCK MITIGATED RAFTING: MODELING, SIMULATION AND VALIDATION 35
Dr. Russ Miller, Jeff O'Brien, Brenden Woolrich, Jeff Gorfain, Anteon Corp *35*
DD(X) MACHINERY AND ELECTRONICS SHOCK MITIGATED RAFTING: TEST ARTICLES 35
William Dickson, Vince Godino, Russ Miller, Jeff O'Brien, Anteon Corporation *35*
DD(X) WHOLE SHIP TRANSIENT ANALYSIS 36
Tom Littlewood, Morgan Eash, Chris Key, Christian Whitney, Anteon Corporation *36*

SPECIAL SESSIONS ON DTRA NUCLEAR WEAPONS EFFECTS TECHNOLOGIES: NON-IDEAL AIR BLAST LOADING (LIMITED)

DTRA Software Tools for Target Damage Assessment 36
Michael Giltrud, Defense Threat Reduction Agency *36*
NIAB Overview 36
Ken Kreyenhagen, NGIT *36*
Airblast Environment Modeling Laboratory Scale Experiments 37
Paul Yarrington, Sandia National Laboratory *37*
Loading on Closely Spaced Structures 37
Dr. Mike Kerry, Dr. Keith Seal, AWE *37*
Response of Closely Spaced Multiple Objects when Subject to Blast Loading 37
Dr. Keith Seal, Dr. Mike Kerry, AWE *37*
Non Ideal Airblast Efects from Urban and Natural Terrain 37
Joe Crepeau, Charles Needham, ARA *37*
Urban Airlast Calculations 38
Jack Klump, SAIC *38*
Airblast from Underground Explosions 38
Philip Hookham, Titan Research *38*
Targeting Considerations (VNTK Overview) 39
Charles Deel SAIC *39*

HIGH PERFROMANCE DATA ACQUISTION SYSTEMS

High Speed Ballistic Digitizer System 39
Dr. Lee Francis, Gary Uhland, Dustin Houseman, Corey Himes, US Army Aberdeen Test Center *39*
Electro-Magnetic Interference (EMI) in Instrumentation Cables During Explosive Testing 40
Scott Walton, U.S. ARMY Aberdeen Test Center *40*
The Accelerometer Cable - It Can't Get No Respect 41
Dr. Patrick Walter, Texas Christian University *41*
New Approaches to High Performance Data Acquisition 41
Gary Schneider, Hi-Techniques *41*
LD TEDS: A Method for Long Distance Communication to Smart Transducers with TEDS.. 41
Douglas Firth, Stephen Finney, Precision Filters, Inc. *41*

BLAST EFFECTS

Dynamic Analysis of Concrete Structure Under Blast Load Using Plastic Damage Model 42
Jim Won Nam, Ho Jin Kim, Yonsei University, Dr. Hyung Jin Choi, Karagozian & Case Inc., Ha-Won Song, Yonsei University *42*
Numerical Modeling Approaches for Simulation of Landmine Blast Loading 42
Laura Donahue, Martec, Ltd., Dr. Amal Bouamoul, Defense R&D Canada - Valcartier, Tim Dunbar, Martec, Ltd. *42*
Consideration on Bridge Blast Analysis and its Damage Evaluation 43
Dr. Hyung Kin Choi, Karagozian & Case Inc. *43*
Protecting Humans From Blast Induced Shock Waves 43
Dr. Ken-An Lou, ArmorWorks, LLC.; Richard Zimmerman, Zerad Inc. *43*
Numerical Method for Evaluating Debris Size and Velocity of Slab 44
Dr. Hyung-Jin Choi, John Crawford, Karagozian & Case Inc. *44*

VIBRATION DAMPING

Rim Dampers for System Modes of a Turbine Engine Integrally Bladed Rotor 44
Dr. John Henderson, John Justice, Philip Johnson, Universal Technology Corp., Brian Runyon, AF Research Laboratory, Ahid Nashif, Consultant, Universal Technology Corporation *44*
Durability Studies of the Resistance of Viscoelastic Materials to High Temperatures 44
Ahid Nashif, Consultant to Universal Technology Corp. *44*

BROADBAND DAMPING IN HIGH TEMPERATURE ENVIRONMENTS USING MULTIPLE TUNED MASS ABSORBERS 45
Dr Jeffery Zapfe, Acentech Incorporated *45*
SOURCES OF ERROR IN OBTAINING DAMPING PROPERTIES OF HARD COATINGS FROM VIBRATION TESTS 45
Dr. Peter Torvik, Consultant to Universal Technology Corporation *45*

BLAST RESPONSE

CONSTITUTIVE MODEL EVALUATION FOR EOD BALLISTIC IMPACT SIMULATIONS 45
Dr. Mark Vulitsky, Naval Explosive Ordnance Disposal Technology Division, Dr. Leonard Schwer, Schwer Engineering & Consulting Services, Kenneth Poe, Dr. Kurt Hacker, Naval Explosive Ordnance Disposal Technology Division *45*
BLAST RESISTANCE OF STEEL AND COMPOSITE BRIDGE PIERS AND DECKS 46
Prof Abolhassan Astaneh-Asl, Jin Son Dr. Marcus Rutner, University of California, Berkeley *46*
PERFORMANCE OF R/C AND COMPOSITE WALLS OF BUILDINGS UNDER BLAST LOADS 46
Prof Abolhassan Astaneh-Asl, Qiuhong Zhao, University of California, Berkeley, Casey Heydari, MSC.Software Corp. *46*
A COMPARISON OF ACCELEROMETER MOUNTING TECHNIQUES ON INTERNAL BLAST CUBICLE EXPERIMENTS UNDERGOING ELASTO-PLASTIC DEFORMATION 47
George Yiannakopoulos, DSTO *47*

TRAINING III

PRACTICAL RANDOM VIBRATION ANALYSIS OF NONLINEAR STRUCTURES VIA FINITE ELEMENT MODELS 47
Dr. Thomas Paez, Sandia National Laboratories *47*
PYROSHOCK TESTING 48
Dr. Vesta Bateman, Sandia National Laboratories *48*
FEA, SPARSE DATA, AND ALIASING 48
Edward Dyer, BAE Systems *48*
SIMULATION PROCESS AND DATA MANAGEMENT INDUSTRY EXAMPLES 48
Matt Macias, MSC.Software Corporation *48*

THE PERIPHERAL VERTICAL LAUNCHER SYSTEM (PVLS) ENGINEERING DEVELOPMENT MODEL (EDM) FOR THE DD(X) DESIGN METHODOLOGY (LIMITED)

THE PVLS EDM & DD(X) DESIGN METHODOLOGY 49
Dr. E. Thomas Moyer, Northrop Grumman Ship Systems, Robert Wunderlick, Naval Surface Warfare Center Carderock Division, Robert DeGraeve, Northrop Grumman Ship Systems *49*
CONTRIBUTION TO BLAST OF SOLID PROPELLANT UNDER SHOCK LOADING - EXPERIMENTS AND MODELS 49
Dr. Michael Kaneshige, Dr. David Crawford, Daniel Sandoval, Dr. Robert Pahl, Sandia National Laboratory *49*
PVLS DESIGN LOAD METHODOLOGY 50
Dr. Christopher Freitas, Southwest Research Institute, Dr. David Crawford, Sandia National Laboratory, Ryan Keedy, Trueman Sharron, Dr. Charles Anderson, Southwest Research Institute ... *50*
PVLS STRUCTURAL ANALYSIS 51
Christopher Joseph, Dr. Tom Moyer, Robert DeGraeve, H.W. Ruth, Northrop Grumman Ship Systems *51*
PLANNING, MANAGEMENT, AND CONDUCT OF DD(X) PVLS EDM FULL-SCALE DEVELOPMENTAL TESTS EVENTS 51
G.D. (Jerry) Hill, Glen Snyder, Alion Science and Technology/JJMA Maritime Sector *51*
PVLS DESIGN EVOLUTION & LESSONS LEARNED 51
Dr. E. Thomas Moyer, Christopher Joseph, Robert DeGraeve, Northrop Grumman Ship Systems *51*
FRAGMENTATION PROTECTION AND WARHEAD RESISTANCE EXPERIMENTS 52
Dr. Charles Anderson, Southwest Research Institute, Dr. E. Thomas Moyer Northrop Grumman Ship Systems, G.D. (Jerry) Hill, Alion Science and Technology/JJMA Maritime Sector, Dr. Christopher Freitas, Ryan Keedy, Erick Sagebiel, Carl Weiss, Southwest Research Institute *52*
MAXIMUM CREDIBLE DETONATION EVENT; MCDE(2) FINAL DESIGN & PERFORMANCE 52

Dr. E. Thomas Moyer, H W Ruth, Christopher Joseph, Northrop Grumman Ship Systems *52*
PVLS Risk Retirement 53
Robert Wunderlik, Naval Surface Warfare Center Carderock Division, Dr. E. Thomas Moyer, Northrop Grumman Ship Systems *53*

SPECIAL SESSIONS ON DTRA NUCLEAR WEAPONS EFFECTS TECHNOLOGIES: VULNERABILITY OF UNDERGROUND FACILITIES (LIMITED)

DTRA IGVN Program Overview 53
Maj Jim Chrisley, Defense Threat Reduction Agency *53*
Target Planning: Ground Vulnerability Number 53
Charles Deel, SAIC *53*
Ground Shock Model, WinGS 54
Russ England, TRT *54*
Structural Response: Local Damage Mode 54
Scott Blouin, ARA *54*
Structural Response Global Damage Mode: Finite Element Modeling 55
Dr. Howard Levine Weidlinger Associates, Inc. *55*
Structural Response Global Damage Mode: Experimental Calibration 55
Dan Burgess, NGIT *55*
Structural Response Global Damage Mode: Engineering Model 56
Regan Burmeister, Applied Research Associates *56*
Field Experiment Comparisons 56
Maj Scott Grammer, Defense Threat Reduction Agency *56*

SHOCK ISOLATION

A Comparison of Elastomeric Isolators for Cabinet Isolation on Naval Vessels 56
Dr Robert Monson, Dr. Jack Yan, Julia Neuman, Lockheed Martin *56*
Dynamic Properties and Modeling of Wire Rope Isolator 57
Dr. Jarkko Keinanen, Dr. Kalle Vehvilainen, VIT, Technical Research Center of Finland *57*

UNDEX ANALYSIS I

Modeling of Unsteady Cavitation Induced by UNDEX 57
Dr. Kin Chew Hung, Institute of High Performance Computing, Dr. Boo Cheong Khoo, Wenfeng Xie, Dr. Tiegang Liu, National University of Singapore *57*
Dynamic Simulation of a Mine Barge Subjected to Underwater Explosions (UNDEX) 58
Dr. Juha Virtanen, Dr. Markku Jutunen, VTT Technical Research Center of Finland *58*
Littoral UNDEX Development Program of The Finnish Navy 58
LT. Turkka Jappinen, Finnish Navy, Dr. Markku Juntenen, VTT Technical Research Center of Finland *58*
Application of Non-linear Contact Surfaces in Modeling Whole Ship Shock Analysis 59
Tony Abbey, Noran Engineering *59*
Fluid-Structure Interaction Effects Resulting From Hull Appendage Coupling 59
LT. Mehmet Avcu, Turkish Navy, Jarema Didoszak, Dr. Young Shin, Naval Postgraduate School *59*
Further Investigation into the Technique and Applicability of DDAM Analysis in Large Models 59
Tony Abbey, Noran Engineering *59*

VIBRATION TESTING

Flutter and Vibration of Bearingless Elastic Helicopter Rotor Blades Featuring Flapping and Feathering Coupling 60
Prof Metin, Orhan Kaya, Ozge Ozdemir, Istanbul Technical University *60*
Analysis of the Effect of Hydrodynamic Preloading on the Acoustic Radiation of a Sonar Array 60
Karl D'Souza, Subham Sett, Dr. Jeffrey Cipolla, ABAQUS, Inc. *60*
New Developments in Shipboard Vibration 61
Chuck Vallance, Raytheon *61*

DEVELOPMENT OF A SEISMO-TECTONIC MODEL FOR THE UNITED ARAB EMIRATES 61
Dr. Azm Al-Homoud, American University of Sharjah 61

UNDEX TESTING

NEARBY UNDEX TESTS ON A THICK PLATE 62
Johannes E. Van Aanhold, TNO Built Environment and Geosciences, Theo N. Bosman, Royal Netherlands Navy 62
NEARBY UNDEX TESTS ON THIN PANELS 62
Johannes E. Van Aanhold, TNO Built Environment and Geosciences, Theo N. Bosman, Royal Netherlands Navy 62
MECHANICAL SHOCK FAILURE OF ELECTRONIC EQUIPMENT 62
Dr. Leland Smith, Thomas Savell, GCAS, Inc. 62
EXPERIMENTAL VERIFICATION OF RELATIONSHIP BETWEEN BUBBLE MOTION AND SHOCK VIBRATION OF SHIP EQUIPMENT 63
Prof. Li Guo-Hua, China Ship Scientific Research Centre 63
ADVANCED MODELING & SIMULATION TO REDUCE RELIANCE ON NAVY SHIP LIFE FIRE TEST & EVALUATION 64
Glen Sturtevant, US Navy PEO Ships 64

UNDEX ANALYSIS II

VR BASED VISUALIZATION SYSTEM FOR UNDEX SHIP SHOCK SIMULATION BY USING DIGITAL MOCK-UP TECHNOLOGY 64
Changmin Lee, Dr. Jung-Hoon Chung, Jaemun Yun, Dr. Hanjin Lee, Korea Research Institute of Ships & Ocean Engineering 64
APPLICATION OF DESIGN OF EXPERIMENT METHODOLOGY TO THE UNDEX WHOLE SHIP SHOCK MODELING & SIMULATION 64
Dr Jung-Hoon Chung, Korea Institute of Machinery and Materials, Jeong-Il Kwon, Dr. Sang-Gab Lee, Korea Maritime University 64
DESIGN OF AN INTEGRATED FRAMEWORK FOR EFFICIENT UNDEX SHIP SHOCK MODELING & SIMULATION 65
Dr. Dae-Seung Cho, Pusan National University, Dr. Jung Hoon Chung, Korea Institute of Machinery and Materials, Dr. Tae-Muk Choi, Jin-Hyeong Kim, Createch 65
BIODYNAMIC RESPONSE ANALYSIS OF A HUMAN ON FLOATING SHOCK PLATFORM TO UNDEX 66
Prof Sang-Gab Lee, Jeong-Il Kwon, Korea Maritime University, Dr. Jung-Hoon Chung, Korea Institute of Machinery and Materials 66
ESTIMATION METHOD FOR LONGITUDINAL BENDING STRENGTH OF A DAMAGED SHIP DUE TO A CLOSE-IN UNDEX BUBBLE 66
Dr. Akihiro Yasuda, Akihiko Imakita, Mitsui Engineering & Shipbuilding Co, Ltd. 66
LITTORAL ENVIRONMENT MODELLING OF UNDEX AND AIR BLAST EVENTS 66
Graeme Birkhead, John McVee, QinetiQ 66

TRAINING IV

ADDRESSING VARIABILITY AND UNCERTAINTY TO IMPROVE PRODUCT DESIGN 67
Gene Allen, MSC.Software Corporation 67
FINITE ELEMENT ANALYSIS 68
Bart Mcpheeters, MSC.Software Corporation 68

STRUCTURAL RESPONSE I (LIMITED)

ARENA FRAGMENT EXPERIMENTS USING MORTARS 68
Lebron Simmons, US Army Engineer Research & Development Center 68
EXPERIMENTS TO INVESTIGATE BEHIND-WALL EFFECTS DUE TO EXPLOSIVE BREACHING OF REINFORCED CONCRETE WALLS 69
Denis Rickman, Jay Ehrgott, US Army Engineer Research & Development Center 69
DEVELOPMENT OF AN IMPROVED MODEL FOR PREDICTING FIRST-CRACK OF LAMINATED GLASS SUBJECTED TO AIRBLAST 69
Steven Lofton, US Army Engineer Research & Development Center, Clayton Hooker, Sentel, Inc. 69

PRESSURE-IMPULSE CURVES FOR AIRBLAST LOADED FLAT SLABS 70
Dr. Kent Goering, Michael Miraglia, Applied Research Associates, Inc. *70*
PORTABLE PRESSURE -- FIELD TEST DEVICES 70
Michael Dean, US Army Aberdeen Test Center, Christina Milazzo, Aberdeen Test Support Services *70*

STRUCTURAL RESPONSE II (LIMITED)

USING COUPLED NUMERICAL SIMULATIONS TO STUDY BLAST FOCUSING 71
Dr. James O'Daniel, James Ray, US Army Engineer Research & Development Center *71*
GROUND SHOCK LOADING ON CONCRETE SLABS WITH VARYING EDGE FIXITY 71
Jay Ehrgott, Dr. Donald Cargile, Jon Windham, US Army Engineer Research & Development Center *71*
OBLIQUE PERFORATION EXPERIMENTS OF URBAN WALL MATERIALS IN URBAN OPERATIONS BY INDIRECT FIRE MUNITIONS 72
Rayment Moxley, Dr. Donald Cargile, US Army Engineer Research & Development Center, Richard Summers, Robert Phillabaum II, US Army Research Laboratory *72*
NUMERICAL SIMULATION OF PROJECTILE PENETRATION INTO THICK AND THIN SLABS OF SAM-35 CONCRETE 72
Erin Williams, Dr. Stephen Akers, Rayment Moxley, Paul Reed, US Army Engineer Research & Development Center *72*
MEASUREMENT OF AIRBLAST FROM CARBON COMPOSITE CASED MUNITIONS CONTAINING DENSE INERT METAL EXPLOSIVE 72
Roosevelt Davis, Donald Cunard, Air Force Research Laboratories *72*

SHOCK LOADING (LIMITED)

DETERMINATION OF DECK FREQUENCIES TO SUPPORT SHOCK ISOLATOR DESIGN 73
Jerry Dwyer, Northrop Grumman Newport News *73*
LPD-17 PRETRIAL SHIP SHOCK RESPONSE PREDICTIONS: PRELIMINARY SHIP SYSTEM RESPONSE 74
Jarema Didoszak, Jose Lepe, LCDR Laura Bollock, Dr. Young Shin, Naval Postgraduate School *74*
LPD-17 PRETRIAL SHIP SHOCK RESPONSE PREDICTIONS: COUPLED SHIP-FLUID MODEL GENERATION... 74
Jarema Didoszak, LCDR Laura Bollock, Jose Lepe, Dr. Young Shin, Naval Postgraduate School *74*

BLAST (LIMITED)

THEORETICAL AND EMPIRICAL ANALYSIS OF THE BEHAVIOR OF ELECTROMAGNETIC EMISSIONS FROM CASED EXPLOSIVES 75
Mark Schmidt, Dr. William Brown, Tim Samaras, and William Broad, Applied Research Associates *75*
PARTIAL-CITY AIR-BLAST EXPERIMENTS AND COMPARISON WITH NUMERICAL PREDICTIONS 75
Dr. James Baylot, Byron Armstrong, Dennis Rickman, US Army Engineer Research & Development Center *75*
BLAST LOAD PREDICTIONS FOR BUILDING GROUPS AND COMPARISON WITH TEST DATA 76
Dr. Jihui Geng, Dr. Kelly Thomas, Baker Engineerig and Risk Consultants, Inc., Dale Nebuda, US Army Corps of Engineers Protective Design Center *76*
A STUDY OF THE EFFECTS OF CASING MATERIAL PROPERTIES ON THE AIRBLAST FROM CASED EXPLOSIVE CHARGES 77
Dr. Alan Ohrt, Air Force Research Laboratory, Dr. Seung Lee, Defense Threat Reduction Agency .. *77*
BENEFITS TO THE WARFIGHTER FROM DTRA HARD TARGET DEFEAT AIR-DELIVERED WEAPON TESTING 77
Dr. Eric Rinehart, Dr. Robert Henny, DTRA Test Division, Robert Cilke, Jeffery Duray, Applied Research Associates *77*

VIBRATION MODELING

STRUCTURAL RESPONSE LIMIT SPECIFICATIONS FOR PRODUCT MODELS 78
Dr. Ronald Merritt, Naval Air Warfare Center *78*
FREE VIBRATION ANALYSIS OF A ROTATING DOUBLE TAPERED TIMOSHENKO BEAM BY DTM 78
Ozge Demiriozg, Prof Metin Orhan Kaya, Istanbul Technical University *78*
DENSIFICATION USING DEEP VIBRO COMPACTION OF HIGHLY COMPRESSIBLE RECLAIMED BEACH SAND CHARACTERIZED BY HIGH PERCENTAGE OF SHELL AND CARBONATES 79

  Prof Azm Al-Homoud, American University of Sharjah ... *79*
RANDOM EXCITATION OF THE VAN DER POL OSCILLATOR ... 80
  Dr. Hans Gruenberger, Consultant ... *80*

ANALYSIS RESULTS

A DIAGNOSTIC METHOD FOR PREDICTING MAINTENANCE REQUIREMENTS IN ROTATING EQUIPMENT ... 80
  Kevin Hunt, William Lindsay, Dofasco, Inc. ... *80*
SOIL PROPERTIES FROM LOW-VELOCITY PROBE PENETRATION ... 81
  Dr. Jerome Johnson, US Army Engineer Research and Development Center, CRREL, Dr. Donald Cargile, Dr. Donald Smith, US Army Engineer Research & Development Center ... *81*
SENSITIVITY ANALYSIS OF SHOT PEENING PARAMETERS USING NUMERICAL MODEL ... 81
  Rengas Venkataraman, Dr. Abdalla Elbella, Sridevi Earmani, Bradley University ... *81*
USE OF SEISMIC SURFACE MEASUREMENTS FOR ASSESSMENT OF GROUND IMPROVEMENT AT RECLAIMED LAND ... 82
  Prof Azm Al-Homoud, American University of Sharjah ... *82*
TESTING AND MODELLING OF SMALL SUBSTRUCTURES OF EQUIPMENT - AN EXERCISE WITH A SCREW JOINT ... 83
  Markku Juntunen, VTT; Dr. Kari Ojala, NOKIA ... *83*
EVALUATION OF INJURY CRITERIA FOR HIGH SPEED PLANING CRAFT ... 83
  Dr. Cameron Bass, University of Virginia, Dr. Ron Peterson, Naval Surface Warfare Center - Panama City, Adam Ziemba, Dr. Robert Salzar, University of Virginia ... *83*
INJURY SPECIFICATION STRATEGY FOR OCCUPANTS IN HIGH-SPEED PLANING CRAFT ... 84
  Dr. Cameron Bass, University of Virginia, Dr. Ron Peterson, Naval Surface Warfare Center - Panama City, Adam Ziemba, Dr. Robert Salzar, University of Virginia ... *84*

VULNERABILITY OF CIVIL INFRASTRUCTURE TO TERRORIST THREATS (CLASSIFIED)

NUMERICAL SIMULATIONS OF NAVIGATION LOCK (LIFT) GATES SUBJECT TO BLAST LOADING ... 85
  Dr. James O'Daniel, Enrique E. Matheu, US Army Engineer Research & Development Center ... *85*
RISK VULNERABILITY ASSESSMENT OF NAVIGATION LOCK PROJECTS ... 85
  Dr. Will McMahon, Yazmin Seda-Sanabria, US Army Engineer Research & Development Center ... *85*
NUMERICAL STUDY OF A SUSPENSION BRIDGE TOWER LEG SUBJECTED TO A LARGE CLOSE-IN DETONATION ... 85
  Dr. James O'Daniel, James C. Ray, US Army Engineer Research & Development Center ... *85*
PHYSICAL VULNERABILITY ASSESSMENT OF WATER SUPPLY SYSTEMS ... 86
  Dr. Will McMahon, US Army Engineer Research & Development Center ... *86*
EMBANKMENT DAMS BLAST RESEARCH AND VULNERABILITY ASSESSMENT METHODOLOGY ... 86
  Todd Hill, U.S. Bureau of Reclamation ... *86*
SIMULATIONS OF FIXED WHEEL AND RADIAL GATE RESPONSE TO UNDERWATER EXPLOSION USING FULLY-COUPLED HYDROCODE ... 86
  Roger Ilamni, Jr., Michael Scherr, NSWC/IHD, Larry Nuss, David Achterberg, Bureau of Reclamation ... *86*

WHIPPING (CLASSIFIED)

WHIPPING ANALYSES OF THE DDG-51 CLASS FULL SHIP MODEL ... 87
  LCDR Gerald Prendergast, US Navy, Dr. Young Shin, Naval Postgraduate School ... *87*
SHOCK ISSUES ASSOCIATED WITH THE INTEGRATION OF THE MULTI-MISSION MODULE (MMM) INTO THE VIRGINIA CLASS SUBMARINES ... 87
  Dawn Barrasso, Electric Boat Corporation ... *87*
EVALUATING SHIP STRUCTURE SUBJECTED TO WHIPPING, DUE TO UNDEX, DURING THE DESIGN PROCESS ... 87
  Nicole Dudley, Northrop Grumman Newport News, Natale Nappi, N.S. Nappi Associates, Inc. ... *87*

SHOCK QUALIFICATION (CLASSIFIED)

SHIPBOARD SHOCK QUALIFICATION OF THE MK54 TORPEDO ... 88
  Frank McNeilly Naval Undersea Warfare Center Division Newport ... *88*

VIRGINIA CLASS MAIN PROPULSION UNIT AND SHIP SERVICE TURBINE GENERATOR QUALIFICATION SHOCK ANALYSES: PROCEDURE OVERVIEW 88
Lee Miller, Electric Boat Corporation 88
MAIN PROPULSION UNIT AND SHIP SERVICE TURBINE GENERATOR QUALIFICATION SHOCK ANALYSES . 89
Jonathan Webster, Lee Miller, Electric Boat Corporation 89
SHOCK TEST PROGRAM AND RESULTS OF THE VIRGINIA (774) CLASS WEAPON STOWAGE AND HANDLING SYSTEM (WSHS) 89
Roland Trailor, Jr., Electric Boat Corporation 89
UNDERWATER EXPLOSION FINITE ELEMENT ANALYSES USING ABAQUS EXPLICIT IN SUPPORT OF THE LOW COST CONFORMAL ARRAY SHOCK QUALIFICATION EFFORT 89
Brett Lussier, Naval Undersea Warfare Center Division Newport 89

SHOCK TESTING I (CLASSIFIED)

UERD TOOLS IMPLEMENTATION OF PRINCIPLE COMPONENT ANALYSIS AND APPLICATION TO UNDEX BARGE 89
Eric Luft, Paul Mantz, Naval Surface Warfare Center Carderock Division 89
APPLICATION OF VIRGINIA COTS LESSONS LEARNED TO FUTURE SHIP DESIGNS 90
Stephen Foltz, Electric Boat 90
UNDEX TESTING OF REPRESENTATIVE HULL STRUCTURE FOR THE GENERAL DYNAMICS LITTORAL COMBAT SHIP 90
Dr. Paul Franklin, Eugene Miller, George Camp, Bath Iron Works 90
OVERVIEW OF THE SUBMERSIBLE UNDEX TEST VEHICLE (SUTV) CHARACTERIZATION SHOCK TEST SERIES 90
Brian Lang, Rhonda Ingler, Jennifer Marr, NSWCCD/UERD 90

SHOCK TESTING II (CLASSIFIED)

AN EVALUATION OF MACHINERY RAFT ISOLATION PERFORMANCE FOR NAVAL APPLICATIONS 91
Dr. Matthew Conti, Bradley Ross, Kyle Martini, David Warwick, Anteon Corporation 91
HULL RADIATION EFFICIENCY: TRANSITION FROM LOCAL TO GLOBAL BEHAVIOR 91
Bart Burkewitz, Kyle Martini, and Dr. Matthew Conti, Anteon Corporation 91
ENCANISTERED MISSILE PERSPECTIVE OF WOX CALIBRATION TEST RESULTS 92
Kenneth Lussky, BAE Systems Land & Armaments 92
QUALIFICATION OF THE WOX- MISSILE SHOCK TEST MACHINE (WOX-MSTM) FOR TESTING STANDARD MISSILE 3 IN A MK21 CANISTER 92
Dr. Jon Yagla, Naval Surface Warfare Center 92