BIBLIOGRAPHY OF NOL TECHNICAL DOCUMENTATION IN AEROBALLISTICS AND HYDROBALLISTICS

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NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

TECHNICAL DOCUMENTS ISSUED BY AERODYNAMICS DEPARTMENT (310)

UNCLASSIFIED DOCUMENTS

NOL Technical Reports

NOLTR 68-129

On Hypersonic Blunt-Body Flow Fields Obtained with a Time-Dependent Technique, by John D. Anderson, Jr., Lorenzo M. Albacete and Allan E. Winkelmann. 22 Oct. 1968. 24p. illus. UNCLASSIFIED

ABSTRACT: (U) New results are presented for inviscid, supersonic and hypersonic blunt-body flow fields obtained with a numerical time-dependent method patterned after that of Moretti and Abbett. In addition, important comments are made with regard to the physical and numerical nature of the method. Specifically, numerical results are presented for two-dimension and axisymmetric parabolic and cubic blunt bodies as well as blunted wedges and cones; these results are presented for zero degrees angle of attack and for a calorically perfect gas with $\gamma = 1.4$. The numerical results are compared with other existing theoretical and experimental data. Also, the effects of initial conditions and boundary conditions are systematically examined with regard to the convergence of the time-dependent numerical solutions, and the point is made that the initial conditions cannot be completely arbitrary. Finally, in order to learn more about the performance of the time-dependent method, a numerical experiment is conducted to examine the unsteady propagation and region of influence of a slight pressure disturbance introduced at a point on the surface of a blunt body.

NOLTR 68-151

An Experimental Investigation of the Surface Pitot Probe including Effects of Heat Transfer and Compressibility, by David L. Brott, William J. Yanta and Roland E. Lee. 17 Oct. 1968. 35p. UNCLASSIFIED

ABSTRACT: (U) Preston and Stanton probes have been investigated experimentally in both subsonic and supersonic flow. The Preston probe was tested in subsonic flow at adiabatic wall temperatures from Mach 0.1 to 0.5. The correlation between probe impact pressure and shear stress obtained directly by a skin-friction balance was independent of Mach number and Reynolds number over the range investigated. The present results are in better agreement with the flat-plate results of Smith and Walker, than the pipe-flow results of Preston or Patel. Both Preston probes and Stanton probes were investigated at a nominal Mach number of 4.8 at ratios of wall temperature to adiabatic wall temperature from 0.74 to 0.48. The correlation between probe impact pressure and shear stress was independent of Reynolds number over the range investigated, and was displaced from the incompressible results. A small effect due to moderate heat transfer rates was observed in the correlation of probe impact pressure with shear stress. The Stanton probe results show more scatter than the Preston probe results, and appear to be independent of heat transfer and Reynolds number over the range investigated.

NOLTR 68-187

Performance Capability of the NOL Hypersonic Tunnel, by Frank P. Baltakis. 24 Oct. 1968. 118p. UNCLASSIFIED

ABSTRACT: (U) This report summarizes the performance capability data of the U.S. Naval Ordnance Laboratory's Hypersonic Tunnel. The report includes a brief description of the facility, overall performance capability data, nozzle calibration data, and some nozzle boundary-layer thickness and temperature variation data. The nozzle aerodynamic design method is indicated and its adequacy in the range of the supply and test flow conditions of the Hypersonic Tunnel is briefly discussed.

NOLTR 68-192

A Method for Determining the Parameters of Ordinary Differential Equations, by Charles E. Knadler, Jr. 5 Nov. 1968. 32p. UNCLASSIFIED

ABSTRACT: (U) This report presents a method for determining the parameters of ordinary differential equations, where it is not necessary that the equation have a closed-form solution. DIFRED, a computer data-reduction program utilizing the method, is also described. The program is written for an IBM 7090 computer operating under the IBSYS monitor. The mathematical formulation of the method is presented, and the FORTRAN lising of DIFRED and instructions for its use are included.

NOLTR 68-195

Roll-Induced Force and Moment Measurements of the M823 Research Store, by Frank J. Regan, Mary Ellen Falusi and Virginia L. Schermerhorn. 1 Nov. 1968. 85p. UNCLASSIFIED

ABSTRACT: (U) The M823 configuration is an instrumented free-fall store used in bomb stability research programs. This report presents some measurement data for the roll-induced force and moments acting on this body. These measurements were made using a newly developed, highly sensitive static wind-tunnel balance.

NOLTR 69-22

An Exploratory Theoretical Investigation of the Effect of Longitudinal Surface Curvature on the Turbulent Boundary Layer, by Neal Tetervin. February 1969. 41p. UNCLASSIFIED

ABSTRACT: (U) The equations of motion and total enthalpy are derived for a compressible turbulent boundary layer on an axisymmetric or two-dimensional surface with non-negligible longitudinal curvature. From these equations are derived the integral-momentum, kinetic-energy, and total-enthalpy equations for non-negligible longitudinal curvature. Calculations indicate that if concave curvature increases the skin friction sufficiently, separation is delayed although the boundary layer is thickened. Also, an increase in curvature in the direction in which the surface pressure rises acts to hasten separation for concave curvature and delay it for convex curvature.

NOLTR 69-36

Separated Flow Phenomena on a Slender Cone at Mach 5, by Robert Feldhuhn and Allan E. Winkelmann. 18 March 1969. 19p. illus. UNCLASSIFIED

ABSTRACT: (U) An experimental investigation illustrating some separated flow phenomena associated with highly inclined circular cones has been conducted in the Supersonic Tunnel at the U.S. Naval Ordnance Laboratory, White Oak, at a nominal Mach number of 5 and at nominal free stream Reynolds numbers per foot of 4.8×10^6. Surface static pressure measurements, Pitot pressure surveys, schlieren photographs, vapor screen photographs, and surface sublimation measurements were obtained on a sharp 5 degree semi-vertex angle cone at angles of attack up to 40 degrees. The static pressure distribution along the most leeward meridian generator was found to be dependent upon the Reynolds number based upon the distance from the vertex of the cone. The vapor screen photographs at 40 degrees angle of attack indicate the existence of imbedded shock waves in the flow field on the leeward side of the cone. The Pitot tube surveys and the surface sublimation photographs indicate the existence of a region of attached flow near the leeward meridian plane. The surface sublimation photographs also indicate the possible existence of a secondary vortex.

NOLTR 69-47

A Generalization to Turbulent Boundary Layers of Mangler's Transformation Between Axisymmetric and Two-Dimensional Laminar Boundary Layers, by Neal Tetervin. 12 June 1969. 35p. UNCLASSIFIED

ABSTRACT: (U) With the restriction that the friction coefficient is expressible as a power function of the local boundary-layer Reynolds number, the Mangler transformation between axisymmetric and two-dimensional laminar boundary-layer flow is generalized to turbulent flow. Relations are obtained between turbulent boundary-layer quantities in an axisymmetric flow and those at corresponding points in a substitute two-dimensional flow. The transformation is applied to the supersonic turbulent

boundary layer on a cone with an attached shock wave and yields simple relations between boundary-layer quantities for a cone and those for a corresponding flat-plate flow. A non-dimensionalization of the equations of continuity, motion, and total-enthalpy gives the variation with Reynolds number of a number of turbulent boundary-layer quantities.

NOLTR 69-51

A Correlation of Heat Transfer and Skin-Friction Data and an Experimental Reynolds Analogy Factor for Highly Cooled Turbulent Boundary Layers at Mach 5.0, by Donald M. Wilson. 5 March 1969. 37p. UNCLASSIFIED

ABSTRACT: (U) Turbulent boundary-layer heat transfer and skin-friction coefficients were measured on sharp slender cones in the U.S. Naval Ordnance Laboratory Hypersonic Tunnel at a free-stream Mach number of 5.0. Wall-to-stagnation temperature ratios from 0.15 to 0.80 were obtained by precooling or preheating the model. Tests were conducted for a wide range of Reynolds numbers by varying the tunnel supply pressure and temperature, thus providing data for naturally turbulent boundary layers. The experimental results have been compared with existing theories which predict convective Stanton number or skin-friction coefficients. These comparisons indicate that the heat-transfer data is best predicted by the Spalding-Chi law and the skin friction by the Sommer-Short reference temperature method. The experimental Reynolds analogy factor $S = 2ST/c_f$, is adequately predicted by Colburn's incompressible correlation for wall-to-stagnation temperature ratios above about 0.5. However, for lower wall temperature ratios, the experimental Reynolds analogy factor decreases with decreased temperature ratios in a manner which has not been previously reported.

NOLTR 69-52

A Time-Dependent Analysis for Quasi-One-Dimensional Nozzle Flows with Vibrational and Chemical Nonequilibrium, by John D. Anderson, Jr. May 1969. 29p. illus. UNCLASSIFIED

ABSTRACT: (U) A new technique is presented for the numerical solution of quasi-one-dimensional, vibrational and chemical nonequilibrium nozzle flows including nonequilibrium conditions both upstream and downstream of the throat. This new technique is a time-dependent analysis which entails the explicit finite-difference solution of the quasi-one-dimensional unsteady flow equations in steps of time, starting with assumed initial distributions throughout the nozzle. The steady-state solution is approached at large values of time. A virtue of the present time-dependent analysis is its simplicity, which prevails from its initial physical formulation to the successful receipt of numerical results. Also, the present solution yields the transient as well as the steady-state nonequilibrium nozzle flows. To exemplify the present analysis, results are given for several cases of vibrational and chemical nonequilibrium expansion through nozzles.

NOLTR 69-56

Balance for Measuring Skin Friction in the Presence of Heat Transfer, by James R. Bruno, William J. Yanta and Donald B. Risher. 10 June 1969. 8p. illus. UNCLASSIFIED

ABSTRACT: (U) The development of a skin-friction balance to be used in a wind tunnel with heat-transfer conditions is described. The balance is a null-type device with a floating head element whose temperature can be maintained between 100°K and 345°K. This is accomplished with a cooled or heated jacket that is placed in direct contact with the friction element. At the desired element temperature the jacket is separated from the element and the shear-force data is taken. The balance was used in a Mach 5 supersonic flow with moderate heat-transfer rates. Shear forces ranging from 0.05 gm/cm^2 to 1 gm/cm^2 have been measured and higher ranges can be obtained by simply changing a coil spring.

NOLTR 69-70

A Wind Tunnel Investigation of the Hypersonic Air-to-Ground Rocket (HAGR) Over an Angle-of-Attack Range from 0° to 180° at Subsonic, Transonic and Supersonic Speeds, by Robert T. Hall. 1 April 1969. 34p. UNCLASSIFIED

ABSTRACT: (U) Experimental static aerodynamic data are presented for the HAGR configuration obtained over an angle-of-attack range from 0° to 180°. Normal force, pitching moment and axial-force data are presented for nominal Mach numbers of 0.5, 0.7, 0.9, 1.0, 1.25, 2.03, 3.02 and 4.11.

NOLTR 69-80

How to Analyze 2-D Schlieren Photographs to Obtain the Density Gradient Structure of 3-D Flow Fields, by Allan E. Winkelmann and Robert H. Feldhuhn. 15 April 1969. 15p. illus. UNCLASSIFIED

ABSTRACT: (U) A technique is outlined by which density gradients visible in two-dimensional schlieren photographs can be analyzed to obtain the density gradient structure (i.e., the shape and location of density gradients such as shock waves and vortices) of three-dimensional flow fields. Practical application of the technique relies on obtaining a series of schlieren photographs of the flow field from different viewing orientations. The analysis is specialized to the case of a right-circular cone at angle of attack. Results are presented which show the shape and location of the bow shock of a 5° half-angle right-circular cone tested in the Supersonic Tunnel No. 2 at the U.S. Naval Ordnance Laboratory, White Oak, at a nominal Mach number of 5.0, a nominal free-stream Reynolds number per foot of 4.8×10^6 and angles of attack equal to 15° and 40°.

NOLTR 69-100

Static-Stability Index and Aerodynamic Coefficients for the 0.125-Scale Model Mark 82 Low-Drag Bomb with Standard and Emtex Snakeye I Fins with Six Retardation Angles at Subsonic Speeds, by Virginia L. Schermerhorn. 20 May 1969. 388p. UNCLASSIFIED

ABSTRACT: (U) The static-stability index, force and moment coefficients are presented as functions of angle of attack for the Mk 82 Low-Drag Bomb with Standard and Emtex Snakeye I Fins. For these tests the fin-opening angles were 60, 70, 80, 90, 100 and 110 degrees; the models' angle of attack ranged from −10 to +20 degrees; the free-stream Mach number was varied from 0.25 to 0.95, and roll angles were at 0, 22.5 and 45 degrees.

NOLTR 69-106

Velocity Profile, Skin-Friction Balance and Heat-Transfer Measurements of the Turbulent Boundary Layer at Mach 5 and Zero-Pressure Gradient, by Roland E. Lee, William J. Yanta and Annette C. Leonas. 16 June 1969. 14p. illus. UNCLASSIFIED

ABSTRACT: (U) The results of a detailed experimental investigation of a two-dimensional turbulent boundary layer at zero-pressure gradient are presented. The studies were made at the free-stream Mach number of 5, momentum-thickness Reynolds number from 4800 to 56,000 and wall-to-adiabatic-wall temperature ratios from 0.5 to 1.0. The data are in analytical terms of velocity profile, temperature profile, law-of-the-wall, velocity-defect law and incompressible form factor. Comparisons of local skin-friction coefficients obtained by four different experimental methods are shown. An empirical equation was derived from the shear-balance data to calculate the friction coefficient from known values of Mach number, heat transfer and Reynolds number.

NOLTR 69-108

Oblique Shock-Interaction Experiments, by David L. Merritt and Philip M. Aronson. 29 May 1969. 57p. UNCLASSIFIED

ABSTRACT: (U) A description is given of a unique experimental technique for simulating the interaction between a re-entry vehicle and an oblique blast wave. The technique combines a ballistics range with a shocktube. Models fly down the range and through the shocktube at an oblique angle. As a model passes through the shocktube, it intercepts a plane shock wave moving down the tube. Sequential photographs show the interaction between the model and the shock wave. Experiments were done with 9- and 15-degree half-angle cone models. The Mach numbers of both the models and the shock waves ranged from 2 to 5. The peak transient pressure on the model resulting from the reflection of the shock wave was calculated using data measured from the photographs. The analysis technique was verified by direct measurements of reflected shock pressures on a stationary cone model. The ratio of the peak transient pressure to the initial cone pressure was found to be strongly dependent on the shock-wave Mach number and almost independent of the model Mach number. A simple two-dimensional analysis of the interaction was compared to the experimental results. The agreement was reasonably good, although the theory predicted a stronger dependence of pressure ratio on model Mach number than actually existed. The theory also predicted that the ratio of peak transient pressure to initial cone pressure would be less for the 15-degree cones than for the 9-degree cones. The experimental data showed no difference between the two. The effects of three-dimensional flow may be the cause of the discrepancies between theory and experiment. A number of hemisphere-cylinder models were flown. It was not possible to get quantitative data from the pictures but they do provide a qualitative idea of how the shock-wave geometry looks at different stages during the interaction.

NOLTR 69-110

Hypersonic-Turbulent Boundary-Layer Separation over a Cone-Cylinder-Flare Configuration, by Arnold Polak and Chris A. Kalivretenos. 6 June 1969. 29p. UNCLASSIFIED

ABSTRACT: (U) Results of a study of hypersonic-turbulent boundary-layer separation over axisymmetric bodies is presented. Pressure, heat-transfer and flow visualization data were obtained for a cone-cylinder-flare con figuration. The experimental data were correlated with a theoretical prediction.

NOLTR 69-155

A Powered Flight Six-Degree-of-Freedom Trajectory Program for Vehicles with Freely Spinning Tail Stabilizers, by John E. Holmes. 30 Oct. 1969. 85p. UNCLASSIFIED

ABSTRACT: (U) This program provides for the simulation of powered six-degree-of-freedom trajectories over a spherical rotating earth for those vehicles which have a fore and aft section, which may or may not rotate at different spin rates, but, which rotate about a common longitudinal axis. The program does not permit any mass or inertial asymmetries, but it can be run using either a rolling or nonrolling vehicle axis system and a variable integration time step.

NOLTR 69-158

Development of a Fast-Response Pressure Transducer, by Frank P. Baltakis. 20 Oct. 1969. 24p. UNCLASSIFIED

ABSTRACT: (U) A small (0.2" diameter), fast-response pressure transducer has been developed for measuring shock-interaction induced transient pressures. Transducer design incorporates the Pressure Bar principle to minimize reflections at the boundaries of the sensing element and a unique orifice-cavity method to isolate the sensing element from the external disturbances. Calibration and wind-tunnel shock-interaction data show that this type of transducer is suitable for measuring pressures of 1/20- to 100-psi magnitude and of 1- to 17-microsecond duration. Transducer performance, design and construction are described.

NOLTR 69-205

Static-Stability and Roll-Damping Coefficients for a Slender Blunted Cone Showing the Effects of Spin, Angle of Attack, and Center-of-Gravity Offset at M=5 and 7.7, by John A. Darling. 10 Nov. 1969. 20p. UNCLASSIFIED

ABSTRACT: (U) Results are presented from wind-tunnel tests performed in the NOL Hypersonic Tunnel at M = 4.96, 5.01 and 7.70. During these tests normal-force, pitching-moment and roll-damping coefficients were obtained on a 7.25-degree, 0.075 bluntness cone model, for a pd/2V value of 0.02 to show the effect of spin, angle of attack, and center-of-gravity offset.

OPEN LITERATURE

(Identified by OL numbers for indexing purposes)

OL 69-97

Anderson, J. D., Jr., Albacete, Lorenzo, Winkelmann, A. E.; *"Applications of the Time-Dependent Technique for the Computation of Compressible Flows"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) A survey is made of some recent NOL numerical calculations of steady, inviscid compressible flows obtained with a time-dependent technique; this technique is particularly advantageous for the analysis of mixed subsonic-supersonic flow fields where steady-flow methods usually encounter difficulties. The time-dependent technique entails the finite-difference solution of the governing unsteady conservation equations in steps of time, starting with assumed initial distributions throughout the flow field. The steady-state flow field, which is the desired result, is approached at large values of time. The technique is exemplified by application to the following cases:

(1) Flow fields about supersonic and hypersonic blunt bodies, assuming a nonreacting calorically perfect gas, and

(2) quasi-one-dimensional, convergent-divergent nozzle expansions of a high temperature gas including vibrational and chemical nonequilibrium conditions both upstream and downstream of the throat. In each case, the advantages of the time-dependent technique over a steady-flow analysis are delineated.

OL 69-98

Anderson, John D., Jr.; *"A Time-Dependent Analysis for Vibrational and Chemical Nonequilibrium Nozzle Flows"*; AIAA Paper No. 69-668, June 16-18, 1969. UNCLASSIFIED.

ABSTRACT: (U) A new technique is presented for the numerical solution of quasi-one-dimensional, vibrational and chemical nonequilibrium nozzle flows including nonequilibrium conditions both upstream and downstream of the throat. This new technique is a time-dependent analysis which entails the finite-difference solution of the quasi-one-dimensional unsteady flow equations in steps of time, starting with assumed initial distributions throughout the nozzle. The steady-state solution, which is the desired result, is approached at large values of time. The present time-dependent analysis circumvents several problems encountered with steady-state analyses, and has the virtue of being a more natural and straightforward approach to the problem. Consequently, it appears to warrant serious consideration for future applications in nonequilibrium nozzle flows. To exemplify the present analysis, results are given for several cases of nonequilibrium expansions through nozzles. In the course of these results, vibrational nonequilibrium conditions are found to prevail upstream of the throat for some practical cases, and consequently the shape of the subsonic section is shown to have a significant effect on the frozen vibrational energy at the nozzle exit.

OL 69-99

Anderson, J. D., Jr.;*"Heat Transfer from a Viscous Nongray Radiating Shock Layer"*; AIAA Selected Reprints, Vol. VII, Radiative Gas Dynamics, pp. 66-68, June 1969. UNCLASSIFIED

ABSTRACT: (U) An analysis has been made for the radiative cooling and nongray self-absorption effects on the viscous, equilibrium, radiating stagnation-region shock layer and stagnation-point heat transfer, using approximation step-models for the nongray continuum absorption coefficient of high temperature air. The effects of uncertainties in gas transport properties, particularly thermal conductivity, have been investigated.

OL 69-100

Anderson, John D., Jr.;*"An Engineering Survey of Radiating Shock Layers"*; AIAA Journal, Vol. 7, No. 9, pp. 1665-1675, September 196. UNCLASSIFIED

ABSTRACT: (U) This paper surveys the technological background pertaining to the calculation of re-entry shock layer radiative heat transfer. Emphasis is placed on three major "quantum jumps" which have occurred in the state-of-the-art in recent years, namely, the recognition of the importance of nongray self-absorption within the shock heated gas, the contribution of atomic line radiation to the shock layer radiative energy flux, and the attenuation of the radiative flux by an absorbing layer of ablation products. Also, emphasis is placed on analysis and experiments which have direct bearing on the engineering calculation of stagnation point heat transfer. In addition, new results are presented for the effects of radiative gas dynamic coupling on surface skin friction and Reynolds analogy. Finally, in light of the current status of shock layer radiative heat transfer calculations, several areas are pointed out for future investigation.

OL 69-101

Anderson, J. D., Jr.; *"A Time-Dependent Analysis of Population Inversions in a Vibrational Nonequilibrium Expanding Gas Mixture"*; Bulletin of the American Physical Society, Vol. 14, No. 11, pp. 1102, Nov. 1969. UNCLASSIFIED

ABSTRACT: (U) A new, time-dependent technique for the numerical solution of convergent-divergent, nonequilibrium nozzle flows has been presented earlier. This technique has now been extended to analyze the rapid, vibrational nonequilibrium expansion of a mixture of CO_2, N_2 and H_2O, wherein the finite rate molecular energy transfer processes can result in a population inversion between the (001) and (100) energy levels of CO_2. Interesting results for such population inversions have been obtained. Among these, a comparison has been made between the present results and the recent results of Basov et al; this comparison indicates that Basov's calculations overestimate the population inversions in an expanding mixture of CO_2 and N_2.

OL 69-102

Baltakis, F. P.; *"Development of a Fast-Response Pressure Transducer"*; Proceedings of the 15th National ISA Aerospace Instrumentation Symposium, 5-7 May 1969. UNCLASSIFIED

ABSTRACT: (U) A small (0.2" diameter), fast-response pressure transducer has been developed for measuring shock interaction induced transient pressures. Transducer design incorporates the Pressure Bar principle to minimize disturbances from the boundaries of the sensing element and a unique orifice-cavity method to avoid disturbances which normally originate at the metal diaphragm. Calibration and wind-tunnel shock interaction data show that this type of transducer is suitable for measuring pressures of 1/20 to 100-psi magnitude and of 1 to 17-microsecond duration. Transducer performance, design and construction are described in the paper.

OL 69-103

Brott, D. L., Yanta, W. J., Voisinet, R. L. and Lee, R. E.; *"An Experimental Investigation of the Compressible Turbulent Boundary Layer with a Favorable Pressure Gradient"*; AIAA Paper No. 69-685, 16-18 June 1969. UNCLASSIFIED

ABSTRACT: (U) This paper describes the results of a detailed experimental investigation of a two-dimensional turbulent boundary layer in a favorable pressure gradient where the free-stream Mach number varied from 3.8 to 4.6; the ratio of wall to adiabatic wall temperature remained constant at a value of 0.82. Detailed profile measurements were made with pressure and temperature probes; skin friction was measured directly with a shear balance. The velocity and temperature profile results are compared with zero pressure gradient and incompressible results. The skin friction data are correlated with momentum thickness Reynolds number and the pressure gradient parameter $\beta = -\theta/\tau_w \frac{dP}{dx}$. The skin friction decreases with decreasing β for a constant value of momentum thickness Reynolds number.

OL 69-104

Bruno, J. R., Yanta, William, Risher, D.; *"Balance for Measuring Skin Friction in the Presence of Heat Transfer"*; International Congress on Instrumentation in Aerospace Simulation Facilities, May 5, 6, 7 8, 1969. UNCLASSIFIED

ABSTRACT: (U) The development of a skin-friction balance to be used in a wind tunnel with heat-transfer conditions is described. The balance is a null-type device with a floating head element whose temperature can be maintained between 100°K and 345°K. This is accomplished with a cooled or heated jacket that is placed in direct contact with the friction element. At the desired element temperature the jacket is separated from the element and the shear-force data is taken. The balance was used in a Mach 5 supersonic flow with moderate heat-transfer rates. Shear forces ranging from 0.05 gm/cm^2 to 1 gm/cm^2 have been measured and higher ranges can be obtained by simply changing a coil spring.

OL 69-105

Bruno, J. R.; *"Balance for Measuring Skin Friction in the Presence of Ablation"*; IEEE 3rd International Congress on Instrumentation in Aerospace Simulation Facilities, 5-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) This report describes a skin-friction balance that is presently being used to measure shear stresses acting on the wall of an ablative duct. Tests have been conducted in the 3 Megawatt Arc Tunnel with a Mach number of 3, a stagnation enthalpy of 3000 BTU/lb, and a stagnation pressure of 20 atmospheres. The balance is a direct deflection measuring device in that balance arm rotation is measured with a linear variable differential transformer as the balance arm deflects due to shear loads acting on the end of the balance arm.

OL 69-106

Feldhuhn, R. H., Winkelmann, A. E., and Pasiuk, L.; *"An Experimental Investigation of the Hypersonic Aerodynamic Characteristics of Slender Bodies of Revolution at High Angles of Attack"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) An experimental investigation of the aerothermodynamic properties associated with axisymmetric bodies at large angles of incidence has been conducted in two of the wind tunnels at the Naval Ordnance Laboratory (NOL). During this study, surface pressure, heat transfer and static force measurements were obtained with a slender 5° half-angle cone. Static force measurements were also obtained with a 2/3 power-law body and two ducted cone configurations. In addition, flow visualization experiments and a limited series of Pitot-tube surveys provided some information concerning the separated flow field on the leeward side of a yawed cone.

OL 69-107

Humphrey, Richard; *"An Experimental Investigation of Transpiration Cooling Near the Stagnation Point of a Cylinder"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) A series of tests were made with a cylindrical model equipped with transpiration cooling over a region ±15 degrees from the stagnation line. The model was instrumented with thermocouples to measure wall and reservoir temperatures. Air was used as a cooling medium. The tests were made at a nominal Mach number of 6.5 and stagnation point gas temperatures of 2500 to 3500°K and a Pitot pressure of 0.14 atm. The dimensionless temperatures agree within 5 to 7 percent with predictions while heat-transfer rates agree within 15 percent. The effect of the external pressure distribution on the local coolant flow rate and wall temperature is discussed.

Varying wall thickness and permeability may not be the whole answer.

OL 69-108

Kalivretenos, C. A.; *"An Investigation of the Aerodynamic Behavior of Submissiles During Ejection from a High-Speed Rocket"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) The average angle of attack of a cluster of submissiles ejected normal to the longitudinal axis of a rocket flying at hypersonic speeds is strongly influenced by the nonuniform flow field behind the vehicle's bow shock wave and the interactions between submissiles. In an effort to observe the effect of these interactions, tests were conducted in the NOL Hypersonic Tunnel. Aerodynamically stable, finned submissiles were ejected in clusters of 53 and 107 from an ogive-cylinder body, simulating the nose of a high-speed rocket. Scaled submissiles were ejected into a high-speed airstream at simulated full-scale velocities up to 300 ft/sec. The submissile trajectories were recorded by high-speed movie cameras. Filmed results indicate that an increase in the ejection velocity decreases the influence of the flow interactions; therefore, the average submissile angle of attack is reduced and its terminal velocity increased.

OL 69-109

Kluth, E. E.; *"An Analysis of a Slewed-Launch Technique for Air-Launched Missiles"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) Slewed launch, a new missile-launch technique, is being studied. The aerodynamic problems associated with slewing a missile about its center of gravity during the initial portion of its flight from the aircraft, prior to ignition of the propulsion system, are being determined.

OL 69-110

Polak, A. and Kalivretenos, C. A.; *"Hypersonic Turbulent Boundary-Layer Separations at High Reynolds Numbers"*; Journal of Spacecraft and Rockets, Vol. 6, No. 8. pp. 954-955. August 1969. UNCLASSIFIED

ABSTRACT: (U) Results of a study of turbulent boundary-layer separation over a cone-cylinder-flare configuration at zero angle of attack are reported. The tests were run at Mach 5, 6, and 7 with a maximum unit Reynolds number of 4.9×10^7/ft. The emphasis was on determining the dependence of the extent of separation on various parameters. At all test conditions, transition occurred naturally well upstream of the separation location. The model was instrumented with pressure orifices and thermocouples. Flow visualization was realized by taking schlieren photographs and using a surface oil technique.

OL 69-111

Regan, F. J., Tanner, F. J., Shannon, J. H. W.; *"Free Fall Vehicle Dynamics–Observation and Prediction"*; AIAA Paper No. 69-229. UNCLASSIFIED

ABSTRACT: (U) During the past five years, the U.S. Naval Ordnance Laboratory, the Royal Aircraft Establishment and the Australian Weapons Research Establishment have been engaged in a joint study of free-fall vehicle dynamics. The goal of this program was to obtain highly detailed wind tunnel measurements on research shapes and then use these data to carry out computer simulations of vehicle trajectories. These simulations were compared with actual measurements obtained from a full-scale instrumented store in free flight. The program was also concerned with a wind tunnel and free-flight investigation of novel stabilizers (tails) designed to eliminate various types of dynamic instabilities.

OL 69-112

Schindel, Leon H.; *"Effects of Vortex Separation on the Lift Distribution on Bodies of Elliptic Cross Section"*; Journal of Aircraft, Vol. 6. No. 6. pp. 537-543. Nov.-Dec. 1969. UNCLASSIFIED

ABSTRACT: (U) Vortex separation from slender bodies causes nonlinear increases of lift with angle of attack. A two-vortex representation of the separated flow is analyzed for bodies of elliptic cross section and arbitrary nose contour. The delta wing theory of Brown and Michael and the circular cone and cylinder solutions of Bryson are special cases of the more general geometry analyzed here. Comparisons with experiment show good agreement over a significant range of values of geometrical and flow parameters.

OL 69-113

Tetervin, N.; *"Approximate Calculation of Reynolds Analogy for Turbulent Boundary Layer with Pressure*

Gradient"; AIAA Journal, Vol. 7, No. 6, pp. 1079-1085. June 1969. UNCLASSIFIED

ABSTRACT: (U) An approximate method is developed to calculate the Reynolds analogy factor for a turbulent boundary layer with pressure gradient. The inverse of the Reynolds analogy factor is found to equal the integral across the boundary layer of the product of the slope of the nondimensional velocity profile and the ratio of the nondimensional energy transfer to the nondimensional shear. This result requires a Prandtl number of unity. Approximations for the shear stress, energy transfer, and velocity distribution across the boundary layer make the Reynolds analogy factor depend on a nondimensional pressure gradient parameter and on a velocity profile shape parameter. An adverse pressure gradient is predicted to increase and a favorable pressure gradient to decrease the Reynolds analogy factor. Comparison with experimental data indicates this result to be qualitatively correct, but more data are needed for a quantitative test. Also obtained is a generalization of Crocco's relation between velocity and total enthalpy for a nonadiabatic surface without pressure gradient. As the pressure gradient departs from zero, the relation between the nondimensional total enthalpy and the nondimensional velocity varies widely from Crocco's relation.

OL 69-114

Werle, M. J., Driftmyer, R. T., Shaffer, D. G.; *"Two-Dimensional Jet-Interaction Experiments–Results of Flow-Field Probing and Scale Effects Studies"*; Proceedings of the 8th Navy Symposium on Aeroballistics, May 6-8 1969. UNCLASSIFIED

ABSTRACT: (U) This paper describes the results of two experimental studies concerning the injection of a gaseous secondary jet into an unbounded supersonic flow field which is uniform outside a turbulent boundary layer.

OL 69-115

Williams, J. B.; *"A Correlation of the Windward Shock Angle on Yawed Cones"*; AIAA Journal, Vol. 7, No. 7. p. 1398, July 1969. UNCLASSIFIED

ABSTRACT: (U) A correlation of the shock angle parameter $(\beta_w + \alpha)/(\theta_c + \alpha)$ in terms of a single variable $M_\infty(\theta_c + \alpha)$ for the windward shock angle on yawed cones is presented.

OL 69-116

Wilson, D. M.; *"A Reynolds Analogy for the Compressible Turbulent Boundary Layer"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) An experimental investigation has been performed to obtain the heat-transfer and skin-friction measurements from which a Reynolds analogy for the highly cooled turbulent boundary layer could be determined. The experiments were conducted on sharp cone models at Mach number 5.0 and wall-to-stagnation temperature ratios between 0.12 and 0.80. The experimental measurements of Stanton number and average skin-friction coefficient have been compared with existing theories. These comparisons indicate that the skin friction is accurately predicted by the Sommer-Short reference temperature method, and the heat transfer, for wall-to-stagnation temperature ratios above 0.3, by the Spalding-Chi law. A direct comparison of the heat-transfer and skin-friction data indicate that Colburn's form of Reynolds analogy is valid for temperature ratios above 0.5. However, for lower ratios, the experimental Reynolds analogy decreases with decreasing wall temperature in a manner which has not been previously reported.

OL 69-117

Winkler, E., Humphrey, R., Koenig, J., and Madden, M. T.; *"Supersonic Laminar and Turbulent Ablation Studies with Teflon"*; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 1969. UNCLASSIFIED

ABSTRACT: (U) Experimental programs have been carried out in the U. S. Naval Ordnance Laboratory 3-Megawatt Arc Tunnel to study the interaction of ablation and a vehicle's aerodynamic characteristics. The test conditions involve stagnation pressures of 20 to 30 atmospheres, temperatures of 4000 to 9000°R, and Mach numbers of 2.3 and 3. The test models, made of teflon, were smooth or had cracks machined into the surface. They were instrumented for pressure, temperature, heat-transfer, and skin-friction measurements. The laminar data are compared with the predictions of a numerical procedure known as BLIMP-CMA. Surprisingly close agreements have been found between experimental data and predictions. Ablation-induced transition is observed in all laminar runs. In fully turbulent runs criss-cross striations are observed. Cracks in the ablative models have pronounced effects on the ablative behavior. Substructure heating can be severe depending upon size and direction of the cracks. Ablation reduces the wall-shear stress by about 40 percent.

OL 69-118

Yanta, W., Brott, D., Voisinet, R., and Lee, R.; *"An Experimental Investigation of the Compressible Turbulent*

Boundary Layer with a Favorable Pressure Gradient"; Proceedings of the 8th Navy Symposium on Aeroballistics, 6-8 May 1969. UNCLASSIFIED

ABSTRACT: (U) This paper describes the results of a detailed experimental investigation of a two-dimensional turbulent boundary layer in a favorable pressure gradient where the free-stream Mach number varied from 3.8 to 4.6; the ratio of wall to adiabatic wall temperature remained constant at a value of 0.82. Detailed profile measurements were made with pressure and temperature probes; skin friction was measured directly with a shear balance. The velocity and temperature profile results are compared with zero pressure gradient and incompressible results. The skin-friction data are correlated with momentum-thickness Reynolds number and the pressure gradient parameter $\beta = -\theta/\tau_w \frac{dP}{dx}$. The skin friction decreases with decreasing β for a constant value of momentum-thickness Reynolds number.

OL 69-119

Yanta, W. J., Brott, D. L., and Lee, R. E.; "*An Experimental Investigation of the Preston Probe Including Effects of Heat Transfer, Compressibility and Favorable Pressure Gradient*"; AIAA Paper No. 69-648, 16-18 June 1969. UNCLASSIFIED

ABSTRACT: (U) The applicability of the Preston probe to indicate the local friction drag on the nozzle wall of both subsonic and supersonic two-dimensional nozzles was investigated. The probe data were referenced to the local shear forces measured by a floating element skin-friction balance. The subsonic flow studies were made at free-stream Mach numbers between 0.1 and 0.5 on an adiabatic flat-plate extension to a subsonic nozzle. The investigation of the Preston probe in a supersonic flow was carried out on the flat plate of the Naval Ordnance Laboratory (NOL) Boundary Layer Channel, at Mach 4.8 for zero-pressure gradient flow and at Mach numbers between 3.8 and 4.6 for favorable pressure gradient. The results show the correlations to be independent of Reynolds number. The supersonic results are displaced from the subsonic results by a constant factor. Some effects due to heat transfer and pressure gradients were observed.

PATENTS

(Listed serially by U. S. patent number and Indexed Pat.)

U. S. Patent No. 3,412,604

Wind Tunnel Balance, by Joseph Iandolo. UNCLASSIFIED

ABSTRACT: (U) This invention relates to Magnus balances, and more particularly to a Magnus balance wherein sufficient sensitivity in yaw is provided at small angles of attack (2 to 5 degrees) without greatly reducing balance stiffness. This is accomplished by providing a thin eccentric column on which the yaw gages are mounted. The eccentric column is attached to the main column by thin necked portions at either end which act like pin joints. As the balance is subject to yaw leads, a secondary bending is induced in the eccentric column due to the compressive end loads. The eccentric column then acts much like a mechanical amplifier permitting the measure of small yaw loads without greatly sacrificing balance rigidity.

U. S. Patent No. 3,447,369

Wind Tunnel Balance, by Eugene V. Horanoff. UNCLASSIFIED

ABSTRACT: (U) This invention relates to a means for combining the Magnus and roll damp testing of a model in a wind tunnel.

U. S. Patent No. 3,456,503

Free Flight Wind Tunnel Model Launcher, by Charles M. Wise. UNCLASSIFIED

ABSTRACT: (U) This invention relates to a free flight wind tunnel model launcher. The model launcher will launch an aerodynamic model at an initial angle of attack, spin rate, temperature, and velocity to insure a trajectory within the viewing region of a wind tunnel.

U. S. Patent No. 3,460,574

Multiport Valve, by Donald B. Risher. UNCLASSIFIED

ABSTRACT: (U) This invention relates to a system for calibrating and measuring pressures within supersonic and hypersonic wind tunnels, and more particularly to a high speed calibration and pressure measurement at a large number of stations within a wind tunnel.

TECHNICAL DOCUMENTS ISSUED BY BALLISTICS DEPARTMENT (320)

UNCLASSIFIED DOCUMENTS

NOL Technical Reports

NOLTR 68-190

Preliminary Analysis of the NOL Hydroballistics Tank Blowdown Water Tunnel, by Victor C. Dawson and Arnold E. Seigel. 1 Oct. 1968. 19p. UNCLASSIFIED

ABSTRACT: (U) The unique features of the NOL Hydroballistics Facility make it ideally suited for use as a blowdown water tunnel. This report is a preliminary analysis of such a system and indicates the range of test section conditions that can be achieved with various modes of operation.

NOLTR 69-2

Weight Comparison of Hull Structural Configurations for Massive Glass Deep Submersibles, by Jack E. Goeller. 20 Dec. 1968. 34p. UNCLASSIFIED

ABSTRACT: (U) This report represents the results of a study of three hull configurations for a deep submersible constructed of massive glass with titanium reinforcing rings. The configurations studied were a sphere, a bisphere, and a cylindrical hull with hemispherical ends. Local discontinuity stresses at the joints were considered. It was shown that an optimum length to diameter (L/D) exists for the cylindrical hull which minimizes the weight to displacement ratio. At large values of L/D, the bisphere was shown to be optimum. It was shown that weight-displacement ratio of .5 is feasible for massive glass hulls with an Adiprene shock mitigator on the outside.

NOLTR 69-17

Analysis of Shock Mitigation for Glass Submersibles, by Jackson C. S. Yang and Frederick P. Stecher. 10 Dec. 1968. 44p. UNCLASSIFIED

ABSTRACT: (U) In this analysis equations are developed to obtain the response of models of deep submergence glass hulls with Adiprene cladding which are subjected to impact loading. Combined stresses in the glass hull, cladding deflection, cladding velocity, impact force and duration of impact are calculated from the impact theory of Hertz and the shallow shell theory of Reissner for various initial velocities of impact. Both the analog and the digital computers were utilized in the solution of the equations. Nondimensional scaling equations are developed to predict the response of both the prototype and model.

NOLTR 69-31

A Splitter Plate for the Prevention of Vortex Shedding behind Finite Circular Cylinders in Uniform Cross Flow, by Dirse W. Sallet. 10 July 1967. 26p. UNCLASSIFIED

ABSTRACT: (U) Vortex shedding of circular cylinders in uniform cross flow may be prevented by the installation of a radially extending plate, which is rigidly attached to the cylinder. The principle of vortex shedding prevention by such a splitter plate is explained and the minimum dimensions of the plate are theoretically derived and compared with experimentally found values.

NOLTR 69-139

Longitudinal Forces Required with Loose Liner Barrel Construction, by Jack E. Goeller and Victor C. D. Dawson. 15 July 1969. 11p. UNCLASSIFIED

ABSTRACT: (U) A previous study demonstrated the advantages that could be obtained in using loose liner barrel construction, particularly if the liner is autofrettaged. This report deals with the longitudinal forces required to assemble and disassemble such constructions and shows that with close control of tube straightness and initial clearance, these forces are relatively small.

NOLTR 69-162

Stress Analysis of an Autofrettaged Loose Liner for Gun Barrel Construction Precompressed in the Longitudinal Direction, by Jack E. Goeller. 16 Sept. 1969. 28p. UNCLASSIFIED

ABSTRACT: (U) Gun barrel erosion in high-velocity research guns and naval guns necessitates costly replacement of barrels. This report contains a stress analysis of a loose liner which can be easily installed and removed. Axial precompression is used to take up some of the initial clearance between the liner and barrel necessary to install the liner.

OPEN LITERATURE

(Identified by OL numbers for indexing purposes)

OL 69-120

Abelson, H. I.; *"The Behavior of the Cavity Formed by a Projectile Entering the Layer Vertically"*; Doctoral Thesis, University of Maryland, June 1969. UNCLASSIFIED

ABSTRACT: (U) A procedure to predict cavity behavior after vertical entry has been developed and is applicable to several families of projectiles of practical interest. Based on available analytical methods and empirical data, the procedure has been confirmed by experimental results obtained as part of this study. Extensive measurements of cavity pressure prior to deep closure have been made for vertical entries of a 140-degree concial-nosed projectile up to 250 feet per second and correlated with high-speed motion pictures. The results of this experimental study, some of which contradict previous assumptions on cavity pressure, are presented.

OL 69-121

Gates, D. F., Brown, H. S., and Seigel, A. E.; *"An Analytic and Experimental Study of the Heat Transfer and Erosion in the NOL Hypervelocity Launcher"*; AIAA Paper #69-336, AIAA 4th Aerodynamic Testing Conference, April 1969. UNCLASSIFIED

ABSTRACT: (U) An evaluation has been made of the interior ballistics conditions leading to launch tube erosion in hypervelocity launchers. This evaluation is based upon information obtained from a one-dimensional Lagrangian computer code developed to simulate hypervelocity launcher operation. Launch tube wall temperatures are predicted from propellant gas temperatures and flow times and correlated with the erosion measured in a series of tests with varying launcher conditions. A proposed criterion defining the onset of significant erosion is outlined.

OL 69-122

Goeller, J. E.; *"A Theoretical and Experimental Investigation of a Flexible Cable System Subjected to Longitudinal Excitation"*; Doctoral Thesis, Catholic University, June 1969. UNCLASSIFIED

ABSTRACT: (U) A theoretical and experimental study was conducted on the dynamic response of cable systems subjected to deterministic longitudinal excitation. Two conditions were simulated; namely, longitudinal oscillation due to ocean wave motion, and breakaway of an object held by ocean sediments. Various mathematical models were used to predict response and included a distributed mass system, for segmented cables made of two viscoelastic materials, with internal damping and linear external damping. Good agreement was obtained between the theoretical predictions and experiments over a large range of frequencies. The occurrence and magnitude of cable snap were accurately predicted.

OL 69-123

Lyons, W. C.; *"Capability of NOL Ballistics Ranges for Obtaining Sphere Drag Coefficient Data"*; Proceedings of Symposium on Status of Passive Inflatable Falling Sphere Technology for Atmospheric Sensing to 100 km, September 1969. UNCLASSIFIED

ABSTRACT: (U) Descriptions of three ballistics range facilities at the Naval Ordnance Laboratory are

presented. The Mach number-Reynolds number capability for each facility is shown for the case of obtaining drag coefficients of spheres. It is shown that these three facilities can cover most of the Mach number-Reynolds number field between Mach numbers of 0.1 and 22 and Reynolds numbers between 10^1 and 10^7. A discussion of various sources of errors involved in measuring sphere drag coefficients in a ballistics range and of estimates of the magnitude of the errors is presented.

OL 69-124

Lyons, W. C.; *"Hypersonic Laminar and Turbulent Heat Transfer for Slightly Blunted Slender Cones"*; Doctoral Thesis, Univ. Maryland, 1969. UNCLASSIFIED

ABSTRACT: (U) An energy-integral method has been developed for predicting pertinent characteristics of the thermal boundary layer on a slightly blunted slender cone which considers nonisentropic flow at the outer edge of the boundary layer. Relations were developed for both the laminar and turbulent Stanton numbers and used in the solution of the energy-integral equation. Using the computer program developed from these equations, a parametric study of the effect of nose bluntness on the thermal boundary layer of a slender cone was studied. Experiments were performed in a ballistics range facility to obtain measurements of the total drag coefficient for slightly blunted slender cones. The boundary layer on these models was turbulent. Values for the mean turbulent skin friction were calculated from these total drag measurements. These indirectly measured turbulent skin friction coefficients were compared with calculated mean Stanton numbers through the use of Reynolds analogy. The agreement obtained from this comparison was very good.

OL 69-125

Phinney, R. E., Werle, M. J., Knott, J., and Volz, W. C.; *"Slot-Jet Interaction Studies at M_{oo}=4 and 5"*; AIAA Journal, Vol. 7, #8, pp. 1627-1628, August 1969. UNCLASSIFIED

ABSTRACT: (U) An experimental study of the control forces and moments generated by a slot-type secondary jet located near the base of an ogive cylinder in a Mach 4 and 5 free stream was conducted in the NOL Supersonic Tunnel No. 2. The free-stream Reynolds number, based on body length, was held constant at 12×10^6 and the missile angle of attack was varied from -10 to $+10°$. The jet slot spanned one quadrant of the cylindrical surface and was contained between two low aspect ratio fins.

OL 69-126

Seigel, A. E., and Waser, R. H.; *"On the Use of a Spring-Mass to Approximate a Bar-Mass System Subjected to a Rectangular Force Pulse"*; International Journal Solid Structures, Vol. 5, pp. 767-780, 1969. UNCLASSIFIED

ABSTRACT: (U) An analysis with experimental confirmation of a bar-mass system is described. The bar is built in at one end and has a rigid mass connected to the other end. To the rigid mass is applied a rectangular-step-force pulse of magnitude such that the bar is *elastically* deformed. The resulting behavior of the bar-mass system is calculated with the assumption that the stresses in the bar are one-dimensional. These calculations yield the fact that the bar-mass system experiences forces that are significantly larger than those experienced by an equivalent spring-mass approximation in the case of short pulse duration and/or magnitude of mass. The calculated results are confirmed by experiments performed on a bar-mass system.

OL 69-127

Sheetz, N. W., Jr.; *"Ballistics Range Experiments on the Effect of Unit Reynolds Number on Boundary-Layer Transition"*; Proceedings of 8th Navy Symposium on Aeroballistics, May 1969. UNCLASSIFIED

ABSTRACT: (U) It has been observed in numerous experimental investigations that the unit Reynolds number appears to have a significant effect on the boundary-layer transition Reynolds number. Many wind-tunnel investigations have indicated that, for an increase in the unit Reynolds number of a factor of 10, the transition Reynolds number can increase by a factor of 1.5 to 4, depending upon the particular experiment. In order to help define the effect of varying the unit Reynolds number on transition, a test was conducted in the NOL ballistics range. These results indicated the existence of a unit Reynolds number effect, but suggested that it may not be as strong as observed in many previous investigations.

OL 69-128

Sloan, G. J.; *"Recent Passive Density Sensor Effort at the Naval Ordnance Laboratory"*; Proceedings of Symposium on Atmospheric Density Sounding Systems, September 1969. UNCLASSIFIED

ABSTRACT: (U) The Naval Ordnance Laboratory has developed an atmospheric sounding system known as HASP, or High Altitude Sounding Projectile, capable of shipboard launching from a five-inch 38-caliber slow-fire gun. In this system, which is based upon the Loki anti-aircraft rocket system, a three-inch-diameter booster is

used to boost a dart vehicle to a velocity of about 5,000 feet per second in 1.9 seconds, at which time the booster separates, and the dart vehicle coasts to an altitude of 65 to 70 kilometers. For such a system to have good altitude capability, the dart must have a high sectional density. The normal HASP dart is therefore 1-3/8 inches in diameter, 40 inches long, and weighs eight to ten pounds, depending on the payload. The space available in such a dart is a compartment one inch in diameter and 20 inches in length, which is a volume of about 16 cubic inches. Efforts to develop a passive density sensor have been directed towards a system compatible with the small payload volume. The purpose of the paper is to briefly describe the efforts to develop a useful passive density system for the HASP dart.

OL 69-129

Sloan, G. J.; *"Deceleration Devices for High Altitude"*; Proceedings of AGARD Symposium, September 1969. UNCLASSIFIED

ABSTRACT: (U) Effort to extend our knowledge of the atmosphere to 100 kilometers on practically a routine basis has imposed rather severe design requirements for the retardation engineer. He must now reach for that retardation device that will produce infinite drag with no weight and no volume, along with excellent stability, high reliability, and low cost. The problem, therefore, breaks down into three principal areas of interest, namely, sectional density of the decelerator, deployment, and stability of the data-sensing system. The purpose of the paper is to discuss the present approach to these problems and outline some of the approaches under study.

OL 69-130

Yang, J. C. S., and Seigel, A. E.; *"Stress Waves in Multilayered Cylinders and Conical Frustrums"*; Proceedings 40th Shock & Vibration Symposium, October 1969. UNCLASSIFIED

ABSTRACT: (U) The purpose of this paper is to report on an investigation of the spallation problem of multilayered conical structures by analyzing the propagation of elastic stress waves in multilayered cylinders and conical frustrums using the method of characteristics. A numerical method was utilized to solve the characteristic equations, using an electronic computer. The results were verified by a comparison with experimental strain-time results in truncated cones impacted by spheres observed by V. Kenner and W. Goldsmith.

OL 69-131

Yang, J. C. S.; *"Analysis of Shock Mitigation for Glass Submersibles"*; Proceedings of 40th Shock & Vibration Symposium, October 1969. UNCLASSIFIED

ABSTRACT: (U) In this analysis equations are developed to obtain the response of models of deep submergence glass hulls clad with a viscoelastic strain-attenuating material (Adiprene) which are subjected to impact loading. Both the analog and the digital computers were utilized in the solution of the equations. Nondimensional scaling equations are developed to predict the response of both the prototype and model. The analytical results were reasonably well confirmed by experiments performed using an air gun to impact steel spherical projectiles onto strengthened glass hemispherical shells with Adiprene cladding.

PATENT

(Listed serially by U.S. Patent number and indexed Pat.)

U.S. Patent No. 3,469,733

Rupture Disc Unit, by Rayner A. Montgomery and Eugene E. Kilmer. UNCLASSIFIED

ABSTRACT: (U) This invention provides a quick and reliable valve means for flooding a compartment in a submerged weapon. The valve comprises a metal disc with a spherical shaped groove machined into the disc, explosive material cemented over the groove and a suitable detonator. Upon command the detonator fires activating the explosive material causing the metal disc to rupture along the scored lines.

TECHNICAL DOCUMENTS ISSUED BY MATHEMATICS DEPARTMENT (330)

UNCLASSIFIED DOCUMENTS

NOL Technical Reports

NOLTR 68-166
A Source-Sink Problem, by Stuart L. Brodsky. 31 Oct. 1968. 15p. UNCLASSIFIED

ABSTRACT: (U) Considered is the problem of a three dimensional source and sink whose strengths are growing like t^2 and moving with constant velocities -w and +w respectively from the origin at t = 0 along one of the coordinate axes. This problem is shown to be a self-similar problem and a qualitative discussion is made of its solution.

NOLTR 68-177
IBM 7090–Remote Terminal FORTRAN IV Interface Package, by Carol J. Bakker and John O. Lyles. 28 Oct. 1968. 36p. UNCLASSIFIED

ABSTRACT: (U) THE IBM 7090–Remote Terminal FORTRAN IV Interface Package is a set of programs used at the Naval Ordnance Laboratory to transfer FORTRAN IV programs between the remote terminal system and the IBM 7090. The report describes the usage and supplies the listings for the package.

NOLTR 69-18
NOLFR–A Computer Program to Read Wind-Tunnel Free-Flight Data Film, by Mary E. Beszterczei and Frank J. Regan. 16 Dec. 1968. 68p. UNCLASSIFIED

ABSTRACT: (U) A computer program has been developed to control an automatic optical scanner in reading specialized wind-tunnel free-flight data film. In each frame, the program locates the model, a slender pointed cone, and calculates the attitude of the model centerline and the planar coordinates of the center of gravity relative to fixed fiducial marks. The program is written in FORTRAN and assembly language for the IBM 1800 computer interfaced with an automatic optical scanner.

NOLTR 69-26
The Vertical Water Entry of a Cone, by Charles F. Weber. 30 Jan. 1969. 55p. UNCLASSIFIED

ABSTRACT: (U) This report outlines a method which has been used to solve the problem of computing the hydrodynamic effects of a cone entering the water vertically. The method is essentially one of representing the potential as due to a source and dipole sheet on the cone and free surfaces, respectively. Preliminary results of a computer program are presented.

NOLTR 69-168
Asymptotic Distributions and some Integral Equations, by Stuart L. Brodsky. 2 Oct. 1969. 62p. UNCLASSIFIED

ABSTRACT: (U) Considered is a method for the asymptotic solution of integral equations of convolution type within the theory of distributions of Laurent

Schwartz. A distributional theory of asymptotics is developed and an investigation is made of distributional convolution equations arising from integral equations with difference kernels. The results are combined to show how one can obtain asymptotic expansions for the solutions of some integral equations of this type.

OPEN LITERATURE

(Identified by OL numbers for indexing purposes)

OL 69-132

Aziz, A. K. and Knight, R. B.; *"Existence of Generalized Solutions of Quasi-linear Elliptic Equations in Two Independent Variables"*; Gorden Breach Publishing Company, pp. 405-413, 1969. UNCLASSIFIED

ABSTRACT: (U) In this paper we shall be concerned with the question of existence of generalized solutions of the following Dirichlet problem:

$$L(u) \equiv a(x, y, u, u_x, u_y)\, u_{xx} + 2b(x, y, u, u_x, u_y)u_{xy} \quad (1.1)$$
$$+ c(x, y, u, u_x, u_y)u_{yy} + d(x, y, u, u_x, u_y) = 0$$
$$u|_\Gamma = \varphi(x, y) \quad (1.2)$$

where Γ denotes the boundary of a simply connected domain G in the xy-plane.

OL 69-133

Aziz, A. K. and Meyers, A. M.; *"Periodic Solutions of Hyperbolic Partial Differential Equations in a Strip"*; Transactions of the American Mathematical Society, Chapter 146, 1969. UNCLASSIFIED

ABSTRACT: (U) In this paper we shall investigate the questions of existence, uniqueness, and continuous dependence on initial data of periodic solutions of the nonlinear hyperbolic equation:

$$(1.1)\ Lu \equiv u_{xy} + a(x, y)u_x + b(x, y)u_y + c(x, y)u =$$
$$f(x, y, u, u_x, u_y)$$

in the strip $S = \{(x, y);\ -\infty < x < \infty, 0 \leqq y \leqq \eta\}$. Here the functions a, b, c and f are assumed to be periodic in x with the same period T. We ask for a classical solution of (1.1), periodic in x with period T and satisfying the initial condition

$$u(x, 0) = \theta(x),$$

where $\theta(x)$ is continuously differentiable and periodic with period T.

OL 69-134

Cohen, Edgar A., Jr.; "A Polynominal with Prescribed Properties"; SIAM Review, October 1969. UNCLASSIFIED

ABSTRACT: (U) Given a closed interval [a, b], consider the class C^1 [a, b], of all smooth functions on this interval. For a given $f \in C^1$ [a, b], find a polynominal P (x) with the following properties:

1. $P(a) = f(a),\ P(b) = f(b)$
   $P'(a) = f'(a), P'(b) = f'(b).$

2. $\int_a^b f(x)\ P(x)\ dx = 0$

OL 69-135

Gleyzal, A.; *"Complex Gravitation"*; Notices of the American Mathematical Society, Vol. 16, No. 1, p. 320, January 1969. UNCLASSIFIED

ABSTRACT: (U) We propose that a *pure complex analytic riemannian geometry* $a_{\alpha\beta} = [a_{\alpha\beta}] = [a_{\alpha\beta}, 0]$, where $ds^2 = a_{\alpha\beta}da^\alpha da^\beta$ and $a_{\alpha\beta} = a_{\alpha\beta}$ are ten complex analytic functions $a_{\alpha\beta}(a^\gamma)$ of the four complex coordinate variables a^γ, represents the physical universe [cf. Abstract 64T-30, these *Notices* 11 (1964), 135; Navai Ordnance Lab. Tech. Rep. 66-189 and 68-112]. A relaxation of this proposal is that a test particle w_n, n = 0,1,2,..., of complex mass $w_0 = m = \underset{\sim}{m} + i\underset{\sim}{e}/\sqrt{\gamma}$ introduced into $a_{\alpha\beta}$ is represented by a *dual geometry* $[a_{\alpha\beta}(a^\gamma), \tilde{\Psi}(a_{\alpha\beta}(a^\gamma), w_n)]$, where $\tilde{\Psi}(a_{\alpha\beta}(a^\gamma), w_n) = \Psi(a^\gamma, w_n)$, Ψ is analytic in a^γ and w_n, $\tilde{\Psi}$ is a functional of $a_{\alpha\beta}(a^\gamma)$ and w_n, and Ψ denotes a *complex de Broglie wave* for m in $a_{\alpha\beta}$. Let $a_{\alpha\beta} = a_{\alpha\beta}(a^\gamma, m_0)$ be the *complex Schwarzschild field* of $a = \gamma\, m_0/c^2$ where $m_0 = \underset{\sim}{m}_0 + i\underset{\sim}{e}_0/\sqrt{\gamma}$. We consider dual geometries $[m_0, m] = [a_{\alpha\beta}(a^\gamma, m_0), \tilde{\Psi}(a_{\alpha\beta}(a^\gamma, m_0), m)]$. Suppose $a^{\alpha\beta}\Psi_{\alpha\beta} - (m^2c^2/\hbar^2)\Psi = 0$ or, as in a Dirac theory, $\gamma^\alpha\Psi_\alpha + (mc/\hbar)\Psi = 0$ where γ^α is suitably defined. A radial differential equation for R(r) may then be derived. Let the coefficients of this radial equation be suitably altered by factors $1 + \beta a/r$ where $|\beta| < 4$. Then $|\beta a/r| < 10^{-24}$ if $|r| > 10^{-9}$ cm. The usual eigenvalues (energy levels) of the hydrogenic dual particle $[m_0, m]$ will result.

OL 69-136

Glick, I. I.; *"Phillips Integral Representations of Linear Operators from Banach Spaces into L^p Spaces"*, Journal

of Mathematical Analysis and Applications, Vol. 28, No. 2, pp. 431-439, November 1969. UNCLASSIFIED

ABSTRACT: (U) In this paper we establish representation theorems expressing any bounded linear operator from a Banach space χ into an L^p space, $1 \leq p$, in terms of a Phillips integral. The principal tool used for this is the Radon-Nikodym theorem of Rickart. In addition, we find it advantageous to use spaces of countably additive set functions which are isometrically isomorphic to the L^p spaces.

OL 69-137

Weber, Charles F.; *"A Theorem on the Representation of Potential Flows Having Unbounded Free Surfaces"*; Quarterly of Applied Mathematics, Vol. XXVII, No. 2, pp. 267-269, July 1969. UNCLASSIFIED

ABSTRACT: (U) Consider an incompressible (non-steady) potential flow with a free boundary extending to infinity. Suppose the flow is axially symmetric, the free surface initially planar and at rest, and the potential well enough behaved so that the Bernoulli equation applies on the surface. Suppose there is a disturbance which is, at any fixed time, local (as defined above), with no external forces. Then, under these circumstances, the potential ϕ cannot be represented by a collection of singularities in the finite part of space, for t small enough.

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TECHNICAL DOCUMENTS ISSUED BY AERODYNAMICS DEPARTMENT (310)

UNCLASSIFIED DOCUMENTS

NOL Technical Reports

NOLTR 69-122

Investigation of Substructure Heating on Cracked Ablative Heat Shields, by Eva Winkler et al. 22 July 1969. 13p. UNCLASSIFIED

ABSTRACT: An experimental program has been carried out in the U.S. Naval Ordnance Laboratory (NOL) 3 Megawatt Arc Tunnel to study the effect of cracks in an ablative heat shield on the substructure heating. The test conditions involved stagnation pressures of 20 to 30 atmospheres, temperatures of 4000 to 9000°R, and Mach numbers of 2.3 and 3. The models, made of teflon, had transverse and longitudinal cracks machined into the surface. They were instrumented for pressure, temperature, heat transfer and skin-friction measurements. The cracks were found to have pronounced effects on the ablative behavior. The heating is moderate under a laminar boundary layer, but can be catastrophic when the boundary layer is turbulent, depending upon the size and direction of the crack. The results for the transverse cracks were compared with an available analytical prediction. Ablation was found to reduce the wall shear stress by 40 percent or more.

NOLTR 69-125

Supersonic Ablation Studies with Teflon, by Eva Winkler et al. 6 October 1969. 20p. UNCLASSIFIED

ABSTRACT: An experimental program has been carried out in the Naval Ordnance Laboratory (NOL) 3 Megawatt Arc Tunnel to study the interaction of ablation and a vehicle's aerodynamic characteristics. The test conditions involved stagnation pressures of 20 to 30 atmospheres, temperatures of 4000 to 9000°R and Mach numbers of 2.3 and 3. The test models, made of teflon, were instrumented for pressure, temperature, heat transfer, and skin-friction measurements. Laminar and turbulent boundary-layer data were obtained. The laminar data were compared with the predictions of a numerical procedure known as BLIMP-CMA. Surprisingly close agreement was found between most of the experimental data and predictions. Ablation-induced transition was observed in all laminar runs. In fully turbulent runs cross-hatched striations were observed. Ablation reduced the wall shear stress by about 60 percent for the laminar runs and by 40 percent for the turbulent runs.

NOLTR 69-143

An Experimental Investigation of the Compressible Turbulent Boundary Layer With a Favorable Pressure Gradient, by David Brott et al. 25 August 1969. 11p. UNCLASSIFIED

ABSTRACT: This paper describes the results of a detailed experimental investigation of a two-dimensional turbulent boundary layer in a favorable pressure gradient where the free-stream Mach number varied from 3.8 to 4.6 and the ratio of wall to adiabatic-wall temperature had a nominal value of 0.82. Detailed profile measurements were made with pressure and temperature probes; skin friction was measured directly with a shear balance. The velocity- and temperature-profile results were compared with zero pressure gradient and incompressible results. The skin-friction data were correlated with momentum-thickness Reynolds number and pressure-gradient parameter $\beta = -\theta/\tau_w \, dP/dx$. The skin friction decreases with decreasing β for a constant value of momentum-thickness Reynolds number.

NOLTR 69-151

Measurements of Blast-Induced Transient Pressures at the Base of a Cone in Supersonic Flow, by Frank Baltakis and Gary Senechal. 5 November 1969. 60p. UNCLASSIFIED

ABSTRACT: Transient pressures, induced by a head-on blast wave, have been measured at the base of a nine-degree half-angle cone in a supersonic stream using a wind-tunnel shocktube technique. Tests were conducted at free-stream Mach numbers of 3, 5 and 6.5 and at blast wave Mach numbers of 1.5 to 3, 2 to 5 and 4 to 8 at free-stream Mach numbers of 3, 5 and 6.5, respectively. Within the range of this experiment, the shock-induced base pressure was found to increase approximately in proportion to the blast wave Mach number squared. When expressed in ratio to the free-stream static pressure, the induced base pressure was found to decrease, approximately, linearly with increasing free-stream Mach number. At the free-stream/blast wave Mach number conditions of 3/3, 5/5 and 6.5/8 the respective induced base pressure to initial free-stream static pressure ratios were 5, 8 and 18.

NOLTR 69-164

Static Stability and Axial Force Coefficients for the 0.125 Scale Model Mark 82 Low Drag Bomb With Closed Snakeye I Fins at Subsonic and Transonic Speeds, by Virginia Schermerhorn. 17 September 1969. UNCLASSIFIED

ABSTRACT: Static stability and axial force coefficients are presented as a function of angle of attack for the Mk 82 Low Drag Bomb with Snakeye Fins in the closed position. These data were obtained for a Mach number range from 0.6 to 1.1; an angle of attack range from –6 to +20 degrees; and, a roll angle range from 0 to 225 degrees in the NOL Supersonic Tunnel No. 1, using a subsonic nozzle.

NOLTR 69-187

An Experimental Investigation of the Flow Field Around a Yawed Cone, by Robert Feldhuhn. 3 November 1969. 23p. UNCLASSIFIED

ABSTRACT: An experimental investigation of the flow field associated with a highly yawed cone has been conducted in the Supersonic Tunnel No. 2 at the U.S. Naval Ordnance Laboratory (NOL), White Oak, at a Mach number of 5 and a free-stream Reynolds number per foot of 4.4×10^6. Surface static pressure measurements, flow-field surveys and schlieren photographs were obtained on a sharp five-degree semivertex angle cone at an angle of attack of 24 degrees. The results of the measurements indicate that the flow field on the leeward side of a highly yawed cone is very similar to that of a circular cylinder in supersonic cross flow. The essential difference between these two flow fields is the presence of a disturbance from the tip of the cone which separates the gas which has passed through the shock wave on the windward side from the flow which has passed through the weaker portion of the shock wave on the leeward side of the cone.

NOLTR 69-200

A Time-Dependent Quasi-One-Dimensional Analysis of Population Inversions in an Expanding Gas, by John D. Anderson, Jr. 12 December 1969. 22p. UNCLASSIFIED

ABSTRACT: A time-dependent technique for the numerical solution of convergent-divergent, nonequilibrium nozzle flows has been used to analyze the rapid, vibrational nonequilibrium, supersonic expansion of CO_2-N_2-H_2O and CO_2-N_2-He mixtures, wherein the finite rate molecular energy transfer processes can result in a population inversion between the (001) and (100) vibrational energy levels of CO_2. Results for such population inversions are presented. Among these, a comparison has been made between the present results and the recent results of Basov et al.; this comparison indicates that Basov's calculations overestimate the population inversion in an expanding mixture of CO_2 and N_2. In addition, results are presented from a series of numerical experiments conducted to assess the validity of several simplified methods for computing population inversions.

NOLTR 69-212

A Computer Program for the Interception of a Re-Entry Body by a Ground-Launched Interceptor, by E. Leroy Harris and Carolyn Piper. 26 November 1969. 40p. UNCLASSIFIED

ABSTRACT: A computer program is described which calculates the trajectory of a ground-launched vehicle intercepting a maneuvering re-entry body. The motion is planar and proportional navigation is used. Allowance is made for the finite length of time it takes the data acquisition system to process the tracking data, and for the time lag between the demand for a new course and the response to that demand. Both vehicles are represented as point masses with drag coefficient of the form $a + bC_L^2$. The Fortran listing of the program and a sample calculation are given.

NOLTR 69-214

Magnus Measurements on the M823 Research Store with Fixed and Freely Spinning Cruciform Stabilizers, Freely Spinning Monoplane Stabilizers and Split-Skirt Stabilizers, by Frank Regan, John Holmes, and Mary Falusi. 25 November 1969. 134p. UNCLASSIFIED

ABSTRACT: The M823 configuration is an instrumented free-fall store used in bomb stability research programs. This report presents the results of Magnus wind-tunnel tests on the basic forebody with fixed and freely spinning cruciform stabilizers, freely spinning monoplane stabilizers and split-skirt stabilizers.

NOLTR 69-217

Static Wind-Tunnel Tests of the Mk 82 Free-Fall Store with Two Modified Stabilizers, by Frank Regan, Grant Edwards, and Mary Falusi. 8 December 1969. 111p. UNCLASSIFIED

ABSTRACT: The Mk 82 is an operational free-fall store in use by the U.S. Navy. This report presents the results of static wind-tunnel tests of two proposed stabilizers for this weapon. The purpose in carrying out these tests was to provide data for a comparison between the currently used stabilizer and the proposed modified stabilizers.

NOLTR 69-232

The Joint NOL/RAE/WRE Research Program on Bomb Dynamics Part II A Low-Drag Bomb with Split-Skirt Stabilizers, by Frank Regan, Jon Shannon and Frank Tanner. UNCLASSIFIED

ABSTRACT: Research on the free-fall dynamics of bombs has been conducted as a cooperative program supported by organizations in the United States, United Kingdom and Australia. In addition to full-scale flight trials of instrumented research stores carried out by the Australian Weapons Research Establishment (WRE), wind-tunnel tests have been made on mutually agreed models at the Aircraft Research Association and Royal Aircraft Establishment (RAE) in England; the Naval Ordnance Laboratory (NOL) in the United States; and at the Aeronautical Research Laboratory in Australia. RAE, WRE and NOL have separately prepared digital-computer programs to simulate test vehicle trajectories using wind-tunnel measurements as inputs. Correlation between the predicted and observed flight results have provided considerable insight into problems associated with dynamic behavior during the critical release phase and stability criteria needed for good ballistics consistency. This is the second report on the research program and it presents results relating to the study of split-skirt stabilizers. These stabilizers are designed to eliminate the effects of roll-yaw cross coupling and to provide a variable-drag capability.

NOLTR 70-2

On the Hypersonic Flow Past Blunted, Flat Delta Wings, by Arnold Polak. 5 January 1970. 21p. UNCLASSIFIED

ABSTRACT: In this report the flow of a perfect gas over the slab portion of a blunted delta wing flying at hypersonic speeds is studied. A set of approximate equations is derived and a solution—for an inviscid flow—is obtained. Using this solution as a representation for the inviscid flow problem, a formulation to the laminar boundary-layer equations is presented; one which is applicable to the flow field's azimuthal planes where the crossflow gradients are not too large. Numerical solutions to these boundary-layer equations have been obtained; however, these are restricted to the azimuthal planes and near to the leading edges. The results indicate the presence of a dividing surface streamline since a numerical solution could not be obtained near the centerplane of the wing, where the crossflow velocity is large.

NOLTR 70-12

The NOL Four-Ring Three-Phase AC Arc Heater (Mk IV), by Eva Winkler, Richard Humphrey and Joseph Koenig. 13 January 1970. 12p. UNCLASSIFIED

ABSTRACT: The design and performance of a four-ring three-phase ac Arc Heater are described. Successful operation at pressures of 10 to 33 atmospheres, temperatures of 2000 to 5000°K and efficiencies of 25 to 60 percent has been demonstrated. Improvements in heater components will allow pressures of 70 atmospheres to be obtained.

NOLTR 70-48

Transpiration Cooling Experiments Near the Stagnation Line of a Cylinder in Cross Flow, by Richard Humphrey. 10 March 1970. 10p. UNCLASSIFIED

ABSTRACT: Tests were made with a cylindrical model transpiration cooled over a region ±15° from the stagnation line. Air was used as the coolant. The model was tested in the U.S. Naval Ordnance Laboratory (NOL) 3 Megawatt Arc Tunnel at a nominal Mach number of 7.0. Wall temperatures and heat-transfer rates were in good agreement with predicted values. The effect of the external pressure distribution on the local coolant flow rate and wall temperature is discussed.

NOLTR 70-50

Two-Dimensional Jet Interaction with a Mach 4 Mainstream, by Richard Driftmyer, David Shaffer, Michael Werle. 1 May 1970. 108p. UNCLASSIFIED

ABSTRACT: This report describes the results of an experimental study concerning the injection of a gaseous secondary jet into an unbounded supersonic flow field which was uniform outside of a turbulent boundary layer. The investigation was principally concerned with the definition of the proper scale length to be associated with turbulent two-dimensional jet-interaction flows. In support of this objective, results are presented for a Mach 4 test conducted using a flat-plate model containing a sonic secondary jet directed normal to the mainstream. Secondary jet strengths were varied from approximately 0 to 1000 for jet throat sizes of 0.005 inch, 0.020 inch and 0.030 inch. The jet-interaction phenomenon was studied using detailed surface pressure distributions measured fore and aft of the secondary jet in conjunction with comprehensive shadowgraph coverage of the interaction flow field.

NOLTR 70-81

A Fine-Wire Stagnation Temperature Probe, by William Yanta. 15 June 1970. 12p. UNCLASSIFIED

ABSTRACT: A temperature probe using a small thermocouple wire with its axis placed normal to an airstream

has been designed, built and tested. The primary purpose of the probe is to measure the stagnation temperature distribution through a supersonic turbulent boundary layer. The small probe size permits measurements in the laminar sublayer region. The probe's simple geometric shape and design provides simplicity in determining the local gas temperature. Experiments have shown that it is possible to measure the local stagnation temperature of the flow with an accuracy of 5°R over a moderate temperature range of 560°R to 780°R.

NOLTR 70-93

Flow Visualization Studies of a Fin Protuberance Partially Immersed in a Turbulent Boundary Layer at Mach 5, by Allen Winkelmann. 20 May 1970. 14p. UNCLASSIFIED

ABSTRACT: Various flow-visualization results are presented for a cylindrically blunted, unswept fin (yawed and unyawed) partially immersed in a turbulent boundary layer ($\delta \approx 2.6$ inches). The model, consisting of a fin-flat plate combination, was mounted on the test plate nozzle wall of the U.S. Naval Ordnance Laboratory, (NOL) Boundary Layer Channel. Experiments were completed at a nominal Mach number of 5 and nominal free-stream Reynolds numbers per foot of 2.8×10^6 and 7.4×10^6. Azobenzene tests show regions of high heat transfer to occur on the flat plate immediately upstream and downstream of the fin. Oil smear tests show in detail the surface shear directions and locations of separated flow which occur on the model. Schlieren and shadowgraph photographs indicate the complex shock wave structure which exists in front of the fin. A possible flow-field model is suggested to account for the observed flow patterns.

NOLTR 70-103

Equilibrium Normal Shock Properties for Vibrationally Excited CO_2-N_2-He Gas Mixtures, by Michael Madden, John Anderson, Jr., and Carolyn Piper. 28 May 1970. 10p. UNCLASSIFIED

ABSTRACT: Results are given for equilibrium properties behind incident and reflected normal shock waves in CO_2-N_2-He mixtures wherein the gas may be vibrationally excited but not chemically reacting. A rapid numerical iterative analysis is described, and the results are given in simple graphical form for convenient use in shock tube and shock tunnel experiments. The results are anticipated to be of particular use in determining reservoir conditions for shock tunnel experiments dealing with vibrational population inversions in rapidly expanding mixtures.

NOLTR 70-148

Calculation of Laminar Skin Friction on a Porous Plate by a Refined Integral Method, by Tse-Fou Zien. 10 August 1970. 23p. UNCLASSIFIED

ABSTRACT: The skin friction on a porous flat plate in the presence of an incompressible laminar boundary layer is calculated by a generalization of a refined integral technique developed by Volkov. This method is based on a double integration of the momentum equation, replacing the skin-friction term by an integral representation involving the assumed velocity profile. Both the case of similarity blowing (or suction) in which $v_w \sim x^{-1/2}$ and the case of uniform blowing (or suction) in which v_w = const. have been studied. Using two simple and crude velocity profiles of polynominal form with constant coefficients, closed-form solutions are obtained through simple procedures and compared with the available exact solutions. Remarkably accurate results for both cases have been found covering the entire region of suction up to the region of fairly strong blowing, and the insensitivity of the results to the choice of velocity profiles is also demonstrated. In addition, these analytical solutions are shown to reduce correctly to the asymptotic suction limit for large suctions. They also have correct qualitative behavior near the blow-off point. The same profiles are then employed in the usual integral method to calculate the corresponding skin friction. While the same degree of simplicity in calculation remains, the results are far less satisfactory, particularly in the entire region of blowing and the region of mild suction.

NOLTR 70-197

The Prediction of Errors and the Improvement of Data Obtained in Wind-Tunnel Heat-Transfer Tests, by Donald Wilson. 24 September 1970. 38p. UNCLASSIFIED

ABSTRACT: The measurement of heat-transfer data in a high-speed wind tunnel is considered in detail. The analysis is restricted to tests where transient temperature measurements are made by thermocouples attached to the back face of a thin-walled model. Methods of estimating the error in obtaining a heat-transfer coefficient due to extraneous heat-transfer rates or the choice of a data-reduction method are presented. The error caused by the presence of a thermocouple in a thin wall was found experimentally. Methods of improving heat-transfer data, including the Thomas-Fitzsimmons conduction correction method, are discussed. Heat-transfer data and wind-tunnel test conditions from a previous heat-transfer test conducted at the Naval Ordnance Laboratory (NOL) were used to exemplify the conclusions and analysis of this report.

NOLTR 70-198

Numerical Experiments Associated with Gas Dynamic Lasers, by John D. Anderson, Jr. 24 September 1970. 24p. UNCLASSIFIED

ABSTRACT: A previous time-dependent finite-difference numerical solution of second order accuracy for quasi-one-dimensional nonequilibrium nozzle flows using 3 terms of a Taylor's series expansion in time is modified such that only

2 terms of a series expansion are required for second order accuracy. As a result, an already straightforward analysis of non-equilibrium nozzle flows is made even simpler. With the present solution, numerical experiments are carried out for gas dynamic laser flows in order to study the consequences of large H_2O content, high reservoir pressures and small nozzle throat heights. The results indicate that (1) H_2O content up to 7 percent by volume can be tolerated without complete degradation of small-signal gain, (2) a finite small signal gain can be achieved for high reservoir pressures on the order of 100 atm for starved CO_2 mixtures, thus confirming previous predictions by Hertzberg, and (3) in order to achieve increased gain with a minimum length contoured nozzle as the throat height is reduced to values as low as 0.mm, the nozzle length should be maintained long enough (and hence area ratio increased large enough) such that the ν_1 and ν_2 vibrational modes of CO_2 have ample time to equilibrate inside the divergent portion of the nozzle rather than in the constant area section. This latter conclusion is supported by basic fluid mechanical reasoning. Finally, in order to assess the validity of the present analysis, limited comparisons are made with experiment.

NOLTR 70-211

Supersonic Magnus Measurements of the 10-Caliber Army-Navy Spinner Projectile with Wrap-Around Fins, by Frank Regan and Virginia Schermerhorn. 1 October 1970. 84p.
UNCLASSIFIED

ABSTRACT: A research configuration was formed by attaching wrap-around fins in a cruciform arrangement to a 10-caliber Army-Navy Spinner Projectile. This configuration was tested in the Naval Ordnance Laboratory's Supersonic Tunnel No. 2 to get the Magnus force and moment, as well as the normal force and pitching moment. Model spin rate was generated by means of fin cant.

NOLTR 70-214

Vibrational Population Inversion Within Normal Shock Waves in CO_2-N_2-He Mixtures, by John Anderson, Jr., Michael Madden, and Carolyn Piper. 7 October 1970. 19p.
UNCLASSIFIED

ABSTRACT: Numerical solutions are given for vibrational population inversions created in CO_2-N_2-He mixtures due to shock wave heating of a cold gas. The results indicate that population inversions between the (040) and (001) energy levels of CO_2 and, to a lesser degree, between the (200) and (001) levels, can be created in the vibrational nonequilibrium flow behind a normal shock front. The properties of these inversions as a possible laser medium are assessed; the results indicate that the laser properties of this shock-induced nonequilibrium flow are not as promising as those of lasers operating on the principle of rapid expansions.

NOLTR 70-228

Feasibility of Non-Destructively Testing Fuze Mechanisms in a Ballistic Range, by Alfred Berger, Hilton Carter, and Raynor Montgomery. 20 October 1970. 18p.
UNCLASSIFIED

ABSTRACT: Tests were conducted which demonstrated the feasibility of employing the free-flight technique in a ballistics range to non-destructively test naval ammunition fuze components. Three models containing either an actual or dummy fuze clock were launched in the Naval Ordnance Laboratory's Pressurized Ballistics Range. Each model was launched at 2850 feet per second, a spin rate of 73 revolutions per second, and an axial acceleration loading of 18,000 g's. These conditions simulate those encountered during the firing of a 5"/38 naval gun. Two models were recovered. One of these contained an actual fuze clock which was recovered virtually undamaged. Average deceleration loading for this recovery was 3000 g's. A wider range of launching conditions can be provided to simulate a great variety of firing simulations. In addition, lower recovery loadings appear practicable.

OPEN LITERATURE

(Identified by OL numbers for indexing purposes)

OL 70-100

Anderson, John D., Jr.: "*Aerospace Engineering Education in the 1970's–A User's Viewpoint*"; American Society for Engineering Education, Annual Meeting, 22-25 June 1970.
UNCLASSIFIED

ABSTRACT: The following questions are approached and some possible answers are given: (1) what type of graduate will be most desirable as the finished product of an aerospace engineering curriculum in the 1970's, and (2) how can aerospace engineering education produce this desired finished product? As a prerequisite, some prognostications are made concerning the future government and industrial aerospace environment in the 1970's. Conclusion is made that the 1970's will be dominated by consolidation of contemporary research advances with increasing emphasis on engineering applications. Hence, suggestions are made for the growth of an "applications-academic" complex as an equal partner with the already existing "research-academic" complex. The nature of such an "applications-academic" complex and its influence on education are discussed.

OL 70-101

Anderson, J. D., Jr.; *"A Time-Dependent Analysis for Vibrational and Chemical Nonequilibrium Nozzle Flows"*; AIAA Journal, Vol. 8, #3, March 1970. UNCLASSIFIED

ABSTRACT: An unsteady technique is presented for the numerical solution of quasi-one-dimensional, vibrational and chemical nonequilibrium nozzle flows including nonequilibrium conditions both upstream and downstream of the throat. This technique is a time-dependent analysis which entails the explicit finite-difference solution of the quasi-one-dimensional unsteady flow equations in steps of time, starting with assumed initial distributions throughout the nozzle. The steady-state solution is approached at large values of time. A virtue of the present time-dependent analysis is its simplicity, which prevails from its initial physical formulation to the successful receipt of numerical results. To exemplify the present analysis, results are given for several cases of vibrational and chemical nonequilibrium expansions through nozzles.

OL 70-102

Anderson, J. D., Jr.; *"Time-Dependent Analysis of Population Inversions in an Expanding Gas"*; The Physics of Fluids, Vol. 13, #8, pp. 1984-1989. August 1970. UNCLASSIFIED

ABSTRACT: A time-dependent technique for the numerical solution of convergent-divergent, nonequilibrium nozzle flows has been used to analyze the rapid, vibrational nonequilibrium, supersonic expansion of a mixture of CO_2, N_2, and H_2O, wherein the finite rate molecular energy transfer processes can result in a population inversion between the (001) and (100) vibrational energy levels of CO_2. Results for such population inversions are presented. Among these, a comparison has been made between the present results and the recent results of Basov *et al.*; this comparison indicates that Basov's calculations overestimate the population inversion in an expanding mixture of CO_2 and N_2. In addition, results are presented from a series of numerical experiments conducted to assess the validity of several simplified methods for computing population inversions.

OL 70-103

Anderson, J. D., Jr.; *"Time-Dependent Solutions of Nonequilibrium Nozzle Flows–A Sequel"*; AIAA Journal, Vol. 8, #12, pp. 2280-2282, December 1970. UNCLASSIFIED

ABSTRACT: A previous time-dependent finite-difference numerical solution of second order accuracy for quasi-one-dimensional nonequilibrium nozzle flows using 3 terms of a Taylor's series expansion in time is modified such that only 2 terms of a series expansion are required for second order accuracy. As a result, an already straightforward analysis of nonequilibrium nozzle flows is made even simpler.

OL 70-104

Brott, D. L., Yanta, W. J., Voisinet, R. L., and Lee, R. E.; *"An Experimental Investigation of the Compressible Turbulent Boundary Layer with a Favorable Pressure Gradient"*; AIAA Journal, Vol. 8, #7, pp. 1270-1274, July 1970. UNCLASSIFIED

ABSTRACT: This paper describes the results of a detailed experimental investigation of a two-dimensional turbulent boundary layer in a favorable pressure gradient where the freestream Mach number varied from 3.8 to 4.6; the ratio of wall to adiabatic wall temperature remained constant at a value of 0.82. Detailed profile measurements were made with pressure and temperature probes; skin friction was measured directly with a shear balance. The velocity and temperature profile results are compared with zero pressure gradient and incompressible results. The skin-friction data are correlated with momentum-thickness Reynolds number and the pressure gradient parameter $\beta_\theta = (\theta/\tau_w)(dP/dx)$. The skin friction increases with decreasing β_θ for a constant value of momentum-thickness Reynolds number.

OL 70-105

Feldhuhn, R. H., Winkelmann, A. E., and Pasiuk, L., NOSC; *"An Experimental Investigation of the Flow Field Around A Yawed Cone"*; AIAA 3rd Fluid and Plasma Dynamics Conference, 29 June-1 July 1970. UNCLASSIFIED

ABSTRACT: An experimental investigation of the flow field associated with a highly yawed five degree half-angle cone has been conducted in the wind tunnels at the U.S. Naval Ordnance Laboratory (NOL). The measurements, obtained for the most part at Mach 5, included surface pressure distributions, flow visualization photographs, and detailed leeward side flow-field surveys. Analysis of these results indicates that the flow field associated with a highly yawed cone at high supersonic velocities resembles that of a circular cylinder in a supersonic crossflow. The conical inviscid flow field on the windward side of the cone is analogous to the blunt body type flow field established by a circular cylinder. The structure of the flow field on the leeward side of a highly yawed circular cone is similar in appearance to that in the wake of the circular cylinder. The essential difference between these flow fields is the presence in the cone flow field of a "vortical singularity like" gradient which separates the flow traversing the stronger portion of the shock wave on the windward side from the flow traversing the weaker portion of the shock wave on the leeward side.

OL 70-106

Kalivretenos, C. A.; *"Aircraft/Store Interference"*; AGARD Conference Proceedings #71, pp. 35-1 to 35-13. UNCLASSIFIED

ABSTRACT: The U.S. Naval Ordnance Laboratory recently completed a series of tests relating to the carriage and separation characteristics of a newly developed rocket launcher pod. The objectives of the tests were to identify

those flight conditions under which separation of the launcher might result in damage to the aircraft and to obtain data from which the separation behavior could be predicted. Included in this series of tests was a pod installation, force test, a flow-field survey test and a pod jettison test. In each investigation, the loaded and empty rocket launcher pods were suspended from the centerline and outboard shoulder stations of the scaled Triple Ejector Rack (TER). The TER was located on the inboard wing station of an A-4 aircraft model. In brief, forces and moments acting on the pod are strong functions of the pod's position within the local flow field. The pod tends to pitch nose upward at high aircraft angles of attack and nose downward at low aircraft angles of attack. Full-scale free-flight store separation trajectories support these results. In full-scale tests the nose of the empty pod collides with the wing of the aircraft when launched from the TER shoulder station at airspeeds below 250 knots and the tail impacts the TER rack when launched from the TER centerline at airspeeds above 450 knots.

OL 70-107

Merritt, D. L.; *"A Wind Tunnel for the Future"*; NAVORD BULLETIN, June 1970. UNCLASSIFIED

ABSTRACT: A new wind tunnel unlike any wind tunnel now in existence is being built at NOL. The new tunnel, called the Hypervelocity Wind Tunnel, will enable scientists to study the flight characteristics of high performance re-entry vehicles for use in the future. The new tunnel is unique in its ability to produce very high Reynolds numbers at high Mach numbers. For the first time, naturally turbulent boundary layers similar to those which occur on re-entry vehicles in flight can be obtained on wind-tunnel models at realistic re-entry Mach numbers. The Hypervelocity Wind Tunnel will use pure nitrogen as the test gas, supplied to the five-foot diameter nozzles at pressures up to 45,000 psi and temperatures up to 4600°F. The maximum running time will be four seconds. The tunnel will go into operation in 1972.

OL 70-108

Werle, M. J., Virginia Polytech. Inst., Shaffer, D. G., and Driftmyer, R. T.; *"Freejet Terminal Shocks"*; AIAA Journal, Vol. 8, #12, pp. 2295-2297, December 1970. UNCLASSIFIED

ABSTRACT: The problem of interest here is that of expanding a two-dimensional gas jet into a quiescent medium. The jets studied are highly underexpanded at their entrance into this medium and subsequently form a classical freejet plume with its attendant barrel and terminal shock waves. The objective of the present study was to provide a suitable means of predicting the terminal shock's position relative to the jet exit plane for jet nozzle Mach numbers equal to or greater than one. Motivation for such an effort has come principally from the field of jet interaction controls where experimental and theoretical studies have indicated that the terminal shock height is a significant scale length. Hence, a definite need exists for a simple model of the two-dimensional freejet.

OL 70-109

Werle, M. J., Virginia Polytech. Inst., Driftmeyer, R. T., and Shaffer, D. G.; *"Jet-Interaction-Induced Separation of Supersonic Turbulent Boundary Layers–The Two-Dimensional Problem"*; AIAA 3rd Fluid and Plasma Dynamics Conference, Los Angeles, Paper #70-765, 29 June-1 July 1970. UNCLASSIFIED

ABSTRACT: An experimental study supporting the development of an analytical model for the title problem is discussed. Extensive flat-plate tests were conducted at a Mach number of four and two Reynolds numbers. Surface pressures were recorded fore and aft of the four, sonic, normal jet slots tested. Shadowgraphs, taken through glass-ported side plates, were made of both the interacting and free-jet plume characteristics. Generalized correlations showed that the entire problem scales directly with the observed shock heights and that these shock heights are predictable from free-jet considerations.

OL 70-110

Werle, M. J., Virginia Polytech. Inst., Shaffer, D. G., and Driftmeyer, R. T.; *"Downstream Pressure Distributions for Two-Dimensional Jet Interactions"*; AIAA Journal, Vol. 8, #6, pp. 1165-1167, June 1970. UNCLASSIFIED

ABSTRACT: The general problem considered here is the use of reaction jets to generate control forces in a supersonic environment. A limited-scope, two-dimensional, experimental study has recently been completed at the Naval Ordnance Laboratory. This study is related to the definition of the controlling parameters for the surface pressure distributions aft of a secondary jet blowing normal to the supersonic mainstream. Only the case for turbulent separation forward of the jet was considered. Numerous authors have hinted that the forces produced downstream of the jet may well be beneficial for control purposes. The only attempt to model this region was by Barnes et al. using a limited amount of experimental data. The NOL study, with additional experimental data, found that the over-all behavior of the pressure distribution was different from that implied by the earlier study.

OL 70-111

Winkler, E. M., Humphrey, R. L., Madden, M. T., and Koenig, J. A.; *"Structure Heating on Cracked Ablative Heat Shields"*; AIAA Journal, Vol. 8, #10, pp. 1895-1896, October 1970. UNCLASSIFIED

ABSTRACT: Ablative materials are used to protect re-entry vehicles from the intense heating during certain

phases of the flight. However, if cracks develop in the heat shield prior to the re-entry, the substructure may be subjected to excessive heating. The ablative behavior of the heat shield may be altered in the vicinity of the cracks which in turn can affect the aerodynamics of the vehicle. The analytical description of the processes is inadequate to allow a safe design of heat shields. A moderate number of studies have been performed on non-ablating, shallow cavities and rectangular notches of various aspect ratios. The present research program was formulated to look into this matter for ablating surfaces in high-speed flow. It was supplemented by independent analytical and experimental studies carried out by the Aeronautical Research Associates of Princeton, Inc.

OL 70-112

Winkler, E. M., Humphrey, R. L., Madden, M. T., and Koenig, J. A.; *"Heating in Cracks on Ablative Heat Shields"*; IES-AIAA Space Simulation Conference, National Bureau of Standards Special Publication 336, p. 853, October 1970. UNCLASSIFIED

ABSTRACT: An experimental program has been carried out in the U.S. Naval Ordnance Laboratory (NOL) 3 Megawatt Arc Tunnel to study the effect of cracks in an ablative heat shield on the substructure heating. The tests used a supersonic contoured nozzle with a Teflon duct attached to it. The ducts had transverse and longitudinal cracks machined into the surface. They were instrumented for pressure, temperature, heat transfer and skin-friction measurements. The cracks were found to have pronounced effects on the ablative behavior. The heating is moderate under a laminar boundary layer, but can be catastrophic when the boundary layer is turbulent, depending upon the size and direction of the crack. The results for the transverse cracks were compared with an available analytical prediction. The heat-transfer measurements tend to support the concept of vortex cells existing within the cracks. Cracks that are deep as compared with their width result in very little substructure heating.

OL 70-113

Winkler, E. M., Madden, M. T., Humphrey, R. L., and Koenig, J. A.; *"Ablation Phenomena in Supersonic Laminar and Turbulent Flows"*; IES-AIAA Space Simulation Conference, National Bureau of Standards Special Publication 336, p. 813, October 1970. UNCLASSIFIED

ABSTRACT: Arc tunnel experiments using pipe specimens of TFE-7 examine the ablation of Teflon under a supersonic laminar and turbulent boundary layer. Test conditions include Mach numbers of 2.3 and 3.0, supply pressures of 2×10^6 N/m^2 to 3×10^6 N/m^2 and supply temperatures of 2200°K to 5000°K. Experimental results are compared with computer predictions. In two laminar boundary-layer tests, parallel striations appear; in all turbulent boundary-layer tests, criss-cross striations appear.

PATENT

(Listed serially by U.S. Patent number and indexed Pat.)

U.S. Patent No. 3,521,492

Fast Response Pressure Gage, by Frank P. Baltakis. UNCLASSIFIED

ABSTRACT: This invention relates to a pressure seal for a fast response pressure gage which prevents pressurization of the sensing element about the periphery without the use of a conventional diaphragm.

TECHNICAL DOCUMENTS ISSUED BY BALLISTICS DEPARTMENT (320)

UNCLASSIFIED DOCUMENTS

NOL Technical Reports

NOLTR 69-152

Application of the Hertz Contact Law to Problems of Impact in Plates, by Jackson Yang and Do Sup Chun. 5 September 1969. 26p. UNCLASSIFIED

ABSTRACT: An experimental and theoretical investigation of transverse impact produced by the collision of strikers with steel square plates with and without covering was performed. The purpose of this report is to determine: (1) the validity of the static treatment of pressure on thin plates for the dynamic cases of intermediate impact velocities, (2) the use of the Hertz law for the contact of an elastic projectile (steel) on elastic (steel), viscoelastic (Adiprene), and plastic (Lexan) bodies, and (3) the use of viscoelastic and plastic materials as shock mitigators.

NOLTR 69-159

A New Approach to the Determination of the Steady-State Inflated Shape and Included Volume of Several Parachute Types, by William Ludtke. 11 September 1969. 73p. UNCLASSIFIED

ABSTRACT: A new approach is presented to obtain the steady-state inflated shape of the gore mainseam and the canopy volume of flat circular, 10 percent extended skirt, elliptical, hemispherical, 16 percent porous ring slot, 24 percent porous ribbon in 12- and 16-gore configurations and cross-type parachutes. The canopies are demonstrated to be closely elliptical in cross section. The axis ratios of the ellipses are derived from photographic coverage of wind-tunnel tests of models of each type of parachute. Wind-tunnel tests were conducted at various velocities from 17 mph to 200 mph using flat parachute models of approximately 40-inch diameter and shaped gore models of approximately 26-inch inflated diameter. Axis ratios, scale factors, and methods of computing the coordinates of the inflated canopy shape are presented. A new approach to the steady-state volume of the parachute, which includes the volume of the billowed gore and an air volume ahead of the skirt hem of the canopy, is given. The results of this investigation are particularly applicable to studies of canopy stress analysis and determination of the volume of air, which must be collected during canopy inflation process for use in the calculation of opening-shock force.

NOLTR 69-213

Medium Strain Rate, Tensile Testing of Selected Plastic Materials, by Frederick Stecher. 10 July 1969. 44p. UNCLASSIFIED

ABSTRACT: Stress-strain relations have been obtained in tension at medium strain rates for selected plastic materials suitable for shock mitigation. Data have been acquired at room temperature for rates of strain between .001 in/in/sec and 1.00 in/in/sec. A conventional high-speed testing machine was used to obtain the data. All of the materials exhibited strain rate sensitivity over the range tested.

NOLTR 69-215

A Theoretical and Experimental Investigation of Snap Loads in Stranded Steel Cables, by Jack Goeller. 26 November 1969. 35p. UNCLASSIFIED

ABSTRACT: During longitudinal oscillation of a cable with a payload supported at the lower end, a severe impact load called snap can be experienced if the cable should go slack. This report presents an analog model and a digital

program for computing snap loads in cables during longitudinal oscillation simulating ocean wave motion. The theory is shown to agree well with experimental tests on stranded steel cable oscillated in water. Schemes for mitigating the snap load are discussed.

NOLTR 70-5

Stability of a Viscous Jet-Newtonian Liquids, by Ralph Phinney and Wayman Humphries. 7 January 1970. 64p. UNCLASSIFIED

ABSTRACT: An experimental investigation of stability is made of laminar viscous jets of a Newtonian fluid. The breakup length is measured by electrical means as a function of fluid properties, together with jet exit velocity and diameter. Nozzles with orifice plate exits, as well as long, cylindrical pipes, were tested. The conditions for the maximum breakup distance were determined, as well as the functional form of the breakup curve before and after the peak. The results are discussed in comparison to the other known sources of data, as well as the theories which are applicable.

NOLTR 70-11

A Study of Hertzian Impact on Glass and Aluminum Hemispherical Shells with Mitigator, by Jackson Yang and James Camper. 5 September 1969. 24p. UNCLASSIFIED

ABSTRACT: In this study, Hertzian impact theory and a solution published by E. Reissner for an unrestrained shallow spherical shell are used to find total stress on the inner surface of a hemispherical shell covered by a viscoelastic mitigator. From data obtained by experimental means and published references, it is concluded that Hertzian impact theory is valid for certain type shells as well as solid bodies and that a mitigator will effectively reduce stresses in an impacted shell.

NOLTR 70-38

Analytical and Experimental Study of the Dynamic Response of Cable Systems, by Jack Goeller. 23 February 1970. 47p. UNCLASSIFIED

ABSTRACT: The dynamic response of steel and nylon cables with a suspended payload in water was investigated analytically and experimentally. Ocean wave motion was simulated at the top of the cables by a sinusoidal displacement function. A generalized distributed mass analytical model including internal and external damping was used to predict cable tone. Experimental results on cables of the order of 70 feet in length and .25 inch diameter compared well with theoretical predictions.

NOLTR 70-41

Computer Program for a Monobloc, Hollow, Closed-end Cylinder Subjected to Internal Pressure, by Victor Dawson. 27 February 1970. 41p. UNCLASSIFIED

ABSTRACT: This report describes a computer program written in BASIC language which calculates the stresses and strains in a monobloc, hollow, closed-end cylinder subjected to internal pressure. Examples of typical calculations are given, including, among others, conditions that cause autofrettage and reverse yielding.

NOLTR 70-49

An Investigation of the Effect of Flexible Trailing Wire on a Hypervelocity Cone, by Norman Sheetz and Maigonis Krumins. 11 March 1970. 58p. UNCLASSIFIED

ABSTRACT: A program to investigate the effect of a flexible trailing wire on the aerodynamic characteristics of a cone at very high Mach numbers is described. This experimental program was conducted in the 1000-foot Hyperballistics Range at the U.S. Naval Ordnance Laboratory. The development of the technique for launching a conical configuration which has a small-diameter flexible wire attached to its base is described in detail. The effect of this appendage on the drag coefficient and the stability of the cone is presented. Also, the radar cross section of a cone with and without the trailing wire is compared.

NOLTR 70-135

Fatigue of Thick-Walled, High Pressure Cylinders, by Victor Dawson and Jack Goeller. 1 June 1970. 23p. UNCLASSIFIED

ABSTRACT: This report contains the results of a study to develop a theoretical approach whereby uniaxial fatigue data can be used to predict the permissible number of cycles of a thick-walled cylinder. Experimental data from the literature were examined on open end and closed end cylinders in an autofrettaged and non-autofrettaged condition with wall ratios from 1.2 to 2.0. Distortion energy was used to reduce the triaxial stress state to an equivalent uniaxial stress. A new method was then developed whereby the number of cycles could be predicted as a function of the mean and alternating pressure.

NOLTR 70-141

Comparison of Mechanical and Acoustic Properties for Selected Nonferrous, Ferrous, and Plastic Materials, by Stuart Hanlein, William Hinckley, and Frederick Stecher. 1 July 1970. 110p. UNCLASSIFIED

ABSTRACT: Mechanical and acoustic properties have been tabulated for 356 nonferrous, 173 ferrous, and 67 plastic materials. These properties include density, Young's modulus of elasticity, ultimate tensile strength, yield strength, strength-to-density ratio, elastic sound speed, and acoustic impedance. The tabulation was accomplished by means of a computer program. The limited number of materials and material properties presented allows the user to make an initial selection. Further information on similar materials should be obtained from other sources.

NOLTR 70-174

The Performance of Small Arms Ammunition When Fired Into Water, by Barry Noonan and Howard Steves. 8 September 1969. 23p. UNCLASSIFIED

ABSTRACT: Standard small arms ammunition was tested by firing into water from air. The test results show this ammunition to be relatively ineffective in water, having a lethal slant range of 1.5 feet. By proper design of the projectile, staying within the restrictions for standard ammunition, the lethal slant range can be increased to about 8 feet.

NOLTR 70-202

Protective Eye Shield Against Small Fragments, by Robert Hassett, Stuart Hanlein, Jack Goeller. 1 June 1970. 21p. UNCLASSIFIED

ABSTRACT: Casualty reports from Southeast Asia indicate a need for a small fragment protective eye shield which will not interfere with the normal duties of the user. Commercially available eye goggles which are in accordance with Federal Specification FSN 4240-052-3776 were evaluated and found to provide inadequate ballistic protection. A polycarbonate eye shield which can be easily attached to the M-1 steel helmet was designed and found acceptable in evaluation reports from Vietnam. Ballistic data on the shield and construction details are given in this report.

NOLTR 70-217

In-Flight Observation of Ablation/Erosion at Hypersonic Velocities in a Ballistics Range, by John Lankford. 23 November 1970. 48p. UNCLASSIFIED

ABSTRACT: This report summarizes techniques and instrumentation applied to a hypervelocity ballistics range for the observation of ablation/erosion and model shape change during hypersonic flight. Methods are outlined for highly controlled water injection for rain erosion and liquid impact studies.

OPEN LITERATURE

(Identified by OL numbers for indexing purposes)

OL 70-114

Abelson, H. I.; *"Pressure Measurements in the Water-Entry Cavity"*; Journal of Fluid Mechanics, Vol. 44, Part 1, pp. 129-144, 1970. UNCLASSIFIED

ABSTRACT: Significant experimental results from a study of pressure in the water-entry cavity are presented. Projectiles were fired into water at velocities up to 250 ft./sec and entry angles of 90°, 60°, and 45°. Pressure data obtained using underwater probes were correlated with high-speed motion pictures taken of the entries. Results indicate that the cavity pressure drop prior to surface closure is an order of magnitude greater than previously assumed. As the entry angle is decreased from 90°, the pressure drop decreases. The minimum cavity pressure decreases linearly with increasing entry velocity over the test range. As the entry angle is increased, the minimum entry velocity required to produce a measurable pressure drop becomes greater. An improved pressure-volume correlation is obtained if the volume enclosed by the cavity walls is corrected to account for re-entrant jet volume and air volume enclosed by the splash walls. Cavity pressure during the closed cavity phase behaves approximately according to the isentropic pressure-volume relation. Pressure drop and history are strongly dependent on projectile nose geometry. No appreciable cavity pressure gradient, axial or transverse, was found to exist. Deep closure or cavity collapse is accompanied by relatively high-pressure pulses.

OL 70-115

Lankford, J. L.; *"Application of Laser and Flash X-ray Techniques in Hypervelocity Ablation-Erosion Investigations in a Hyperballistics Range"*; Proceedings of 9th International Congress on High-Speed Photography, Denver, Colorado, 2-7 August 1970. UNCLASSIFIED

ABSTRACT: Conventional capacitor-spark light sources combined with shadowgraph or schlieren optical systems have proved inadequate to cope with the demand for sharp, unblurred photographs of models in hyperballistic flight simulation. For this reason, during the last few years feasibility studies have been carried out to develop giant-pulse laser techniques suitable to the study of hypersonic missile flight, ablation, erosion and related phenomena. A successful combination proved to be the use of laser frontlighting, shadowgraph and silhouette techniques, in conjunction with flash x-ray photography, which permitted the detection of surface profile changes of only a few mils in contour. Previously unrevealed characteristics of the mechanisms of tip melting and hypervelocity particle impact have also been observed and recorded.

OL 70-116

May, A.; *"Review of Water-Entry Theory and Data"*; Journal of Hydronautics, Vol. 4, #4, pp. 140-142, October 1970. UNCLASSIFIED

ABSTRACT: Water-entry problem areas include the impact force system, cavity growth and decay, and missile trajectory. Instrumentation suitable for measurement of impact deceleration has been developed, and is in use in current research. This includes studies for the development of scaling laws applicable to entries for which weight, buoyancy, and friction drag must be considered. Whip research is scant and the scaling of whip is not yet possible. Some

research has been done on cavity shape and history, and on the pressure within the water-entry cavity. Design criteria for satisfactory water-entry stability and trajectory have seen little improvement.

OL 70-117

Sallet, D. W.; *"A Method of Stabilizing Cylinders in Fluid Flow"*; Journal of Hydronautics, Vol. 4, #1, pp. 40-45, January 1970. UNCLASSIFIED

ABSTRACT: The flutter motions which may occur when partly restrained circular cylinders are brought into uniform flow may be prevented by the installation of a splitter plate. The stabilizing principle of such a plate is explained and the optimum plate dimensions are discussed.

OL 70-118

Yang, J. C. S. and Seigel, A. E.; *"Stress Waves in Multilayered Cylinders and Conical Frustrums"*; Shock and Vibration Bulletin, Bulletin 40, Part 4, December 1969. UNCLASSIFIED

ABSTRACT: The purpose of this paper is to report on an investigation of the spallation problem of multilayered conical structures by analyzing the propagation of elastic stress waves in multilayered cylinders and conical frustrums using the method of characteristics. Two approaches were utilized in the analysis of the propagation of elastic stress waves. The conical frustrum was first analyzed as a multilayered cylinder with step changes in area and varying impedances and then a numerical method was utilized to solve the characteristic equation as the area of the conical frustrum is changing continuously. Both approaches were effected by use of electronic computer programs. The programs were verified as being correct and functioning properly by a comparison with experimental strain-time results in truncated cones impacted by spheres observed by V. Kenner and W. Goldsmith.

PATENTS

(Listed serially by U.S. Patent numbers and indexed Pat.)

U.S. Patent No. 3,499,311

Omnidirectional Blast Wave Sensor, by John L. Lankford, Arnold E. Seigel, and Robert E. Wilson. UNCLASSIFIED

ABSTRACT: This invention relates to an aerodynamic sensor which is applicable to the measurement of static pressure behind weak blast waves.

U.S. Patent No. 3,499,325

Atmospheric Determining Apparatus, by George J. Sloan, Jr. UNCLASSIFIED

ABSTRACT: This invention provides a density sensing system for sensing atmospheric density at altitudes from 100,000 to 300,000 feet.

U.S. Patent No. 3,514,058

Self-inflating Retardation and Floatation Device, by George J. Sloan, Jr. and William P. Ludtke. UNCLASSIFIED

ABSTRACT: This invention relates to a recovery device for a high altitude instrument canister which provides sufficient retardation to prevent damage on water entry and floatation for several days.

TECHNICAL DOCUMENTS ISSUED BY MATHEMATICS DEPARTMENT (330)

UNCLASSIFIED DOCUMENTS

NOL Technical Reports

NOLTR 70-22

Feasibility Study for Missile Tracking from Shock Recordings, by David E. Olive and Edward Malmgren. 30 June 1970. 49p. UNCLASSIFIED

ABSTRACT: In this report it is assumed that a high-speed object generates a shock wave which is a right circular cone, and that the arrival time of the shock wave is obtained at various microphones. Arrival times are first calculated for a prescribed flight path, and then random errors are superimposed on the computer times to simulate experimental data. The speed and line of flight of the object are then determined from these data containing errors by using the method presented in NOLTR 68-33. This is done with a few different arrangements of the microphones. The errors in the calculated flight parameters are studied as a function of the errors that were introduced into the data. The calculation procedure is considered to be a feasible one to use in practice if satisfactory calculated results are obtained in spite of errors of an expected magnitude in the simulated data.

NOLTR 70-131

Supersonic Nozzle Design, by Stuart Brodsky. 22 September 1970. 22p. UNCLASSIFIED

ABSTRACT: This paper is concerned with a method of finite differences for determining two-dimensional and axisymmetric supersonic nozzle contours. The approach taken is to specify a Mach number or velocity array along the entire centerline of the nozzle and then to integrate the equations numerically to obtain the desired nozzle shape. In spite of the fact that the original problem is not "well posed" in the subsonic region, reasonable results were found provided the Mach number gradient was not too steep in a neighborhood of the sonic line.

OPEN LITERATURE

(Identified by OL numbers for indexing purposes)

OL 70-119

Gleyzal, A.; *"Absolute Newtonian Coordinate Calculus"*; Notices of the American Mathematical Society, Vol. 17, #4, p. 668, June 1970. UNCLASSIFIED

ABSTRACT: Let $ds^2 = z_{iA\,jA}\,dz^{iA}\,dz^{jA}$ and $d\sigma = u^S_{NiA}\,dz^{iA}$, summed on repeated indices iA, jA, etc., be two fundamental invariant forms of a curved Newtonian space-time N. Let $z^{iA} = z^{iA}(z^{\alpha B})$, $z^{4A} = z^{4B} = t$ = time express the class of all Newtonian transformations, where $\alpha A = 1, \ldots, 4$; $iA = 1, \ldots, 3$; and the symbols A, B, C, . . ., Z denote arbitrary coordinate systems. Let S be motionless, let $u^A_B = u^{A\,iA}_B = z^{iA}_{4B} = z^{iA}_{4B} = \partial z^{iA}/\partial z^{4B}$, and let $u^{A\,iC}_B = u^{A\,iA}_B z^{iC}_{iA}$, where $z^{iC}_{iA} = z^{iC}_{,iA} = \partial z^{iC}/\partial z^{iA}$. Then $u^A_B + u^B_C = u^A_C$. This is the addition law of relative velocities, where the vector u^A_B is the velocity of B relative to A. Consider a tensor expression $\lambda^{\cdots}_{\cdots} = \lambda^{iA\ldots iB\,;\,iE\ldots iF\,;\,4I\ldots 4J}_{iC\ldots iD\,;\,iG\ldots iH\,;\,4K\ldots 4L}$,

where $\lambda^{\cdots\cdots}_{\cdots iN\cdots} = \lambda^{\cdots\cdots}_{\cdots iM\cdots} z^{iM}_{iN}$. For a vector λ^{iA} for example: $\lambda^{iA}_{4B} = \lambda^{iA}_{4A} + \lambda^{iA}_{jA} u^{AjA}_{B}$, $\lambda^{iA}_{jA} = \lambda^{iA}_{,jA}$, $\lambda^{iA}_{4A} = \lambda^{iA}_{,4A} + \lambda^{jA} u^{SiA}_{AjA} = \lambda^{iA}_{4A} + \lambda^{jA}(u^{SiA}_{A,jA} + u^{SkA}_{A} \Gamma^{iA}_{kAjA})$, and $\lambda^{iA}_{4C} = \lambda^{iA}_{4B} + \lambda^{iA}_{jA} u^{BjA}_{C}$. The "Christoffel time connection" is thus $\Gamma^{SiA}_{A.jA} = u^{SiA}_{AjA}$ and is not a tensor due to the presence of three A's, although u^{SiB}_{AiC} is a tensor. General tensor time derivatives of $\lambda^{\cdots}_{\cdots}$ are similarly defined with $\Gamma^{SiA}_{A.jA}$ or $\Gamma^{S.jA}_{AiA}$ The acceleration vector of B relative to A is $\eta^{AiC}_{B} = u^{AiC}_{B4B}$, in coordinates of C. Field equations and machine programs may thus be unified for all flow problems.

OL 70-120

Heiche, G., and Mason, E. A., Brown Univ.; *"Ion Mobilities With Charge Exchange"*; Journal of Chemical Physics, Vol. 53, #12, pp. 4687-4696, 15 December 1970.

UNCLASSIFIED

ABSTRACT: Quantum-mechanical calculations are presented for various elastic cross sections that describe the motion of atomic ions through their parent gases; the effects of nuclear spin are included. The cross sections are linear in the gerade-ungerade pairs of molecular states. An exact relation between the diffusion and charge-exchange cross sections is derived. Detailed calculations are given for the total, charge-exchange, and first three transport cross sections over the energy range of about 10^{-6}–10 eV, for potentials and masses corresponding to He^+ in He, and Cs^+ in Cs. The cross sections exhibit structure due to orbiting resonances and glory interferences, but the ion mobility depends smoothly on temperature. The semi-classical, impact-parameter, random-phase, and polarization approximations are tested and found to be surprisingly accurate, apart from the quantum-mechanical structure.

OL 70-121

Reid, W. P.; *"Acoustic Tracking of Supersonic Objects"*; AIAA Journal, Vol. 8, #5, pp. 973-974, May 1970.

UNCLASSIFIED

ABSTRACT: In this Note equations are developed for determining the location, speed, and direction of motion of an object traveling faster than the speed of sound from the times at which the shock wave arrives at some microphones.