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# Bibliography of Dr. Chul Park

Lawrence A. Gochberg, Ethiraj Venkatapathy, and Chul Park

May 1995




National Aeronautics and
Space Administration

NASA Technical Memorandum 110353

# Bibliography of Dr. Chul Park

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Ethiraj Venkatapathy, Thermosciences Institute, Eloret, Sunnyvale, California
Chul Park, Ames Research Center, Moffett Field, California

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Space Administration

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TABLE OF CONTENTS

# Dedication

This document was created to honor the occasion of Dr. Chul Park's retirement after 27 years of distinguished government service at the NASA Ames Research Center. We, as his colleagues in the Reacting Flow Environments Branch, feel honored to have been associated with him. Our wishes are for him to continue to be the great educator, researcher, leader and inventor in all his future endeavors.

December 14, 1994

Abstract

The contents of this bibliography of Dr. Chul Park were compiled primarily from the NASA RECON data base. The RECON citations have been modified to appear in a uniform format with all other citations. These other citations were located by computer searches in the INSPEC, NTIS, COMPENDEX, and Chemical Abstracts data bases, as well as through the cooperation of Dr. Chul Park, and his associates in the Reacting Flow Environments Branch at NASA Ames Research Center. All citations are presented in an approximate reverse chronological order from the present, according to the date of publication.

The following describes each line item entry in the forthcoming citations:

| | |
|---|---|
| Title: | Title of the paper, article, or report. |
| Author: | Names of the author and co-author(s). |
| Corp: | Corporate source; the organization(s) for whom the author(s) were working at the time of publication. |
| Source: | Source of the publication, i.e. conference name, journal name, or report series name. |
| Sponsor: | Sponsoring organization for the publication. |
| Doc. Type: | Conference paper, journal article or report. |
| Major Term: | Primary topics of the document using subject terms from the NASA Thesaurus (from NASA RECON citation when possible, otherwise, determined by the authors of this bibliography). |
| Minor Term: | Secondary topics of the document using subject terms from the NASA Thesaurus (from NASA RECON citation when possible, otherwise, determined by the authors of this bibliography). For documents earlier than 1968, NASA RECON uses only Major Terms, therefore are no Minor Terms denoted. |
| Abstract: | Paper abstract (edited if author abstract is not available). |

We have, to the best of our abilities, tried to present a complete record of Dr. Park's publication accomplishments. If any of Dr. Park's publications are not listed in the 180 citations in this document, we would appreciate hearing about it to update our records.

Lawrence A. Gochberg
December 14, 1994

## Biography of Dr. Chul Park

Chul Park recently retired from the NASA Ames Research Center, where he worked as a Staff Scientist in the Reacting Flow Environments Branch (formerly the Aerothermodynamics Branch). He joined Ames Research Center in 1964, beginning with a three year position as a National Research Council Post-Doctoral Research Associate. His pioneering works include conception and design of aeroassisted transfer vehicles, for which he holds a patent, study of radiation and radiative transport in air not in thermodynamic equilibrium, environmental impact of the Space Shuttle on the ozone layer, and an impact of meteor penetration of the Earth's atmosphere. He is the author of a book entitled Nonequilibrium Aerothermodynamics, and authored or co-authored over 180 articles and reports in scientific conferences and journals. Chul Park received a B.S. (1957) and M.S. (1960) in Aeronautical Engineering from Seoul University, Seoul, Korea, served briefly as an Instructor of Aeronautics at the Korean Air Force Academy, Seoul, Korea, and received his Ph.D. (1964) in Aeronautics (hypersonics) from Imperial College of Science and Technology, London, England. He is currently a Professor on the Faculty of Engineering in the Department of Aeronautics and Space Engineering at Tohoku University, Sendai, Japan.

Citations

1) Title: Conceptual study of a bent-biconic single-stage-to-orbit vehicle
Author: Park, Chul; Menees, Gene P.; Bowles, Jeffrey V.; Lawrence, Scott L.; Davies, Carol B.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Sterling Software, Palo Alto, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 33rd, Reno, NV; January 9-12, 1995, AIAA Paper 95-0716, 10 p.
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*HORIZONTAL SPACECRAFT LANDING /*SINGLE STAGE TO ORBIT VEHICLES/*TRIPROPELLANTS /*VERTICAL TAKEOFF
Minor Term: / AERODYNAMICS/ DELTA WINGS/ TRAJECTORY PLANNING
Abstract: A new design concept is proposed for an all-propulsive, vertical-take-off, horizontal-landing, reusable single-stage-to-orbit space transportation system. The vehicle is to carry a unmanned payload of 11 tons to a 400 km orbit inclined at 51 degrees. It is shaped in a bent-biconic geometry, has no wings but horizontal and vertical stabilizers, and relies on a para-wing for landing. Its tripropellant propulsion system uses both RP1-LOX and LH2-LOX. The vehicle is sized and the weights of its components are estimated using an existing methodology. The ascent and entry flight scenarios are calculated, and their features are compared with those of the NASA baseline design. The new design is found to be competitive with the existing design in its performance. Potential advantages of the new design are discussed. 12 Refs.

2) Title: Feasibility study of the laboratory simulation of rocket engines in flight
Author: Bogdanoff, David W.; Park, Chul
Corp: Thermosciences Institute, Sunnyvale, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 33rd, Reno, NV; January 9-12, 1995, AIAA Paper 95-0715, 11 p.
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*BASE HEATING/*DAMKOHLER NUMBER/*HIGH PRESSURE /*ROCKET ENGINES/*ROCKET TEST FACILITIES
Minor Term: / FEASIBILITY ANALYSIS/ SINGLE STAGE TO ORBIT VEHICLES
Abstract: This paper examines the feasibility of producing a model rocket engine for incorporation into a sub-scale rocket vehicle to be tested in a ground-based laboratory for the purpose of studying the base flow heating phenomenon. Since the base heating phenomenon is dictated mostly by the afterburning of the effluent from the engines and since its extent is controlled by the Damkohler number of the process, the model engine must operate at a pressure about 100 times higher than the flight value for a true simulation. Five possible schemes for producing such a small rocket engine are examined and the electrical arc-heating and piston-compression techniques are found to be able to produce the highest chamber pressures and Damkohler numbers. The Damkohler number values of 12-29 percent of those in flight can be produced by these schemes, with limitations due to the strength of materials. The paper presents reasons why other schemes cannot produce the same results. 33 Refs.

3) Title: Spectroscopic determination of enthalpy in an arc-jet wind tunnel
Author: Babikian, Dikran S.; Park, Chul; Raiche, George A.
Corp: Thermosciences Institute, Sunnyvale, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA; Hamilton College, Clinton, NY, USA
Source: AIAA, Aerospace Sciences Meeting, 33rd, Reno, NV; January 9-12, 1995, AIAA Paper 95-0712, 11 p.
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ATOMIC SPECTRA/*HYPERVELOCITY WIND TUNNELS /*NITRIC OXIDE/*NITROGEN/*OXYGEN /*NONEQUILIBRIUM RADIATION/*THERMAL RADIATION /*SPECTRA/*SPECTROSCOPIC ANALYSIS/*SPECTROSCOPY /*WIND TUNNEL TESTS
Minor Term: / ARC HEATING/ ENTHALPY/ IONIZATION/ SHOCK LAYER / STAGNATION PRESSURE
Abstract: The enthalpy of the flow produced in an arc-jet wind tunnel was determined from spectroscopic measurement of radiation emitted by the shock layer over a flat plate model of 15 cm diameter placed in the test section. Spectral radiation emanating from various distances from the surface of the model was observed from the direction normal to the flow at stagnation pressures of 0.028 and 0.01 atm. The main features of the observed spectra were (1) N2+ First Negative System, (2) NO band systems, and (3) the atomic nitrogen and oxygen lines. For the high pressure run, the ratios among the intensities of the three radiation mechanisms remained approximately constant over a distance of 12 to 18 mm from the model surface, while it varied for the low pressure case. Assuming that equilibrium prevailed in that region for the high pressure case, enthalpy of the gas is deduced from the ratio of the observed intensities of atomic nitrogen lines to those of the bands of N2+ and NO. A one-dimensional nonequilibrium code predicted the occurrence of the observed equilibrium region. 23 Refs.

4) Title: Measurement and analysis of nitric oxide radiation in an arcjet flow
Author: Babikian, D. S.; Gopaul, N. K. J. M.; Park, C.
Corp: Eloret Institute, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Thermophysics and Heat Transfer (ISSN: 0887-8722), vol. 8, no. 4, October-December 1994, p. 737-743. (see also AIAA, Thermophysics Conference, 28th, Orlando, FL, July 6-9, 1993, AIAA Paper 93-2800, 8 p. (see A93-46540))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROTHERMODYNAMICS/*ARC JET ENGINES /*HYPERVELOCITY WIND TUNNELS/*NITRIC OXIDE /*THERMAL RADIATION/*WIND TUNNEL TESTS
Minor Term: / ENTHALPY/ HEAT SHIELDING / NONEQUILIBRIUM THERMODYNAMICS/ REENTRY / VIBRATIONAL SPECTRA
Abstract: Radiation from the nitric oxide (NO) band systems emitted by the flow in the test section of a 20-MW arcjet wind tunnel was measured and compared with the computed values for the purpose of testing the validity of an existing thermochemical model. The settling chamber pressure and enthalpy were 2.4 atm and 28 ± 10 MJ/kg, respectively. The measurements were made using photographic films in the wavelength region from 225 to 305 nm. Of the four band systems of NO (beta, gamma, delta, and episilon), vibrational transitions were observed from only the upper v' = 0 levels. Excitation temperatures were deduced by comparing the experimental spectrum with those calculated using the nonequilibrium radiation code, NEQAIR. The rotational, vibrational, and electronic excitation temperatures deduced from the data were Tr = 560 ± 50 K, Tv = 950 ± 50 K, and Tex = 11,500 ± 520 K, respectively. A multitemperature nonequilibrium nozzle flow code, NOZNT was used to calculate the nozzle flow. The calculated temperatures were Tr = 560 K, Tv = 950 K, and Te = 6100 K, respectively at 30 MJ/kg. The presented results show that by using the centerline enthalpy value deduced from heat transfer measurements and the NOZNT code, one can predict the freestream conditions in the arcjet wind-tunnel flow fairly well. 28 Refs.

5) Title: Spectral measurements in the arc column of an arc-jet wind tunnel

Author: Terrazas-Salinas, Imelda; Park, Chul; Strawa, Anthony, W.; Gopaul, Nigel K. J. M.; Tanuk, Jaswinder S.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Thermosciences Institute, Sunnyvale, CA, USA

Source: AIAA, Aerospace Ground Testing Conference, 18th, Colorado Springs, CO, June 20-23, 1994, AIAA Paper 94-2595, 18 p.

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ATOMIC SPECTRA/*HYPERVELOCITY WIND TUNNELS /*NITROGEN/*OXYGEN/*NONEQUILIBRIUM RADIATION /*THERMAL RADIATION/*SPECTRA/*SPECTROSCOPIC ANALYSIS /*SPECTROSCOPY/*WIND TUNNEL TESTS

Minor Term: / ARC HEATING/ ENTHALPY/ GAS TEMPERATURE / HEAT TRANSFER/ IONIZATION/ VIBRATIONAL SPECTRA

Abstract: The spectral characteristics of the radiation emanating from the flow in the arc column of an arc-jet wind tunnel at NASA's Ames Research Center were measured. The measurements were made using a 0.3 m McPherson spectrograph in the wavelength region of 350 to 900 nm. Nitrogen and oxygen lines and continua were observed and analyzed to determine the average temperature of the gas in the arc column at 2 locations under 4 different operating conditions. Comparison between the experimentally-determined average temperatures and those obtained by synthesized spectra based on gas temperature distribution calculated by a computer code show good agreement. Spectral characteristics are generally predicted well and the relative heating rates between upstream and downstream locations agree with those predicted by the code. The measured relative intensities of radiation between upstream and downstream ends agree approximately with the bulk heat transfer measurements of other investigators. 27 Refs.

6) Title: Options for upgrade of the Ames 16-inch shock tunnel
Author: Bogdanoff, David W.; Wilson, Gregory J.; Park, Chul
Corp: Eloret Institute, Sunnyvale, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 32nd, Reno, NV, January 10-13, 1994, AIAA Paper 94-0545, 14 p.
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*GAS HEATING/*SHOCK TUNNELS/*UPGRADING /*WIND TUNNEL DRIVES/*WIND TUNNEL TESTS
Minor Term: / DATA ACQUISITION/ ENTHALPY/ FLIGHT CONDITIONS / PRESSURE/ SCRAMJET ENGINES/ SCRAMJETS
Abstract: There is a need for large ground test high-enthalpy impulse facilities with greater enthalpy and pressure capabilities. Such facilities are required for more faithful duplication of flight conditions for scramjet combustors, aerospace planes and planetary entry vehicles. In this connection, various options for modifying and upgrading the 16-Inch Combustion-Driven Shock Tunnel existing at NASA Ames Research Center are examined. The options are: (1) operational procedure changes with the current combustion driver or heating of the driver gas with an electrical heater to increase the driver pressure, (2) tapering the driven section to increase test gas pressure and enthalpy, (3) operating as a non-reflecting shock tunnel, and (4) operating as an expansion tube. These options can be applied to the facility singly or in combination. The conditions in the driven section are calculated using the equilibrium relations with empirical loss corrections. The expanding flows in the nozzle of the shock tunnel and in the acceleration section of the expansion tube are calculated using a one-dimensional finite-rate computer code. The thermodynamic conditions at the entrance of a combustor are calculated for two applications: a direct-connect configuration and a diffuser inlet undergoing a two-step oblique shock compression. The calculated conditions are shown to be close to the nominal flight conditions for typical scramjet engine conditions. 24 Refs.

7) Title: Review of chemical-kinetic problems of future NASA missions, II: Mars entries

Author: Park, Chul; Howe, John T.; Jaffe, Richard L.; Candler, Graham V.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN: 0887-8722), vol. 8, no. 1, January-March 1994, p. 9-23 (see also AIAA, Aerospace Sciences Meeting, 29th, Reno, NV, January 7-10, 1991, AIAA Paper 91-0464, 31 p. (see A91-21500))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROTHERMOCHEMISTRY/*ATMOSPHERIC ENTRY /*NONEQUILIBRIUM CONDITIONS/*REACTION KINETICS /*REENTRY VEHICLES/*SHOCK LAYERS/*SHOCK WAVES /*THERMOCHEMISTRY/*THERMODYNAMIC EQUILIBRIUM

Minor Term: / AXISYMMETRIC FLOW/ BLUNT BODIES/ DAMKOHLER NUMBER / HEAT FLUX/ IONIZATION COEFFICIENTS / MOLECULAR OSCILLATIONS/ MOLECULAR RELAXATION / RADIATIVE HEAT TRANSFER/ STAGNATION POINT / THERMODYNAMIC PROPERTIES

Abstract: The present work aims to derive a set of thermomechanical relaxation rate parameters and chemical reaction rate coefficients relevant to future interplanetary missions. It also attempts to assess the impact of thermochemical nonequilibrium phenomena on radiative heating rates for the stagnation point of the Martian entry vehicle. 61 Refs.

8) Title: Design and analysis of an ellipsoid-paraboloid aerobrake for GEO satellite retrieval

Author: Venkatapathy, Ethiraj; Park, Chul

Corp: Eloret Institute, Sunnyvale, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 32rd, Reno, NV, January 10-13, 1994, AIAA Paper 94-0035, 11 p.

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*AEROBRAKING/*AEROTHERMODYNAMICS /*BLUNT BODIES/*GEOSYNCHRONOUS ORBITS /*REENTRY VEHICLES

Minor Term: / CONVECTIVE HEAT TRANSFER / CRYOGENIC ROCKET PROPELLANTS / RADIATIVE HEAT TRANSFER/ REENTRY TRAJECTORIES / SATELLITE CAPTURE

Abstract: A new scheme for an aeroassisted space transportation vehicle (ASTV) is proposed for retrieval of geosynchronous-earth-orbit (GEO) satellites using an aerobrake of the shape of an ellipsoid-paraboloid. The vehicle, equipped with a yet-to-be-developed small cryogenic engine, is to be placed in the GEO or geotransfer orbit (GTO) using an existing expendable launcher such as Delta, Atlas, or Titan. It will then retrieve a satellite, deploy a flexible aerobrake, enter the atmosphere, and land by a parafoil. The geometry of the aerobrake is generated by rotating a fourth-order polynomial of variable coefficients around the longitudinal axis. The flow field over this geometry is calculated under an ideal gas assumption with a gamma value of 1.15. From the solutions, the drag coefficient and lift-to-drag ratio for this geometry are determined to be 0.41 and 0.3, respectively, at zero angle of attack. Typical trajectories of atmospheric entry flights of such a vehicle, and its dynamic and heat transfer characteristics at each trajectory point, are calculated. The peak value of the sum of the convective and radiative heat transfer rates is below 8 W/cm-2, while the peak deceleration is about minus 6 g. 16 Refs.

9) Title: Calculation of real-gas effects on airfoil aerodynamic characteristics
Author: Park, Chul; Yoon, Seokkwan
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; MCAT Institute, Moffett Field, CA, USA
Source: Journal of Thermophysics and Heat Transfer (ISSN: 0887-8722), vol. 7, no. 4, October-December 1993, p. 727-729. (see A94-60436 and A93-54477, see also AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990, AIAA Paper 90-1712, 9 p. (see A90-38414))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AERODYNAMIC COEFFICIENTS/*AIRFOILS/*ELLIPSES /*NONEQUILIBRIUM CONDITIONS/*REAL GASES /*THERMOCHEMICAL PROPERTIES
Minor Term: / ANGLE OF ATTACK/ COMPUTATION/ FLIGHT ALTITUDE / NATIONAL AEROSPACE PLANE PROGRAM / SPACE SHUTTLE MISSIONS
Abstract: The effects of high temperature thermochemical phenomena on the aerodynamic characteristics at hypersonic speeds are calculated for two-dimensional airfoils in air. The calculations are performed on an airfoil similar to that used for the Space Shuttle Orbiter, and ellipses of thickness ratios varying between 5 and 15 percent. For the airfoil, one light condition is considered. For the ellipses, the calculations are carried out over a range of chord lengths, flight velocities, flight altitudes, and angles of attack. It is shown that the lift and drag coefficients are consistently reduced by the thermochemical phenomena, and that the behavior can be represented by a specific heat ratio value less than 1.4. The center of pressure shifts forward due to the thermochemical phenomena, but its extent is sensitively affected by the geometry and angle of attack and cannot be represented by a fixed specific heat ratio. The calculated results are in qualitative agreement with the data obtained during the entry flights of the Space Shuttle vehicle. 4 Refs. (edited)

10) Title: Measured and calculated spectral radiation from a blunt body shock layer in an arc-jet wind tunnel

Author: Babikian, Dikran S.; Palumbo, Giuseppe; Craig, Roger A.; Park, Chul; Palmer, Grant; Sharma, Surendra P.

Corp: Eloret Institute, Palo Alto, CA, USA; MCAT Institute, Moffett Field, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 32nd, Reno, NV, January 10-13, 1994, AIAA Paper 94-0086, 10 p. (see N95-13720); In MCAT Institute, Planetary Entry Experiments, 10 p. (see N95-13717)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ATMOSPHERIC ENTRY/*ATOMIC SPECTRA /*NONEQUILIBRIUM RADIATION/*SHOCK LAYERS/*SPECTRA /*WIND TUNNEL TESTS

Minor Term: / ARC HEATING/ ARGON/ BLUNT BODIES / CONTINUUM MODELING/ IONIZATION/ NITROGEN/ OXYGEN / STAGNATION POINT

Abstract: Spectra of the shock layer radiation incident on the stagnation point of a blunt body placed in an arc-jet wind tunnel were measured over the wavelength range from 600 nm to 880 nm. The test gas was a mixture of 80 percent air and 20 percent argon by mass, and the run was made in a highly nonequilibrium environment. The observed spectra contained contributions from atomic lines of nitrogen, oxygen, and argon, of bound-free and free-free continua, and band systems of N2 and N2(+). The measured spectra were compared with the synthetic spectra, which were obtained through four steps: the calculation of the arc-heater characteristics, of the nozzle flow, of the blunt-body flow, and the nonequilibrium radiation processes. The results show that the atomic lines are predicted approximately correctly, but all other sources are underpredicted by orders of magnitude. A possible explanation for the discrepancy is presented. 22 Refs.

11) Title: Modeling of hypersonic reacting flows
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Advances in hypersonics, vol. 2 - modeling hypersonic flows (ISBN 0-8176-3663-3, see A94-10759), Birkhaeuser, Boston, MA, 1992, p. 104-127. (see A94-10763, see also University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, January 16-20, 1989, 30 p. (see A89-33631))
Sponsor: Birkhaeuser, Boston, MA, USA
Doc. Type: Book Article, Short Course
Major Term: /*AERODYNAMIC HEAT TRANSFER/*HYPERSONIC FLOW /*HYPERSONIC VEHICLES/*NONEQUILIBRIUM THERMODYNAMICS /*REACTING FLOW
Minor Term: / AERODYNAMIC CHARACTERISTICS/ ANGLE OF ATTACK / CONVECTIVE HEAT TRANSFER/ PITCHING MOMENTS
Abstract: The effect of nonequilibrium thermochemical processes on the aerodynamic and heat transfer characteristics of a hypersonic vehicle is illustrated with examples. It is shown that the conventional method of predicting chemical reactions always predict that the flow is closer to equilibrium than it actually is, leading to incorrect predictions of aerodynamic characteristics of a vehicle. A method is presented for predicting chemical processes using a two-temperature kinetic model, which is developed on the basis of combining conservation equations for vibrational energy and for electron electronic energy, which are also derived. The validity of the two-temperature model is proven using two types of experimental data: radiation and shock shapes.
22 Refs.

12) Title: Validation of multi-temperature nozzle flow code NOZNT
Author: Park, Chul; Lee, Seung-Ho
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Eloret Institute, Palo Alto, CA, USA
Source: AIAA, Thermophysics Conference, 28th, Orlando, FL, July 6-9, 1993, AIAA Paper 93-2862, 10 p. (see A93-46595)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*COMPUTATIONAL FLUID DYNAMICS /*NONEQUILIBRIUM CONDITIONS/*NOZZLE FLOW /*ONE DIMENSIONAL FLOW
Minor Term: / CHEMICAL REACTIONS/ MATHEMATICAL MODELS / REACTION KINETICS/ SHOCK TUNNELS/ WIND TUNNEL TESTS
Abstract: A computer code NOZNT (Nozzle in n-Temperatures), which calculates one-dimensional flows of partially dissociated and ionized air in an expanding nozzle, is tested against five existing sets of experimental data. The code accounts for: a) the differences among various temperatures, i.e., translational-rotational temperature, vibrational temperatures of individual molecular species, and electron-electronic temperature, b) radiative cooling, and c) the effects of impurities. The experimental data considered are: 1) the sodium line reversal and 2) the electron temperature and density data, both obtained in a shock tunnel, and 3) the spectroscopic emission data, 4) electron beam data on vibrational temperature, and 5) mass-spectrometric species concentration data, all obtained in arc-jet wind tunnels. It is shown that the impurities are most likely responsible for the observed phenomena in shock tunnels. For the arc-jet flows, impurities are inconsequential and the NOZNT code is validated by numerically reproducing the experimental data. 43 Refs.

13) Title: Atmospheric entry of Mars-return nuclear-powered vehicles due to accidental termination of operations

Author: Menees, Gene P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993, AIAA Paper 93-2501, 14 p. (see A93-50234)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ABORTED MISSIONS/*HYPERBOLIC REENTRY /*NUCLEAR REACTORS/*NUCLEAR ROCKET ENGINES /*SAFETY MANAGEMENT

Minor Term: / REENTRY EFFECTS/ REENTRY TRAJECTORIES/ SPACE MISSIONS

Abstract: The entry of nuclear reactors into Earth's atmosphere resulting from an accidental or inadvertent abort of a space vehicle powered by nuclear-thermal rockets is investigated. The study is made for a typical piloted Mars mission vehicle incapacitated by an accident or malfunction during the Earth-arrival phase of the Mars-return journey due to simultaneous, multiple failures of its component systems. A single accident/abort scenario resulting in three entry possibilities is considered for a nominal hyperbolic in-bound approach velocity of 8 km/sec. The most severe case involving a direct entry is then analyzed over a broad range of approach velocities extending to 12 km/sec to include sprint-type missions. The results indicate that the severe surface heating, stagnation pressures, and g-loads are greater than 150 kW/sq cm, 300 atm, and 800-g, respectively. The wall heat transfer rate exceeds the value that can be accommodated by a carbon heatshield through radiation equilibrium prior to sublimation at 5500 K. These conditions are beyond our previous experience in crew safety, structural design, and thermal protection. 20 Refs.

14) Title: Comparison of theory with atomic oxygen 130.4 nm radiation data from the Bow Shock ultraviolet 2 rocket flight

Author: Levin, Deborah A.; Candler, Graham V.; Collins, Robert J.; Howlett, Carl L.; Espy, Patrick; Whiting, Ellis; Park, Chul

Corp: Institute for Defense Analyses, Alexandria, VA, USA; University of Minnesota, Minneapolis, MN, USA; Utah State University, Logan, UT, USA; Eloret Institute, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics Conference, 28th, Orlando, FL, July 6-9, 1993, AIAA Paper 93-2811, 14 p. (see A93-46550)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*DATA FLOW ANALYSIS/*FAR ULTRAVIOLET RADIATION /*HYPERSONIC REENTRY/*OXYGEN ATOMS/*ROCKET FLIGHT /*SHOCK WAVES

Minor Term: / COMPARISON/ NITRIC OXIDE/ PHOTOIONIZATION / SHOCK HEATING

Abstract: Comparison is made between the results obtained from a state-of-the-art flow and radiative model and bow shock vacuum ultraviolet (VUV) data obtained the recent Bow Shock 2 Flight Experiment. An extensive data set was obtained from onboard rocket measurements at a reentry speed of 5 km/sec between the altitudes of approximately 65-85 km. A description of the NO photoionization cell used, the data, and the interpretation of the data will be presented. The primary purpose of the analyses is to assess the utility of the data and to propose a radiation model appropriate to the flight conditions of Bow Shock 2. Theoretical predictions based on flow modeling discussed in earlier work and a new radiation model are compared with data. 11 Refs.

15) Title: Measurement and analysis of nitric oxide radiation in an arc-jet flow
Author: Babikian, Dikran S.; Gopaul, Nigel K. J. M.; Park, Chul
Corp: Eloret Institute, Palo Alto, CA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Thermophysics Conference, 28th, Orlando, FL, July 6-9, 1993, AIAA Paper 93-2800, 8 p. (see A93-46540)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMODYNAMICS/*ARC JET ENGINES /*HYPERVELOCITY WIND TUNNELS/*NITRIC OXIDE /*THERMAL RADIATION/*WIND TUNNEL TESTS
Minor Term: / ENTHALPY/ HEAT SHIELDING / NONEQUILIBRIUM THERMODYNAMICS/ REENTRY / VIBRATIONAL SPECTRA
Abstract: Radiation from the nitric oxide band systems emitted by the flow in the test section of a 20 MW arc-jet wind tunnel was measured and computed. The settling chamber pressure and enthalpy were 2.4 atm and 28 ± 10 MJ/kg, respectively, The measurements were made with a 0.3 meter McPherson spectrograph using photographic films in the wavelength region from 225 to 305 nm. Of the four band systems of NO (beta, gamma, delta, and epsilon), vibrational transitions were observed from only the upper v' levels. Excitation temperatures were deduced by comparing the experimental spectrum with those calculated using the nonequilibrium radiation code, NEQAIR. The rotational, vibrational, and electronic excitation temperatures deduced from the data were Tr = 560 ± 50 K, Tv = 950 ± 50 K, and Tex = 11,500 ± 520 K, respectively. A multitemperature nonequilibrium nozzle flow code, NOZNT was used to calculate the nozzle flow. The calculated temperatures were Tr = 560 K, Tv = 950 K, and electron thermal temperature Te = 6100 K, respectively at 30 MJ/kg. The sensitivity of the calculated temperatures to the uncertainty in the measured arc-jet enthalpy is examined. 24 Refs.

16) Title: An overview of Ames experimental aerothermodynamics
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Symposium on Shock Waves and Shock Tubes, 18th, Sendai, Japan, July 21-26, 1991, vol. 1 (see A93-45451); Shock waves, Springer-Verlag, Berlin and New York, 1992, p. 591-596. (see A93-45496)
Sponsor: Shock Wave Research Center, Institute of Fluid Science, Sednai, Japan
Doc. Type: Conference Paper
Major Term: /*AEROTHERMODYNAMICS/*GAS FLOW /*HIGH TEMPERATURE GASES/*HYPERSONIC FLOW /*HYPERSONIC WIND TUNNELS/*REAL GASES
Minor Term: / ATMOSPHERIC ENTRY/ BALLISTIC RANGES/ ELECTRIC ARCS / NONEQUILIBRIUM THERMODYNAMICS/ SHOCK TUBES / SHOCK TUNNELS/ TEST FACILITIES
Abstract: This paper reviews the recent experimental research activities on aerothermodynamics within NASA Ames Research Center. The activities included in this review are those in (1) the electric arc-driven shock tubes, (2) the combustion-driven shock tube, (3) the ballistic ranges, and(4) the arc-jet wind tunnel facilities. The paper is a collection and collation of the papers published previously in the open literature on the activities in these facilities. The paper highlights the contributions made by each facility in the high temperature real-gas flow regimes. 33 Refs.

17) Title: Review of chemical-kinetic problems of future NASA missions. I - Earth entries

Author: Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 7, no. 3, July-September 1993, p. 385-398. (see A93-42899, see also AIAA, Aerospace Sciences Meeting, 29th, Reno, NV, January 7-10, 1991, AIAA Paper 91-0464, 31 p. (see A91-21500))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ATMOSPHERIC ENTRY/*NONEQUILIBRIUM CONDITIONS /*REACTION KINETICS/*SHOCK WAVES/*THERMOCHEMISTRY

Minor Term: / HEAT FLUX/ IONIZATION COEFFICIENTS / MOLECULAR OSCILLATIONS/ MOLECULAR RELAXATION

Abstract: A number of chemical-kinetic problems related to phenomena occurring behind a shock wave surrounding an object flying in the earth atmosphere are discussed, including the nonequilibrium thermochemical relaxation phenomena occurring behind a shock wave surrounding the flying object, problems related to aerobraking maneuver, the radiation phenomena for shock velocities of up to 12 km/sec, and the determination of rate coefficients for ionization reactions and associated electron-impact ionization reactions. Results of experiments are presented in form of graphs and tables, giving data on the reaction rate coefficients for air, the ionization distances, thermodynamic properties behind a shock wave, radiative heat flux calculations, Damkohler numbers for the ablation-product layer, together with conclusions. 52 Refs.

18) Title: Proposed radiometric measurement of the wake of a blunt aerobrake
Author: Strawa, A. W.; Park, C.; Davy, W. C.; Craig, R. A.; Babikian, D. S.; Prabhu, D. K.; Venkatapathy, E.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Eloret Institute, Palo Alto, CA, USA
Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 29, no. 6, November-December 1992, p. 765-772. (see A93-39256, see also AIAA, Thermophysics Conference, 26th, Honolulu, HI, June 24-26, 1991, AIAA Paper 91-1408, 16 p. (see A91-43470))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROBRAKING/*AEROTHERMODYNAMICS/*BLUNT BODIES /*RADIOMETERS/*WAKES
Minor Term: / AFTERBODIES/ CONVECTIVE HEAT TRANSFER/ FLIGHT TESTS / FLOW CHARACTERISTICS/ FLOW DISTRIBUTION / GROUND TESTS/ RADIATIVE HEAT TRANSFER
Abstract: This paper describes the aerothermal environment in the afterbody region of a blunt entry body. Recent ground-based experiments and computational predictions of the afterbody flow structure and radiation are presented. The similarity between the flowfield structures observed in the ground-based experiments and that obtained by calculation is encouraging. Approximate calculations of the radiative heating rate to the base are presented. Many of the phenomena associated with the expanding flow at the corner and the formation of the wake neck, however, are not well understood and require further study. A flight experiment is described that would use spectral and total measurements of the wake radiation as a nonintrusive diagnostic method to provide insight into the thermodynamic state of the wake gas. 31 Refs.

19) Title: Theory of radiation from low velocity shock heated air
Author: Levin, D. A.; Loda, R. T.; Candler, G. V.; Park, C.
Corp: Institute for Defense Analyses, Alexandria, VA, USA; North Carolina State University, Raleigh, NC, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 7, no. 2, April-June 1993, p. 269-276. (see A93-31434, see also AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, January 8-11, 1990, AIAA Paper 90-0133, 18 p. (see A90-19697))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AERODYNAMIC HEATING/*AEROTHERMODYNAMICS /*COMPUTATIONAL FLUID DYNAMICS/*HYPERSONIC FLOW /*RADIATION DISTRIBUTION/*SHOCK HEATING
Minor Term: / DEFENSE PROGRAM/ FLOW DISTRIBUTION/ FLOW VELOCITY
Abstract: Application of hypersonic computational fluid dynamics models to low velocity vehicles is examined. Important modeling aspects such as chemical kinetics, electronic excitation/de-excitation mechanisms, and existence of equilibrium versus nonequilibrium conditions in the flow were examined. Flowfield properties and in-band radiances in the wavelength region of 0.25 micron in the vicinity of the stagnation streamline are given for a hemisphere of 0.762 m. Comparison with recent shock tube data is also shown. 22 Refs.

20) Title: Vibrational relaxation of anharmonic oscillators in expanding flows
Author: Ruffin, Stephen M.; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 30, no. 1, January-February 1993, p. 59-68. (see A93-32286, see also AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, January 6-9, 1992, AIAA Paper 92-0806, 13 p. (see A92-29581)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*DIATOMIC GASES/*GAS EXPANSION /*MOLECULAR OSCILLATIONS/*MOLECULAR RELAXATION
Minor Term: / CARBON MONOXIDE/ COMPUTATIONAL FLUID DYNAMICS / NITROGEN/ NOZZLE FLOW
Abstract: Although the Landau-Teller vibrational model accurately predicts the vibrational excitation process in post-shock and compressing flows, it underpredicts the rate of de-excitation in cooling and expanding flows. In the present paper, detailed calculations of the vibrational relaxation process of N2 and CO in cooling flows are conducted. A coupled set of vibrational transition rate equations and quasi-one-dimensional fluid dynamic equations is solved. Multiple quantum level transition rates are computed using SSH theory. The SSH transition rate results are compared with available experimental data and other theoretical models. Vibration-vibration exchange collisions are responsible for some vibrational relaxation acceleration in situations of high vibrational temperature and low translational temperature. The present results support the relaxation mechanisms proposed by Bray and by Treanor, Rich and Rehm. Qualitative agreement with experimental results is achieved for the overall vibrational relaxation rate; however, the accuracy of the SSH results for vibration-vibration exchange transitions must be studied further and additional experimental investigations are needed for quantitative agreement.
21 Refs.

21) Title: Laboratory simulation of aerothermodynamic phenomena : A review
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Ground Testing Conference, 17th, Nashville, TN, July 6-8, 1992, AIAA Paper 92-4025, 27 p. (see A92-56847)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMODYNAMICS/*COMPUTERIZED SIMULATION /*SPACECRAFT PERFORMANCE/*TEST FACILITIES /*WIND TUNNEL TESTS
Minor Term: / ABLATION/ BOUNDARY LAYER TRANSITION/ GROUND TESTS / PERFORMANCE PREDICTION/ PLASMA JET WIND TUNNELS / RADIATIVE HEAT TRANSFER/ SHOCK WAVE INTERACTION
Abstract: The issues of laboratory simulation of aerothermodynamic phenomena are discussed. The paper first enumerates the seven aerothermodynamic phenomena that affect the performance of high speed aerospace vehicles but are presently beyond our ability to predict accurately, and defines the types of experiments that need to be made to understand and quantify the phenomena. The facilities suited for these experiments are identified. The causes of uncertainty and difficulty in the experiments are cited. The procedures for calibrating the facilities for these purposes are proposed, and the research and development needed for successful laboratory simulation of aerothermodynamic phenomena are identified. 64 Refs.

22) Title: Calculation of real-gas effects on blunt-body trim angles
Author: Park, Chul; Yoon, Seokkwan
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; MCAT Institute, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 30, no. 4, April 1992, p. 999-1007. (see A92-31169, see also AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, January 9-12, 1989, AIAA Paper 89-0685, 16 p. (see A89-28447))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ANGLE OF ATTACK/*BLUNT BODIES/*HYPERSONIC REENTRY /*NONEQUILIBRIUM FLOW/*REAL GASES/*VIBRATION EFFECTS
Minor Term: / APOLLO LUNAR EXPERIMENT MODULE / NAVIER-STOKES EQUATION/ RADIATIVE HEAT TRANSFER / SHOCK LAYERS
Abstract: The effect of vibrational excitation and dissociation at high temperatures on the trim angle of attack of a blunt lifting body is calculated for a nonequilibrium flow regime in air using a computational fluid dynamics technique. Air is considered to consist of five neutral species, O, N, NO, O2, and N2, and both one- and two-temperature thermochemical nonequilibrium models are used in determining the thermodynamic state. A computer code, named CENS2H (Compressible Euler-Navier-Stokes Two-dimensional Hypersonic), is developed by incorporating this model into an existing perfect-gas code named CENS2D, which uses a lower-upper factorization based on the symmetric Gauss-Seidel sweeping technique. The code is applied to compute the forebody flow of a two-dimensional blunt body of the shape of the Apollo Command Module at a finite angle of attack. The results show that the trim angle of attack is smaller for a reacting gas than for a perfect gas. The calculated shift in the trim angle due to the real-gas effect is of the same order as that seen during the Apollo flights. The one-temperature nonequilibrium model yields the same trim angles as the two-temperature model, but the constant-gamma (equals Cp/Cv) solution that reproduces the shock standoff distance fails to reproduce the trim angle. 29 Refs.

23) Title: Atmospheric entry of nuclear-powered vehicles due to accidental/inadvertent termination of operations

Author: Menees, Gene P.; Park, Chul; Tauber, Michael E.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 28th,Nashville, TN, July 6-8, 1992, AIAA Paper 92-3270, 10 p. (see A92-48862)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ABORTED MISSIONS/*ACCIDENTS/*ATMOSPHERIC ENTRY /*EARTH-MARS TRAJECTORIES/*NUCLEAR PROPULSION /*RADIOACTIVE MATERIALS /*UNCONTROLLED REENTRY (SPACECRAFT)

Minor Term: / AERODYNAMIC HEATING/ HEAT TRANSFER / MANNED MARS MISSIONS/ ORBITAL MANEUVERS / PITCH (INCLINATION)/ PROPULSION SYSTEM CONFIGURATIONS

Abstract: The entries of the radioactive components into earth's atmosphere resulting from an accident or inadvertent abort of a space vehicle powered by nuclear-thermal-rockets are investigated. The study is made for atypical piloted Mars mission vehicle incapacitated by an accident or malfunction during the trans-Mars-injection maneuver due to simultaneous multiple failures of its component systems. The three different accident/abort modes considered are the following: (1) a constant-rate angular pitching motion of the vehicle, (2) a constant-acceleration angular pitching motion of the vehicle, and (3) the rocket engine breaks away from the rest of the vehicle with a finite relative (dispersion) velocity. The speeds and angles of the atmospheric entries are calculated for each mode for different values of the time of the accident, pitching rate, acceleration, and dispersion velocity. For the most severe entry speeds and flight-path angles, the stagnation-point pressures, heat transfer rates, thickness, and mass per unit area of the heat shields necessary to protect the radioactive components from disintegrating, deceleration g-loads, and high ground-impact velocities are calculated. The study points out that the high g-loads and high ground-impact velocities are the most serious problems that must be addressed. 22 Refs.

24) Title: Vibrational relaxation of anharmonic oscillators in expanding flows
Author: Ruffin, Stephen M.; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, January 6-9, 1992, AIAA Paper 92-0806, 13 p. (see A92-29581)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*DIATOMIC GASES/*GAS EXPANSION /*MOLECULAR OSCILLATIONS/*MOLECULAR RELAXATION
Minor Term: / CARBON MONOXIDE/ COMPUTATIONAL FLUID DYNAMICS / NITROGEN/ NOZZLE FLOW
Abstract: Although the Landau-Teller vibrational model accurately predicts the vibrational excitation process in post-shock and compressing flows, it underpredicts the rate of de-excitation in cooling and expanding flows. In the present paper, detailed calculations of the vibrational relaxation process of N2 and CO in cooling flows are conducted. A coupled set of vibrational transition rate equations and quasi-one-dimensional fluid dynamic equations is solved. Multiple quantum level transition rates are computed using SSH theory. The SSH transition rate results are compared with available experimental data and other theoretical models. Vibration-vibration exchange collisions are responsible for some vibrational relaxation acceleration in situations of high vibrational temperature and low translational temperature. The present results support the relaxation mechanisms proposed by Bray and by Treanor, Rich and Rehm. Qualitative agreement with experimental results is achieved for the overall vibrational relaxation rate; however, the accuracy of the SSH results for vibration-vibration exchange transitions must be studied further and additional experimental investigations are needed for quantitative agreement. 19 Refs.

25) Title: Estimation of excitation energy of diatomic molecules in expanding nonequilibrium flows

Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, January 6-9, 1992, AIAA Paper 92-0805, 19 p. (see A92-29580)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper

Major Term: /*DIATOMIC GASES/*DIATOMIC MOLECULES/*GAS EXPANSION /*MOLECULAR ENERGY LEVELS/*MOLECULAR EXCITATION /*NONEQUILIBRIUM FLOW

Minor Term: / BOLTZMANN DISTRIBUTION/ CARBON MONOXIDE/ HYDROGEN / HYDROXIDES/ MOLECULAR RELAXATION / MOLECULAR ROTATION/ NITRIC OXIDE/ NITROGEN / NOZZLE FLOW/ OXYGEN

Abstract: The energy contained in the highly excited vibrational and rotational states in a diatomic gas in a thermochemical nonequilibrium state during expansion is estimated. The estimation is made on the assumption that the populations of the vibrational and rotational states, when normalized by their respective equilibrium values, are describable by simple functions containing no more than four arbitrary parameters. A cubic polynomial, a logarithmic-cubic polynomial, and a bimodal step function are used for this purpose. The four parameters are determined by imposing conditions known at the ground state and the dissociation limit and the mass conservation law. The energy in excess of that accounted for by assuming a Boltzmann distribution of these states, defined here as excess excitation energy, is calculated for N2, O2, NO, CO, OH, and H2. A calculation made for a typical nozzle flow shows that the excess energy may reach 6 percent of the total enthalpy of the flow, and that the flow velocity may decrease by as much as 4 percent due to the nonequilibrium excitation phenomenon. 22 Refs.

26) Title: Rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and Herzfeld

Author: Sharma, Surendra P.; Huo, Winifred M.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 6, no. 1, January-March 1992, p. 9-21. (see A92-20301, see also AIAA, Thermophysics, Plasmadynamics and Lasers Conference, San Antonio, TX, June 27-29, 1988, AIAA Paper 88-2714, 19 p. (see A88-47075))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROTHERMOCHEMISTRY/*GAS DISSOCIATION /*HYPERSONIC FLOW/*NITROGEN/*REACTION KINETICS /*VIBRATIONAL SPECTRA

Minor Term: / AEROTHERMODYNAMICS/ COOLING/ ELECTRON TRANSITIONS / MOLECULAR RELAXATION

Abstract: We report a theoretical study of vibrational excitations and dissociations of nitrogen undergoing a nonequilibrium relaxation process upon heating and cooling. The rate coefficients for collisional induced vibrational transitions and transitions from a bound vibrational state into a dissociative state have been calculated using an extension of the theory originally proposed by Schwartz, Slawsky, and Herzfeld (SSH). High-lying vibrational states and dissociative states were explicitly included, but rotational energy transfer was neglected. The transition probabilities calculated from the SSH theory were fed into the master equation, which was integrated numerically to determine the population distribution of the vibrational states, as well as bulk thermodynamic properties. Our results show that 1) the transition rates have a minimum near the middle of the bound vibrational levels, causing a bottleneck in the vibrational relaxation and dissociation rates, 2) high vibrational states are always in equilibrium with the dissociative state, 3) for the heating case, only the low vibrational states relax, according to Landau-Teller theory, 4) for the cooling case, vibrational relaxation cannot be described by a rate equation, and 5) the average vibrational energy removed in dissociation is about 30% of the dissociation energy. 31 Refs.

27) Title: Radiometric investigation of the wake flow of the forthcoming Aeroassist Flight Experiment

Author: Strawa, A. W.; Park, C.; Davy, W. C.; Craig, R. A.; Babikian, D. S.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Eloret Institute, Palo Alto, CA, USA

Source: AIAA, Thermophysics Conference, 26th, Honolulu, HI, June 24-26, 1991, AIAA Paper 91-1408, 16 p. (see A91-43470)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*AFTERBODIES /*COMPUTATIONAL FLUID DYNAMICS /*RADIATION MEASUREMENT/*RADIATIVE HEAT TRANSFER /*STAGNATION POINT

Minor Term: / AEROBRAKING/ FLOW DISTRIBUTION/ SHEAR LAYERS/ WAKES

Abstract: This paper describes the rationale for conducting the proposed radiation measurement in the afterbody region of the Aeroassist Flight Experiment (AFE) vehicle, the results of the calculations of expected radiation intensities performed to date, and the instrumentation for the measurement. The experiment, named the Afterbody Radiometry Experiment (ARE), is one of the experiments that will be carried on board the AFE vehicle. The paper collates the existing experimental data to show the possibility that there may be substantial radiative heating of the afterbody region of an Aeroassist Space Transfer Vehicle, which necessitates an experiment of the kind proposed. Calculations of the radiative heating rate to the base of the AFE are, qualitatively, in fair agreement with previous experimental work, which indicated that the radiative heating of the base is about 5 percent of that at the stagnation point. 26 Refs.

28) Title: Titan atmospheric composition by hypervelocity shock-layer analysis
Author: Nelson, H. F.; Park, Chul; Whiting, Ellis E.
Corp: Missouri University, Rolla, MO, USA; NASA, Ames Research Center, Moffett Field, CA, USA; Eloret Institute, Sunnyvale, CA, USA
Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 5, no. 2, April-June 1991, p. 157-165. (see A91-42255, see also AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, AIAA Paper 89-1770, 15 p. (see A89-43280))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ATMOSPHERIC COMPOSITION/*CASSINI MISSION /*HYPERVELOCITY/*SATELLITE ATMOSPHERES/*SHOCK LAYERS /*TITAN
Minor Term: / METHANE/ MISSION PLANNING/ NITROGEN/ RADIOMETERS / STAGNATION POINT
Abstract: Planning is currently underway to send a probe into the atmosphere of Titan (a moon of Saturn) as part of the Cassini Mission. This paper presents an investigation of the feasibility of determining the mole fractions of the major species in Titan's atmosphere (N2, CH4, and argon, if present) using a radiometer to measure the CN(violet) radiation emitted in the probe's shock layer during the high-velocity portion of the entry. Radiative heating rates spectra are calculated at the probe stagnation point for altitudes near peak heating where the shock-layer gases are in chemical and thermal nonequilibrium. The analysis indicates that the sensitivity of the CN(violet) radiation to the atmospheric composition enables the mole fractions of N2, CH4, and argon to be determined to about plus or minus 0.015, plus or minus 0.003, and plus or minus 0.01, respectively. These values are much less than the current uncertainties. The maximum nonequilibrium radiative heating rate is predicted to be about half of the maximum convective heating rate. (Prior equilibrium calculations had shown that the radiative heating rate was negligible.) Thus, the beryllium heat shield currently planned may be underdesigned, because it has been developed for convective heating only. 30 Refs.

29) Title: Fully coupled implicit method for thermochemical nonequilibrium air at suborbital flight speeds

Author: Park, Chul; Yoon, Seokkwan

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; MCAT Institute, Moffett Field, CA, USA

Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 28, no. 1, January-February 1991, p. 31-39. (see A91-33380, see also AIAA, Computational Fluid Dynamics Conference, 9th, Buffalo, NY, June 13-15, 1989, Technical Papers, p. 440-449, AIAA Paper 89-1974, 10 p. (see A89-41818))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROTHERMOCHEMISTRY /*COMPUTATIONAL FLUID DYNAMICS/*HYPERSONIC FLIGHT

Minor Term: / AERODYNAMIC DRAG/ CHEMICAL EQUILIBRIUM / CIRCULAR CYLINDERS/ CONSERVATION EQUATIONS/ LIFT / NONEQUILIBRIUM THERMODYNAMICS/ PITCHING MOMENTS

Abstract: A computational fluid dynamics (CFD) technique is described in which the finite-rate chemistry in thermal and chemical nonequilibrium air is fully and implicitly coupled with the fluid motion. Developed for use in the suborbital hypersonic-flight speed range, the method accounts for the nonequilibrium vibrational and electronic excitation and dissociation but not ionization. The steady-state solution to the resulting system of equations is obtained by using a lower-upper factorization and symmetric Gauss-Seidel sweeping technique through Newton iteration. Inversion of the left-hand-side matrices is replaced by scalar multiplications through the use of the diagonal dominance algorithm. The code, named compressible Euler-Navier-Stokes two-dimensional hypersonic (CENS2H), is fully vectorized and requires about 8.8 multiplied by 10** minus **5 s per node point per iteration in a Cray X-MP computer. Converged solutions are obtained after about 700 iterations. Sample calculations are made for a circular cylinder and a 10% airfoil at a 10 degree angle of attack. The calculated cylinder flowfield agrees with that obtained experimentally. The code predicts a 10% change in lift and drag and a 20% change in pitching moment for the airfoil caused by the thermochemical phenomena. 14 Refs.

30) Title: Aerothermodynamics of sprint-type manned Mars missions
Author: Park, Chul; Davies, Carol B.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Sterling Software, Inc., Palo Alto, CA, USA
Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, no. 6, November-December 1990, p. 589-596. (see A91-27805, see also AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, January 9-12, 1989, AIAA Paper 89-0313, 21 p. (see A89-26367))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROBRAKING/*AEROTHERMODYNAMICS /*ATMOSPHERIC ENTRY/*MANNED MARS MISSIONS
Minor Term: / LIFT DRAG RATIO/ RADIATIVE HEAT TRANSFER / SPACECRAFT TRAJECTORIES/ TRAJECTORY ANALYSIS / TRANSFER ORBITS
Abstract: The areothermodynamic problems associated with aerobraking of the spacecraft proposed for the sprint-type fast manned Mars mission are studied. The propulsive delta V necessary at departure from Earth and Mars and the velocities of the atmospheric entries into the two planets are first deduced from the existing literature by imposing the constraints that the mission be completed within 330 or 436 days. It is shown that entry velocities up to about 15 km/sec are possible at both Earth and Mars. Through the trajectory calculations of the vehicles during the aerobraking maneuvers, the requirements on the lift-to-drag ratios (L/D) of the vehicles are deduced under the constraint on the allowed deceleration. L/D values of 0.4 and 1.0 are found to be necessary at Earth and Mars, respectively. Density, pressure, and stagnation-point convective heat-transfer rates are calculated for the typical aerobraking flights. Assuming the shock layer flow to be in equilibrium and the gas to be optically thin for the wavelengths longer than 250 nm and optically thick for shorter wavelengths, the stagnation-point radiative heat-transfer rates are calculated and shown to be larger than the convective heat-transfer rates. 21 Refs.

31) Title: The coupling of radiative transfer to quasi 1-D flows with thermochemical nonequilibrium

Author: Gökçen, Tahir; Park, Chul

Corp: Eloret Institute, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 29th, Reno, NV, January 7-10, 1991, AIAA Paper 91-0570, 9 p. (see A91-21538)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Article

Major Term: /*AEROTHERMOCHEMISTRY/*FLOW DISTRIBUTION /*NONEQUILIBRIUM FLOW/*NOZZLE FLOW /*ONE DIMENSIONAL FLOW/*RADIATIVE TRANSFER

Minor Term: / COMPUTERIZED SIMULATION/ DIFFERENTIAL EQUATIONS / INTEGRAL EQUATIONS/ ITERATIVE SOLUTION/ NITROGEN / THERMODYNAMIC PROPERTIES

Abstract: Quasi-one-dimensional nonequilibrium nozzle flows with coupled radiative transfer are considered. The strongly coupled formulation of radiation and flowfield leads to a governing set of integro-differential equations. A fully implicit numerical method using the full matrix inversion or block iteration methods is presented to solve these equations. The nonequilibrium gas model consists of two chemical species, molecular and atomic nitrogen. The thermodynamic state of the gas is described by two temperatures, translational-rotational and vibrational, and the thermal radiation is assumed to be governed by the vibrational temperature. In radiative transfer, gases are assumed to be absorbing and emitting, and a detailed spectral dependency of the absorption coefficient is prescribed for a non-gray gas. The numerical solutions of strongly radiating nonequilibrium flows are presented for both gray and non-gray gases. 17 Refs.

32) Title: Chemical-kinetic problems of future NASA missions
Author: Park, Chul; Howe, John T.; Jaffe, Richard L.; Candler, Graham V.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; North Carolina State University, Raleigh, NC, USA
Source: AIAA, Aerospace Sciences Meeting, 29th, Reno, NV, January 7-10, 1991, AIAA Paper 91-0464, 31 p. (see A91-21500)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMOCHEMISTRY/*REACTION KINETICS /*REENTRY VEHICLES/*SHOCK LAYERS /*THERMODYNAMIC EQUILIBRIUM
Minor Term: / AXISYMMETRIC FLOW/ BLUNT BODIES/ DAMKOHLER NUMBER / HEAT FLUX/ RADIATIVE HEAT TRANSFER/ STAGNATION POINT / THERMODYNAMIC PROPERTIES
Abstract: The problem of thermochemical nonequilibrium in the shock layer surrounding vehicles entering the atmospheres of Earth and Mars at super-escape velocities is examined. The sets of reaction rate coefficients that reproduce experimental data taken in shock tubes are derived through the process of trial and error for the velocities up to 12 km/s for the Earth entry and 9 km/s for the Martian cases. Using rate coefficients so determined, thermodynamic properties are calculated for one-dimensional flows behind a normal shock wave in a shock tube, and for the axisymmetric flow over a non-ablating blunt-body for the nose radii of 1 to 10 meters. Intensities of emitted radiation are calculated for the shock tube flow, and the radiative heat fluxes incident on the wall at the stagnation point are calculated for the blunt-body flow. Examination of the characteristic Damkohler number indicates that the viscous layer of the ablation-product over an ablating heat shield is likely to be in chemical nonequilibrium state. The calculated relaxation characteristics agree well with the experimental data for the Earth entry case, but not so well for the Mars case, especially above the flight velocity of 9 km/s. For the Earth entry case, the thickness of the nonequilibrium region is between 1 and 2 cm at the expected peak radiation point in the aerobraking trajectory. For Martian entry flight, it is between 8 and 23 cm. For the Earth entry case, nonequilibrium phenomena reduce radiative heating rate, while the opposite occurs for the Martian case. The radiative heat transfer rates are significant for the Mars entry conditions at entry velocities equal to or greater than 7 km/s. A one-temperature nonequilibrium model greatly overestimates radiative heating for the Martian entry. 80 Refs.

33) Title: Nonequilibrium hypersonic aerothermodynamics
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Stanford University, Stanford, CA, USA
Source: John Wiley & Sons, New York, 1989, 372 p. (ISBN 0-471-51093-9, see A91-14483)
Sponsor: John Wiley & Sons, New York, NY, USA
Doc. Type: Book
Major Term: /*AEROTHERMODYNAMICS/*HYPERSONIC FLOW /*NONEQUILIBRIUM FLOW
Minor Term: / AIR FLOW/ ATOMIC COLLISIONS/ CHEMICAL REACTIONS / COMPUTATIONAL FLUID DYNAMICS / CONSERVATION EQUATIONS/ GAS-SOLID INTERACTIONS / MOLECULAR COLLISIONS/ WIND TUNNEL TESTS
Abstract: Nonequilibrium phenomena in hypersonic flows are examined on the basis of theoretical models and selected experimental data, in an introduction intended for second-year graduate students of aerospace engineering. Chapters are devoted to the physical nature of gas atoms and molecules, transitions of internal states, the formulation of the master equation of aerothermodynamics, the conservation equations, chemical reactions in CFD, the behavior of air flows in nonequilibrium, experimental aspects of nonequilibrium flow, a review of experimental results, and gas-solid interaction. Diagrams, graphs, and tables of numerical data are provided. 306 Refs.

34) Title: Radiative heating at the stagnation point of the AFE vehicle
Author: Whiting, Ellis E.; Park, Chul
Corp: Eloret Institute, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-102829, November 1990, 44 p. (see X91-10068)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*AEROASSIST/*AEROTHERMODYNAMICS/*FLOW DISTRIBUTION /*NONEQUILIBRIUM THERMODYNAMICS /*ORBIT TRANSFER VEHICLES/*RADIATIVE HEAT TRANSFER /*STAGNATION POINT
Minor Term: / ATMOSPHERIC ENTRY/ COMPUTATIONAL FLUID DYNAMICS / SHOCK LAYERS/ SPACE TRANSPORTATION SYSTEM
Abstract: The goal of the Aeroassist Flight Experiment (AFE) is to advance the technology base needed to design a new class of atmospheric entry vehicles known as the aeroassisted space transfer vehicles (ASTV). The ASTV's will form a workhorse space transportation system that will move people, satellites, supplies, construction material, equipment, and space-manufactured products between low Earth orbit (LEO) where the Space Station Freedom and other space ports will be located and more distant locations, such as geosynchronous Earth orbit (GEO), lunar bases, asteroids, and planets. An estimate of the radiative heating rate at the stagnation point of the AFE vehicle during its flight through the atmosphere is presented. The stagnation point was chosen because it is the location on the vehicle where the maximum, or near-maximum, heating rate occurs. Also, the flow field in the region of the stagnation point can be approximated by relatively simple methods that are not applicable to other portions of the flow field. This allows the radiative heating rate to be calculated using a one-dimensional flow code, which is probably accurate within a factor of two. 28 Refs.

35) Title: Operating characteristics of a 60- and 10-cm electric arc-driven shock tube. I - The driver.

Author: Sharma, Surendra P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 4, no. 3, July 1990, p. 259-265. (see A90-43302, see also AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, January 11-14, 1988, AIAA Paper 88-0142, 19 p. (see A88-22103))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ELECTRIC ARCS/*EQUILIBRIUM FLOW/*HYPERSONIC FLOW /*NONEQUILIBRIUM PLASMAS/*SHOCK TUBES

Minor Term: / FLOW VELOCITY/ HIGH TEMPERATURE GASES / SHOCK TUNNELS/ THERMODYNAMIC PROPERTIES

Abstract: This is the first part of a two-part paper describing the operating characteristics of the electric arc-driven shock-tube facility at NASA Ames Research Center. In this part, the operating envelope of the facility and the technology of the arc driver are presented. Specifically, the question as to how well the behavior of the arc driver is understood and controlled is addressed. A plasma kinetics model of the exploding wire is developed to describe the arc behavior in the driver. Using this model, the performance parameters for the arc driver, and thereby the performance of the facility, can be predicted approximately. 29 Refs.

36) Title: Operating characteristics of a 60- and 10-cm electric arc-driven shock tube. II - The driven section

Author: Sharma, Surendra P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 4, no. 3, July 1990, p. 266-272. (see A90-43302, see also AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, January 11-14, 1988, AIAA Paper 88-0142, 19 p. (see A88-22103))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ELECTRIC ARCS/*EQUILIBRIUM FLOW/*HYPERSONIC FLOW /*NONEQUILIBRIUM PLASMAS/*SHOCK TUBES

Minor Term: / FLOW VELOCITY/ HIGH TEMPERATURE GASES / SHOCK TUNNELS/ THERMODYNAMIC PROPERTIES

Abstract: This is the second part of a two-part paper describing the operating characteristics of the electric arc-driven shock-tube facilities at NASA Ames Research Center. This part discusses the performance of the driven sections when the facility is used as a tool to produce a low-density nonequilibrium flow and when used as a shock tunnel. Specifically, the paper discusses the cleanliness of the driven flow at low densities, and the deviation from the equilibrium conditions at the test section of the shock-tunnel flow. 9 Refs.

37) Title: Nonequilibrium H2-air reactions in shock tunnel nozzle
Author: Lee, Seung-Ho; Bogdanoff, David W.; Cavolowsky, John A.; Park, Chul
Corp: Eloret Institute, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990, AIAA Paper 90-1751, 11 p. (see A90-38444)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AIR FLOW/*COMBUSTION PRODUCTS/*HYDROGEN /*NONEQUILIBRIUM FLOW/*NOZZLE FLOW/*SHOCK TUNNELS
Minor Term: / CHEMICAL REACTIONS/ CONCENTRATION (COMPOSITION) / DENSITY MEASUREMENT/ HYDROXYL RADICALS / LASER SPECTROSCOPY
Abstract: A nitrogen-water vapor mixture simulating hydrogen-air combustion products was produced and expanded in the nozzle of the 16-inch Combustion-Driven Shock Tunnel at NASA Ames Research Center. The measured OH concentrations are smaller than those calculated by the conventional one-temperature reaction model even when the reaction rate coefficients are multiplied by a factor of 10. The values calculated by a two-temperature model bound the experimental values under one operating condition, but fail to do so in the other. The discrepancy between experiment and calculation is unresolved.
20 Refs.

38) Title: Calculation of real-gas effects on airfoil aerodynamic characteristics
Author: Park, Chul; Yoon, Seokkwan
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; MCAT Institute, Moffett Field, CA, USA
Source: AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th,Seattle, WA, June 18-20, 1990, AIAA Paper 90-1712, 9 p.
(see A90-38414)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AERODYNAMIC COEFFICIENTS/*AIRFOILS/*ELLIPSES /*NONEQUILIBRIUM CONDITIONS/*REAL GASES /*THERMOCHEMICAL PROPERTIES
Minor Term: / ANGLE OF ATTACK/ COMPUTATION/ FLIGHT ALTITUDE / NATIONAL AEROSPACE PLANE PROGRAM / SPACE SHUTTLE MISSIONS
Abstract: The effects of high temperature thermochemical phenomena on the aerodynamic characteristics at hypersonic speeds are calculated for two-dimensional airfoils in air. The calculations are performed on an airfoil similar to that used for the Space Shuttle Orbiter, and ellipses of thickness ratios varying between 5 and 15 percent. For the airfoil, one flight condition is considered. For the ellipses, the calculations are carried out over a range of chord lengths, flight velocities, flight altitudes, and angles of attack. The computer codes CENS2H, which assume air to consist of five neutral species, N, O, NO, O2, and N2 and accounts for both thermal and chemical nonequilibrium, and the code CENS2D, which is for an ideal gas with arbitrary gamma (specific heat ratio, Cp/Cv), are used for this purpose. It is shown that the lift and drag coefficients are consistently reduced by the thermochemical phenomena, and that the behavior can be represented by a gamma value less than 1.4. The center of pressure shifts forward due to the thermochemical phenomena, but its extent is sensitively affected by the geometry and angle of attack and cannot be represented by a fixed gamma. The calculated results are in qualitative agreement with the data obtained during the entry flights of the Space Shuttle vehicle.
5 Refs.

39) Title: Survey of simulation and diagnostic techniques for hypersonic nonequilibrium flows

Author: Sharma, Surendra P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 4, no. 2, April 1990, p. 129-140. (see A90-31301, see also AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, January 12-15, 1987, AIAA Paper 87-0406, 17 p. (see A87-24958))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*FLOW VISUALIZATION/*HYPERSONIC FLOW /*NONEQUILIBRIUM FLOW/*SIMULATION

Minor Term: / AEROTHERMODYNAMICS/ CHEMICAL REACTIONS / COMPUTATIONAL FLUID DYNAMICS/ SHOCK TUBES / SPECTROSCOPY

Abstract: With the growing interest in transatmospheric vehicles, maneuvering re-entry vehicles, aeroassisted orbital transfer vehicles (AOTVs), and concepts of advanced space transportation systems, greater attention is being given to the aerothermodynamic aspect of hypersonic flows. With the growing need for higher payload and more maneuverable, more efficient vehicles, accurate data on the flowfields and thermal environments around the vehicle are being demanded. Airflow around hypervelocity vehicles undergoes vibrational excitation, chemical dissociation, and ionization. These chemical and kinetic phenomena absorb energy, change compressibility, cause temperature to fall, and cause density to rise. In high-altitude, low-density environments, the thicknesses of the shock layers can be smaller than the relaxation distances required for the gas to attain chemical and thermodynamic equilibrium. The nonequilibrium phenomena in this environment occur in general to all internal modes (rotation, vibration, and electronic excitation) and external modes (heavy particle translation, electron translation, dissociation, and ionization) of energy. These nonequilibrium phenomena affect the design features and operational characteristics of hypersonic vehicles in at least two ways: (1) radiative heating of the vehicles and (2) pressure distribution around the vehicle. 92 Refs.

40) Title: Assessment of two-temperature kinetic model for ionizing air
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 3, no. 3, July 1989, p. 233-244. (see A90-24826, see also AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987, AIAA Paper 87-1574, 13 p. (see A87-44833))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROTHERMOCHEMISTRY/*GAS IONIZATION /*MOLECULAR OSCILLATIONS/*NONEQUILIBRIUM FLOW /*REACTION KINETICS/*SHOCK LAYERS
Minor Term: / AIR FLOW/ HEAT FLUX/ HIGH TEMPERATURE / MOLECULAR RELAXATION/ RADIATIVE HEAT TRANSFER / SHOCK TUBES
Abstract: A two-temperature chemical-kinetic model for air is assessed by comparing theoretical results with existing experimental data obtained in shock tubes, ballistic ranges, and flight experiments. In the model, one temperature (T) is assumed to characterize the heavy-particle translational and molecular rotational energies, and another temperature (Tv) the molecular vibrational, electron translational, and electronic excitation energies. The theoretical results for nonequilibrium flow in shock tubes are obtained using the computer code STRAP (shock-tube radiation program) and for flow along the stagnation streamline in the shock layer over spherical bodies using the newly developed code SPRAP (stagnation-point radiation program). Substantial agreement is shown between the theoretical and experimental results for relaxation times and radiative heat fluxes. At very high temperatures, the spectral calculations need further improvement. The present agreement provides strong evidence that the two-temperature model characterizes principal features of nonequilibrium airflow. New theoretical results using the model are presented for the radiative heat fluxes at the stagnation point of 6 m radius sphere, representing a aeroassisted orbital transfer vehicle, over a range of freestream conditions. Assumptions, approximations and limitations of the model are discussed. 51 Refs.

41) Title: User's manual for compressible-Euler-Navier-Stokes two-dimensional hypersonic (CENS2H) and associated programs

Author: Park, Chul; Yoon, Seokkwan

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: NASA, Ames Research Center, Aerothermodynamics Branch, Mail Stop 230-2, Moffett Field, CA, USA, June 1990

Sponsor: NASA, Ames Research Center, Moffett Field, CA, USA

Doc. Type: Unpublished Report

Major Term: /*AEROTHERMOCHEMISTRY /*COMPUTATIONAL FLUID DYNAMICS/*HYPERSONIC FLOW /*NONEQUILIBRIUM THERMODYNAMICS

Minor Term: / COMPRESSIBLE FLOW/ COMPUTATION / CONSERVATION EQUATIONS/ NAVIER-STOKES EQUATIONS

Abstract: This manual describes how to use the computer programs Compressible-Euler-Navier-Stokes Two-dimensional Hypersonic Perfect (CENS2D2), Compressible-Euler-Navier-Stokes Two-dimensional Hypersonic Reacting (CENS2H2), DIVIDD, and DIVIDE. The program, CENS2D2, computes a two-dimensional hypersonic flow assuming a constant specific heat ratio, gamma. The program CENS2H2 computes a two-dimensional hypersonic flow in air accounting for thermochemical nonequilibrium using the same computational algorithm as in CENS2D2. The program, DIVIDD converts a formatted output file from the code CENS2D2 to produce a binary file for plotting compatible with the general program, PLOT3D. The program DIVIDE does the same for CENS2H2. 6 Refs.

42) Title: Computational equations for radiating and ablating shock layers
Author: Park, Chul; Milos, Frank S.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, January 8-11, 1990, AIAA Paper 90-0356, 14 p. (see A90-22203)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ABLATION/*BLUNT BODIES
/*COMPUTATIONAL FLUID DYNAMICS
/*PLANETARY ATMOSPHERES/*RADIATIVE TRANSFER
/*SHOCK LAYERS
Minor Term: / ATMOSPHERIC ENTRY/ FLOW DISTRIBUTION
Abstract: The computational equations governing the shock-layer flowfield over a blunt body dominated by radiation and ablation are derived. The flowfield considered is that expected around the vehicles entering the atmosphere of the planet Mars or the earth on return from Mars on a sprint-type manned mission. To determine the appropriate method of approach, the radiative transfer calculations are made first using the existing computer code RASLE (Nicolet et al., 1978), which uses the assumption of equilibrium and a coarse spectral band model for radiative transfer, and the code NONEQ which accounts for thermochemical nonequilibrium and carries out line-by-line calculation of radiation. By comparing the results, it is concluded that a thermochemical nonequilibrium model and a line-by-line spectral model must be used. 15 Refs.

43) Title: Theory of radiation from low velocity heated air
Author: Levin, D. A.; Loda, R. T.; Candler, G. V.; Park, C.
Corp: Institute for Defense Analyses, Alexandria, VA, USA; North Carolina State University, Raleigh, NC, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, January 8-11, 1990, AIAA Paper 90-0133, 18 p. (see A90-19697)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AERODYNAMIC HEATING/*AEROTHERMODYNAMICS /*COMPUTATIONAL FLUID DYNAMICS/* HYPERSONIC FLOW /*RADIATION DISTRIBUTION/*SHOCK HEATING
Minor Term: / DEFENSE PROGRAM/ FLOW DISTRIBUTION/ FLOW VELOCITY
Abstract: The application of hypersonic computational fluid dynamics models to low velocity vehicles is examined. Modeling aspects such as chemical kinetics, electronic excitation/de-excitation mechanisms, and existence of equilibrium versus nonequilibrium conditions in the flow were examined. Flowfield properties and in-band radiances in the wavelength region of 0.25 micron in the vicinity of the stagnation streamline are given for a three-inch hemisphere. Comparison with recent shock tube data is also shown. 25 Refs.

44) Title: Titan atmospheric composition by hypervelocity shock layer analysis
Author: Nelson, H. F.; Park, Chul; Whiting, Ellis E.
Corp: Missouri University, Rolla, MO, USA; NASA, Ames Research Center, Moffett Field, CA, USA; Eloret Institute, Sunnyvale, CA, USA
Source: AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, AIAA Paper 89-1770, 15 p. (see A89-43280)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ATMOSPHERIC COMPOSITION/*CASSINI MISSION /*HYPERVELOCITY/*SATELLITE ATMOSPHERES/*SHOCK LAYERS /*TITAN
Minor Term: / METHANE/ MISSION PLANNING/ NITROGEN/ RADIOMETERS / STAGNATION POINT
Abstract: The Cassini Mission, a NASA/ESA cooperative project which includes a deployment of probe into the atmosphere of Titan, is described, with particular attention given to the shock radiometer experiment planned for the Titan probe for the analysis of Titan's atmosphere. Results from a shock layer analysis are presented, demonstrating that the mole fractions of the major species (N2, CH4, and, possibly Ar) in the Titan atmosphere can be successfully determined by the Titan-probe radiometer, by measuring the intensity of the CN(violet) radiation emitted in the shock layer during the high velocity portion of the probe entry between 200 and 400 km altitude. It is shown that the sensitivity of the CN(violet) radiation makes it possible to determine the mole fractions of N2, CH4, and Ar to about 0.015, 0.003, and 0.01, respectively, i.e., much better than the present uncertainties in the composition of Titan atmosphere. 29 Refs. (edited)

45) Title: A review of reaction rates in high temperature air
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, AIAA Paper 89-1740, 19 p. (see A89-43254)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ATMOSPHERIC TEMPERATURE/*HIGH TEMPERATURE AIR /*HYPERSONIC VEHICLES/*REACTION KINETICS /*THERMAL DISSOCIATION/*THERMOCHEMISTRY
Minor Term: / GAS IONIZATION/ NITRIC OXIDE/ NITROGEN/ NITROUS OXIDES / OXYGEN
Abstract: The existing experimental data on the rate coefficients for the chemical reactions in nonequilibrium high temperature air are reviewed and collated, and a selected set of such values is recommended for use in hypersonic flow calculations. For the reactions of neutral species, the recommended values are chosen from the experimental data that existed mostly prior to 1970, and are slightly different from those used previously. For the reactions involving ions, the recommended rate coefficients are newly chosen from the experimental data obtained more recently. The reacting environment is assumed to lack thermal equilibrium, and the rate coefficients are expressed as a function of the controlling temperature, incorporating the recent multi-temperature reaction concept. 103 Refs.

46) Title: A new rotational relaxation model for use in hypersonic computational fluid dynamics

Author: Chapman, Dean E.; Park, Chul; Lumpkin, Forrest E., III

Corp: Stanford University, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics Conference, 24th, Buffalo, NY, June 12-14, 1989, AIAA Paper 89-1737, 12 p. (see A89-43251)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*COMPUTATIONAL FLUID DYNAMICS/*HYPERSONIC FLOW /*RELAXATION METHOD (MATHEMATICS)/*SHOCK WAVES

Minor Term: / CHAPMAN-ENSKOG THEORY/ MACH NUMBER / NAVIER-STOKES EQUATION/ NITROGEN

Abstract: The theoretical basis for the Landau-Teller equation commonly used to model rotational nonequilibrium is reviewed. Several assumptions underlying this model are indicated to be unrealistic for rarefied hypersonic flow. A new rotational nonequilibrium model based on recent measurements up to 2000K of quantum state transition rates is presented. The new model is applied to the continuum study of normal shock wave structure using both the Burnett equations and a simplified nonlinear constitutive relation. Comparisons are made between shock wave temperature profiles generated from the new model and those generated using the Landau-Teller model. Comparisons of shock reciprocal thicknesses between experimental data for nitrogen and continuum solutions using both rotational models are made. The new rotational model agrees well with experiment up to Mach 6, and under predicts shock thickness at higher Mach numbers. The Landau-Teller model agrees well with experimental shock thickness up to Mach 3, and over predicts the thickness at higher Mach numbers. A modification to the rotational collision number in the Landau-Teller model is found to give results which agree with experimental shock thicknesses at all Mach numbers up to 11. 20 Refs.

47) Title: A fully-coupled implicit method for thermo-chemical nonequilibrium air at sub-orbital flight speeds

Author: Park, Chul; Yoon, Seokkwan
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; MCAT Institute, Moffett Field, CA, USA

Source: AIAA, Computational Fluid Dynamics Conference, 9th, Buffalo, NY, June 13-15, 1989, AIAA Paper 89-1974, 10 p. (see A89-41818, see also AIAA, Computational Fluid Dynamics Conference, 9th, Technical Papers, AIAA, Washington, DC, 1989, p. 440-449. (see A89-41776))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper

Major Term: /*AEROTHERMOCHEMISTRY/*AIRFOILS /*COMPUTATIONAL FLUID DYNAMICS/*HYPERSONIC FLIGHT /*NONEQUILIBRIUM THERMODYNAMICS

Minor Term: / AERODYNAMIC DRAG/ CARTESIAN COORDINATES / CHEMICAL EQUILIBRIUM/ CIRCULAR CYLINDERS / CONSERVATION EQUATIONS/ LIFT/ MOLECULAR EXCITATION / PITCHING MOMENTS

Abstract: A CFD technique is described in which the finite-rate chemistry in thermal and chemical nonequilibrium air is fully and implicitly coupled with the fluid motion. Developed for use in the suborbital hypersonic flight speed range, the method accounts for nonequilibrium vibrational and electronic excitation and dissociation, but not ionization. The steady-state solution to the resulting system of equations is obtained by using a lower-upper factorization and symmetric Gauss-Seidel sweeping technique through Newton iteration. Inversion of the left-hand-side matrices is replaced by scalar multiplications through the use of the diagonal dominance algorithm. The code, named CENS2H (Compressible-Euler-Navier-Stokes Two-Dimensional Hypersonic), is fully vectorized and requires about 8.8 x 10 to the minus 5th sec per node point per iteration using a Cray X-MP computer. Converged solutions are obtained after about 2400 iterations. Sample calculations are made for a circular cylinder and a 10 percent airfoil at 5 degree angle of attack. The calculated cylinder flow field agrees with that obtained experimentally. The code predicts a 10 percent change in lift, drag, and pitching moment for the airfoil due to the thermochemical phenomena. 14 Refs.

48) Title: Modeling of hypersonic reacting flows
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, January 16-20, 1989, 30 p. (see A89-33631)
Sponsor: University of Texas, Austin, TX, USA; U.S. Air Force Academy, Colorado Springs, CO, USA
Doc. Type: Short Course Lecture
Major Term: /*AEROTHERMOCHEMISTRY/*EQUATIONS OF MOTION /*FLOW EQUATIONS/*HYPERSONIC FLOW /*MATHEMATICAL MODELS /*NONEQUILIBRIUM THERMODYNAMICS
Minor Term: / CONSERVATION LAWS/ MODAL RESPONSE / NONEQUILIBRIUM FLOW/ REACTION KINETICS / WIND TUNNEL TESTS
Abstract: The importance of thermochemical nonequilibrium in hypersonic flow is studied as well as the breakdown of a one-temperature kinetic model. Consideration is given to vibration relaxation, reaction rates, and conservation equations for chemical variables. Experimental data on the pitching moment characteristics of the raked-off blunted elliptic cone geometry proposed for use with an aeroassisted orbit transfer vehicle are presented. 19 Refs. (edited)

49) Title: Calculation of real-gas effects on blunt-body trim angles
Author: Park, Chul; Yoon, Seokkwan
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; MCAT Institute, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, January 9-12, 1989, AIAA Paper 89-0685, 16 p. (see A89-28447)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMOCHEMISTRY/*ANGLE OF ATTACK /*BLUNT BODIES/*HYPERSONIC REENTRY/*REAL GASES /*SHOCK LAYERS/*VIBRATION EFFECTS
Minor Term: / APOLLO LUNAR EXPERIMENT MODULE/ COMPUTER PROGRAMS / NAVIER-STOKES EQUATION/ NITROGEN / RADIATIVE HEAT TRANSFER
Abstract: The effect of vibrational excitation and dissociation at high temperatures on the trim angle of attack of a blunt lifting body is calculated for a nonequilibrium flow regime in air using a CFD technique. Air is considered to consist of five neutral species, O, N, NO, O2, and N2. The vibrational excitation energies of the three molecular species and electronic excitation energies of all species are assumed to be characterized by a common temperature Tv which is different from the translational-rotational temperature T. The vibrational-electronic temperature and the species densities are calculated assuming the flow to be in a nonequilibrium state. A new computer code, named CENS2H (Compressible-Euler-Navier-Stokes Two-dimensional Hypersonic), is developed by incorporating this thermochemistry model into an existing perfect-gas code named CENS2D which uses a lower-upper factorization based on symmetric Gauss-Seidel sweeping techniques. The code is applied to compute the forebody flow of a two-dimensional blunt body of the shape of the Apollo Command Module at a finite angle of attack. The results show that the pitching moment around a reference point is larger and the trim angle of attack is smaller for a reacting gas than for a perfect gas. The calculated shift in the trim angle due to the real-gas effect is of the same order as that seen during the Apollo flights. 28 Refs.

50) Title: Aerothermodynamics of manned Mars missions
Author: Park, Chul; Davies, Carol B.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Sterling Software, Inc., Palo Alto, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, January 9-12, 1989, AIAA Paper 89-0313, 21 p. (see A89-26367)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROBRAKING/*AEROTHERMODYNAMICS /*ATMOSPHERIC ENTRY/*MANNED MARS MISSIONS
Minor Term: / LIFT DRAG RATIO/ RADIATIVE HEAT TRANSFER / SPACECRAFT TRAJECTORIES/ TRAJECTORY ANALYSIS / TRANSFER ORBITS
Abstract: The aerothermodynamic problems associated with the aerobraking of the spacecraft proposed for the manned Mars mission are studied. The propulsive Delta V necessary at departure from earth and Mars and the velocities of the atmospheric entries into the two planets are deduced. It is shown that the propulsive Delta V can be reduced by increasing the entry velocities and that entry velocities up to about 15 km/sec are appropriate at both earth and Mars. L/D values of 0.8 and 2.0 are found to be necessary at earth and Mars, respectively. Density, pressure, and stagnation-point convective-heat-transfer rates are calculated for the typical aerobraking flights. Assuming the shock layer flow to be in equilibrium, the stagnation-point radiative-heat-transfer rates are calculated to be larger than the convective-heat-transfer rates. The possible impact of ablation, turbulence, and nonequilibrium are discussed. 29 Refs.

51) Title: Experimental program for real gas flow code validation at NASA Ames Research Center

Author: Deiwert, George S.; Strawa, Anthony W.; Sharma, Surendra P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-100093, July 1989, 19 p. (see N89-26816, see also AGARD, Symposium on Validation of Computational Fluid Dynamics, Lisbon, Portugal, May 2-5, 1988, AGARD CP-437 (see N89-18630))

Sponsor: NASA, Washington, D. C., USA

Doc. Type: Report

Major Term: /*AERODYNAMIC CONFIGURATIONS /*COMPUTATIONAL FLUID DYNAMICS/*COMPUTER PROGRAMS /*COMPUTERIZED SIMULATION/*CONES/*DRAG/*GAS FLOW /*HYPERSONIC FLOW/*PROGRAM VERIFICATION (COMPUTERS) /*REAL GASES

Minor Term: / AEROASSIST/ ARC JET ENGINES/ BALLISTICS / COLUMBIA (ORBITER)/ FLIGHT TESTS/ GALILEO PROBE / HYPERSONIC WIND TUNNELS/ ORBIT TRANSFER VEHICLES / PIONEER VENUS SPACECRAFT/ SHOCK TUBES/ SPACE PROBES / WIND TUNNEL TESTS

Abstract: The experimental program for validating real gas hypersonic flow codes at NASA Ames Research Center is described. Ground-based test facilities used include ballistic ranges, shock tubes and shock tunnels, arc jet facilities and heated-air hypersonic wind tunnels. Also included are large-scale computer systems for kinetic theory simulations and benchmark code solutions. Flight tests consist of the Aeroassist Flight Experiment, the Space Shuttle, Project Fire 2, and planetary probes such as Galileo, Pioneer Venus, and PAET. 21 Refs.

52) Title: Experimental program for real gas flow code validation at NASA Ames Research Center

Author: Deiwert, George S.; Strawa, Anthony W.; Sharma, Surendra P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AGARD, Validation of Computational Fluid Dynamics. Volume 1: Symposium Papers and Round Table Discussion, AGARD CP-437, 16 p. (see N89-18630)

Sponsor: NATO, AGARD, Neuilly sur Seine, France

Doc. Type: Conference Paper

Major Term: /*COMPUTATIONAL FLUID DYNAMICS/*COMPUTER PROGRAMS /*GAS FLOW/*HYPERSONIC FLOW /*PROGRAM VERIFICATION (COMPUTERS)/*REAL GASES

Minor Term: / BALLISTICS/ FLIGHT TESTS/ SHOCK TUBES / WIND TUNNEL TESTS/ WIND TUNNELS

Abstract: The experimental program for validating real gas hypersonic flow codes at NASA Ames is described. Ground based test facilities used include ballistic ranges, shock tubes and shock tunnels, arcjet facilities and heated air hypersonic wind tunnels. Also included are large scale computer systems for kinetic theory simulations and benchmark code solutions. Flight tests consist of the Aeroassist Flight Experiment, the Space Shuttle, Project Fire 2, and planetary probes such as Galileo, Pioneer Venus and PAET. 21 Refs.

53) Title: Theory of idealized two-dimensional ballute in Newtonian hypersonic flow

Author: Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, no. 3, May-June 1988, p. 217-224. (see A88-51389, see also AIAA, Aerospace Sciences Meeting, 24th, Reno, NV, January 6-9, 1986, AIAA Paper 86-0301, 11 p. (see A86-22689))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROBRAKING/*BALLUTES/*HYPERSONIC FLOW /*ORBIT TRANSFER VEHICLES/*SPACECRAFT DESIGN

Minor Term: / BOUNDARY VALUE PROBLEMS/ CENTER OF GRAVITY / DIFFERENTIAL EQUATIONS/ FLOW THEORY / TWO DIMENSIONAL FLOW

Abstract: A differential equation governing the geometry of a two-dimensional ballute in hypersonic flow and its constraining boundary conditions are derived under idealized assumptions. By solving these equations, the shape of the ballute is determined over a range of conditions. Lift, drag, pitching moment, and the allowed limit of center-of-gravity location for stability (metacenter) are then calculated using Newtonian hypersonic approximation. It is shown that the metacenter occurs near the forward end because of compliance of the ballute membrane to the shock-layer pressures, especially at low freestream densities. 16 Refs. (edited)

54) Title: Optimum configuration of high-lift aeromaneuvering orbital transfer vehicles in viscous flow

Author: Davies, Carol B.; Park, Chul

Corp: Sterling Software, Inc., Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, no. 3, May-June 1988, p. 193-201. (see A88-51386, see also AIAA, Thermophysics Conference, 20th, Williamsburg, VA, June 19-21, 1985, AIAA Paper 85-1059, 16 p. (see A85-37673))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROASSIST/*AEROMANEUVERING /*ORBIT TRANSFER VEHICLES/*SPACECRAFT CONFIGURATIONS /*VISCOUS FLOW

Minor Term: / AERODYNAMIC CHARACTERISTICS/ ANGLE OF ATTACK / DELTA WINGS/ LEADING EDGES/ OPTIMIZATION / SPACECRAFT DESIGN

Abstract: An aeroassisted orbit transfer vehicle (AOTV) with a high lift-to-drag ratio (L/D) is appropriate for missions requiring a large plane inclination angle change. This paper compares the aerodynamic characteristics of three geometric configurations appropriate for such purposes and considers the need to protect and support the necessary payloads in the dead air region. The three configurations are the flat-plate delta wing, truncated straight cone, and truncated bent biconic. The analysis includes the effect of viscosity and examines the rounding of the sharp leading edges. Results indicate that, under the constraints of carrying a given volume in the dead air region, all three configurations provide similar values of L/D. However, the truncated bent biconic is the only configuration that provides the necessary stabilizing moments. Also shown is that a leading-edge bluntness with a radius of 0.1 m is easily tolerated for a body length of 35 m, with little degradation of L/D. An exception to this occurs for a high-aspect-ratio delta plate, where the same radius produces up to a 40% decrease in L/D. 14 Refs.

55) Title: The rate parameters for coupled vibration-dissociation in a generalized SSH approximation --- Schwarz, Slawsky, and Herzfeld

Author: Sharma, Surendra P.; Huo, Winifred M.; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics, Plasmadynamics and Lasers Conference, San Antonio, TX, June 27-29, 1988, AIAA Paper 88-2714, 19 p. (see A88-47075)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper

Major Term: /*AEROTHERMOCHEMISTRY/*DISSOCIATION /*MOLECULAR RELAXATION/*REACTION KINETICS /*VIBRATIONAL SPECTRA

Minor Term: / AEROTHERMODYNAMICS/ COOLING/ ELECTRON TRANSITIONS / ENERGY TRANSFER/ MOLECULAR COLLISIONS/ NITROGEN

Abstract: We report a theoretical study of vibrational excitations and dissociations of nitrogen undergoing a nonequilibrium relaxation process upon heating and cooling. The rate coefficients for collisional induced vibrational transitions and transitions from a bound vibrational state into a dissociative state have been calculated using an extension of the theory originally proposed by Schwarz Slawsky, and Herzfeld (SSH). High-lying vibrational states and dissociative states were explicitly included but rotational energy transfer was neglected. The transition probabilities calculated from the SSH theory were fed into the master equation, which was integrated numerically to determine the population distribution of the vibrational states as well as bulk thermodynamic properties. The results show that: (1) the transition rates have a minimum near the middle of the bound vibrational levels, causing a bottleneck in the vibrational relaxation and dissociation rates; (2) high vibrational states are always in equilibrium with the dissociative state; (3) for the heating case, only the low vibrational states relax according to the Landau-Teller theory; (4) for the cooling case, vibrational relaxation cannot be described by a rate equation; (5) Park's two-temperature model is approximately valid; and (6) the average vibrational energy removed in dissociation is about 30 % of the dissociation energy. 29 Refs.

56) Title: The computation of radiation from nonequilibrium hypersonic flows
Author: Candler, Graham; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Thermophysics, Plasmadynamics and Lasers Conference, San Antonio, TX, June 27-29, 1988, AIAA Paper 88-2678, 12 p. (see A88-44595)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROASSIST/*BLUNT BODIES/*HYPERSONIC FLOW /*IONIZED GASES/*RADIATION DISTRIBUTION
Minor Term: / COMPUTATIONAL GRIDS/ FLOW DISTRIBUTION / FREE ELECTRONS/ MACH NUMBER/ ORBIT TRANSFER VEHICLES / RADIATIVE HEAT TRANSFER
Abstract: The results of the solution of the equations that describe a hypersonic ionized flow about an elliptically blunted cone are presented. The flow conditions correspond to those of the proposed Aeroassist Flight Experiment (AFE) vehicle at altitudes between the perigee at 78 km and the approximate limit of the continuum regime at 90 km. For the free-stream velocities of interest, about 9 km/sec, the flowfield is out of thermo-chemical equilibrium, electronically excited, ionized and radiating. The gas consists of eight-chemical species including free electrons. The thermal state of the gas is modeled with a translational-rotational temperature, four vibrational temperatures for the diatomic species and an electron-electronic temperature. The electronic excitation of molecules is included. The nonequilibrium air radiation from each fluid element is computed and the radiative heat flux at the body surface is determined. The stagnation point radiative heating result agrees with previous calculations. 18 Refs.

57) Title: Assessment of a two-temperature kinetic model for dissociating and weakly ionizing nitrogen

Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 2, no. 1, January 1988, p. 8-16. (see A88-30306, see also AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 4th, Boston, MA, June 2-4, 1986, AIAA Paper 86-1347, 12 p. (see A86-39943))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article

Major Term: /*AEROTHERMODYNAMICS/*GAS DISSOCIATION /*GAS IONIZATION/*NITROGEN/*ORBIT TRANSFER VEHICLES /*REACTION KINETICS

Minor Term: / AEROASSIST/ GAS TEMPERATURE/ HEAT FLUX / MOLECULAR EXCITATION/ RADIATIVE TRANSFER / SHOCK WAVES

Abstract: The validity of a two-temperature chemical/kinetic model is assessed by comparing the calculated results with the existing experimental data for nitrogen in the dissociating and weakly ionizing regime produced behind a normal shock wave. The shock tube radiation program (STRAP) based on the two-temperature model is used in calculating the flow properties behind the shock wave, accounting for the diffuse nature of vibrational relaxation at high temperatures but neglecting the preferential high-vibrational-state removal by dissociation. The nonequilibrium air radiation (NEQAIR) program is used in determining the radiative characteristics of the flow. Comparison is made between the calculated and the existing shock tube data on (1) spectra in the equilibrium region, (2) rotational temperature of the N2+ B state, (3) vibrational temperature of the N2+ B state, (4) electronic excitation temperature of the N2 B state, (5) the shape of the time variation of radiation intensities, (6) the times to reach the peak in radiation intensity and equilibrium, and (7) the ratio of nonequilibrium to equilibrium radiative heat fluxes. Good agreement is seen between the experimental data and the present calculation except for the vibrational temperature. A possible reason for the discrepancy is given. 32 Refs.

58) Title: Two-temperature interpretation of dissociation rate data for N2 and O2
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, January 11-14, 1988, AIAA Paper 88-0458, 23 p. (see A88-22336)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*GAS DISSOCIATION/*NITROGEN/*OXYGEN /*REACTION KINETICS/*SHOCK TUBES/*THERMOCHEMISTRY
Minor Term: / HIGH TEMPERATURE/ HYPERSONIC VEHICLES/ SHOCK WAVES / SPACE SHUTTLES/ WAVE REFLECTION
Abstract: The existing experimental data on dissociation of nitrogen and oxygen obtained using shock-tubes during the 1960's and 1970's are reinterpreted using the two-temperature thermo-chemical model developed recently in order to determine the rate coefficients consistent with the model. In this model, the vibrational-electronic temperature is calculated by integrating a separate conservation equation accounting for the suppression of vibrational energy during dissociation due to preferential removal of high vibrational states. The rate coefficient is assumed to be a function of the geometrically-averaged temperature between the translational-rotational temperature and the vibrational-electronic temperature. By comparing the computed overall and species densities with the experimental data, the rate coefficient values most consistent with the model, and their ranges of uncertainty, are deduced for dissociation of N2 through collisions with N2 or N, and for O2 through collisions with O2, O or N2. It is seen that a single set of such rate coefficients fit all existing experimental data closely. According to the two-temperature model, density and species density are insensitive to the rate coefficients, and so the rate coefficients so determined are uncertain to within a factor of at least 1.5. 41 Refs.

59) Title: Operating characteristics of a 60 cm and a 10 cm electric arc-driven shock-tube

Author: Sharma, Surendra P.; Park, Chul; Dannenberg, Robert E.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Kendan Associates, Palo Alto, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, January 11-14, 1988, AIAA Paper 88-0142, 19 p. (see A88-22103)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ELECTRIC ARCS/*EQUILIBRIUM FLOW/*HYPERSONIC FLOW /*NONEQUILIBRIUM PLASMAS/*SHOCK TUBES

Minor Term: / FLOW VELOCITY/ HIGH TEMPERATURE GASES / SHOCK TUNNELS/ THERMODYNAMIC PROPERTIES

Abstract: This paper describes the current status of the operating characteristics of the electric arc-driven shock-tube facility at Ames Research Center, focusing on its potential usefulness in the current and anticipated future applications. The paper specifically addresses the questions as to: (1) how well the behavior of the arc driver is understood and controlled, (2) how well the facility is equipped to test low-density, very high-velocity nonequilibrium flow regimes, and (3) how closely the facility is expected to produce an equilibrium hypersonic flow when operated in shock-tunnel modes. For these issues, it is shown that: (1) a plasma kinetics model of the exploding wire closely describes the arc behavior in the driver, (2) the facility can produce a spectroscopically-clean flow in a low density regime with a shock velocity of 13 km/sec in air when used with an aluminum driven tube, and (3) when operated as a shock-tunnel, the high enthalpy flow in the test section is expected to deviate only slightly from the perfect equilibrium flow conditions at enthalpies corresponding to flight speeds of 5 km/sec or less. 33 Refs.

60) Title: Assessment of two-temperature kinetic model for ionizing air
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987, AIAA Paper 87-1574, 13 p. (see A87-44833)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMOCHEMISTRY/*GAS IONIZATION /*MOLECULAR OSCILLATIONS/*NONEQUILIBRIUM FLOW /*REACTION KINETICS/*SHOCK LAYERS
Minor Term: / AIR FLOW/ HEAT FLUX/ HIGH TEMPERATURE / MOLECULAR RELAXATION/ RADIATIVE HEAT TRANSFER / SHOCK TUBES
Abstract: A two-temperature chemical-kinetic model for air is assessed by comparing theoretical results with existing experimental data obtained in shock-tubes, ballistic ranges, and flight experiments. In the model, named the TTv model, one temperature (T) is assumed to characterize the heavy-particle translational and molecular rotational energies, and another temperature (Tv) to characterize the molecular vibrational, electron translational, and electronic excitation energies. The theoretical results for nonequilibrium air flow in shock tubes are obtained using the computer code STRAP (Shock-Tube Radiation Program), and for flow along the stagnation streamline in the shock layer over spherical bodies using the newly developed code STRAP (Stagnation-Point Radiation Program). Substantial agreement is shown between the theoretical and experimental results for relaxation times and radiative heat fluxes. At very high temperatures the spectral calculations need further improvement. The present agreement provides strong evidence that the two-temperature model characterizes principal features of nonequilibrium air flow. New theoretical results using the model are presented for the radiative heat fluxes at the stagnation point of a 6-m-radius sphere, representing an aeroassisted orbital transfer vehicle, over a range of free-stream conditions. Assumptions, approximations, and limitations of the model are discussed. 32 Refs.

61) Title: A survey of simulation and diagnostic techniques for hypersonic nonequilibrium flows

Author: Sharma, Surendra P.; Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, January 12-15, 1987, AIAA Paper 87-0406, 17 p. (see A87-24958)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*FLOW VISUALIZATION/*HYPERSONIC FLOW /*NONEQUILIBRIUM FLOW/*SIMULATION

Minor Term: / AEROTHERMODYNAMICS/ CHEMICAL REACTIONS / COMPUTATIONAL FLUID DYNAMICS/ SHOCK TUBES / SPECTROSCOPY

Abstract: The possible means of simulating nonequilibrium reacting flows in hypersonic environments, and the required diagnostic techniques, are surveyed in two categories: bulk flow behavior and determination of chemical rate parameters. Flow visualization of shock shapes for validation of computational-fluid dynamic calculations is proposed. The facilities and the operating conditions necessary to produce the required nonequilibrium conditions, the suitable optical techniques, and their sensitivity requirements, are surveyed. Shock-tubes, shock-tunnels, and ballistic ranges in a wide range of sizes and strengths are found to be useful for this purpose, but severe sensitivity requirements are indicated for the optical instruments, which can be met only by using highly-collimated laser sources. Likewise, for the determination of chemical parameters, this paper summarizes the quantities that need to be determined, required facilities and their operating conditions, and the suitable diagnostic techniques and their performance requirements. Shock tubes of various strengths are found to be useful for this purpose. Vacuum ultraviolet absorption and fluorescence spectroscopy and coherent anti-Stokes Raman spectroscopy are found to be the techniques best suited for the measurements of the chemical data. 64 Refs.

62) Title: A survey of aerobraking orbital transfer vehicle design concepts
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, January 12-15, 1987, AIAA Paper 87-0514, 20 p. (see A87-22679)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROBRAKING/*ORBIT TRANSFER VEHICLES /*SPACECRAFT DESIGN
Minor Term: / AERODYNAMIC STABILITY/ AEROTHERMODYNAMICS / AFTERBODIES/ CONVECTIVE HEAT TRANSFER / JET IMPINGEMENT/ SPACE NAVIGATION / SPACECRAFT CONFIGURATIONS/ SPACECRAFT GUIDANCE
Abstract: The five existing design concepts of the aerobraking orbital transfer vehicle (namely, the raked sphere-cone designs, conical lifting-brake, raked elliptic-cone, lifting-body, and ballute) are reviewed and critiqued. Historical backgrounds, and the geometrical, aerothermal, and operational features of these designs are reviewed first. Then, the technological requirements for the vehicle (namely, navigation, aerodynamic stability and control, afterbody flow impingement, nonequilibrium radiation, convective heat-transfer rates, mission abort and multiple atmospheric passes, transportation and construction, and the payload-to-vehicle weight requirements) are delineated by summarizing the recent advancements made on these issues. Each of the five designs are critiqued and rated on these issues. The highest and the lowest ratings are given to the raked sphere-cone and the ballute design, respectively. 74 Refs.

63) Title: A review of shock waves around aeroassisted orbital transfer vehicles
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Symposium on Shock Waves and Shock Tubes, 15th, Berkeley, CA, July 28-August 2, 1985; Shock waves and shock tubes, Stanford University Press, Stanford, CA, 1986, p. 27-41. (see A87-12576, see also A87-12577, see also NASA, Ames Research Center, Moffett Field, CA, NASA-TM-86769, June 1985, 33 p. (see N85-33177))
Sponsor: University of California, Berkeley, CA, USA; Stanford University, Stanford, CA, USA
Doc. Type: Conference Paper
Major Term: /*AERODYNAMIC FORCES/*ATMOSPHERIC EFFECTS /*EARTH ATMOSPHERE/*ORBIT TRANSFER VEHICLES
Minor Term: / AERODYNAMIC BRAKES/ ATMOSPHERIC ENTRY / HIGH TEMPERATURE/ NONEQUILIBRIUM FLOW / SHOCK HEATING/ SHOCK WAVES/ SPACE STATIONS / SPACE TRANSPORTATION
Abstract: Aeroassisted orbital transfer vehicles (AOTVs) are a proposed type of reusable spacecraft that would be used to transport cargoes from one earth-bound orbit to another. Such vehicles could be based on the proposed space station and used to transport commercial satellites from the space station to geostationary orbits or to polar orbits and return. During a mission, AOTVs would fly through earth's atmosphere, thus generating aerodynamic forces that could be used for decelerating the vehicles or changing their direction. AOTV research findings were concerned with the shock-wave-induced, high-temperature airflows that would be produced around these vehicles during atmospheric flight. Special emphasis was placed on the problems of: (1) the chemical physics of multi-temperature, ionizing, nonequilibrium air flows, and (2) the dynamics of the flows in the base region of a blunt body with complex afterbody geometry. 54 Refs.

64) Title: Determining atmospheric density using a space-launched projectile
Author: Menees, G. P.; Park, C.; Brown, K. G.; Wilson, J. F.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Informatics General Corporation, Palo Alto, CA, USA
Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, no. 3, May-June 1986, p. 273-280. (see A86-41737, see also AIAA, Aerospace Sciences Meeting, 23rd, Reno, NV, January 14-17, 1985, AIAA Paper 85-0327, 12 p. (see A85-20866))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROASSIST/*AERODYNAMIC CHARACTERISTICS /*ATMOSPHERIC DENSITY/*FLIGHT CHARACTERISTICS /*HYPERVELOCITY PROJECTILES/*ORBITAL LAUNCHING
Minor Term: / AEROTHERMODYNAMICS/ DECELERATION / DENSITY DISTRIBUTION/ ORBITAL MANEUVERING VEHICLES / TRAJECTORY ANALYSIS/ TRANSFER ORBITS
Abstract: A method that provides advance information about unpredictable atmospheric density dispersions that must be accommodated during random operations of aeroassisted orbital transfer vehicles (AOTVs) is proposed. The principal feature is that a test or 'scout' projectile proceeds the AOTV through the same region of the atmosphere as that of the predicted transatmospheric flight trajectory. The time lag between passage of the projectile and the AOTV can be adjusted to only that time necessary to implement required guidance, navigation, and control corrections. The various strategies available to control the projectile's flight characteristics are analyzed in detail. The results are correlated with aerothermodynamic heating and materials requirements to ensure the survival of the projectile and, consequently, the capability of the AOTV to navigate a variable upper atmosphere within specified limits. 17 Refs.

65) Title: Assessment of two-temperature kinetic model for dissociating and weakly-ionizing nitrogen

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 4th, Boston, MA, June 2-4, 1986, AIAA Paper 86-1347, 12 p. (see A86-39943)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROTHERMODYNAMICS/*GAS DISSOCIATION /*GAS IONIZATION/*KINETIC THEORY/*NITROGEN /*REACTION KINETICS

Minor Term: / AEROASSIST/ GAS TEMPERATURE/ HEAT FLUX / MOLECULAR EXCITATION/ RADIATIVE TRANSFER / SHOCK WAVES/ VIBRATIONAL SPECTRA

Abstract: The validity of the author's two-temperature, chemical/kinetic model which the author has recently improved is assessed by comparing the calculated results with the existing experimental data for nitrogen in the dissociating and weakly ionizing regime produced behind a normal shock wave. The computer program Shock Tube Radiation Program (STRAP) based on the two-temperature model is used in calculating the flow properties behind the shock wave and the Nonequilibrium Air Radiation (NEQAIR) program, in determining the radiative characteristics of the flow. Both programs were developed earlier. Comparison is made between the calculated and the existing shock tube data on (1) spectra in the equilibrium region, (2) rotational temperature of the N2(+) B state, (3) vibrational temperature of the N2(+) B state, (4) electronic excitation temperature of the N2 B state, (5) the shape of time-variation of radiation intensities, (6) the times to reach the peak in radiation intensity and equilibrium, and (7) the ratio of nonequilibrium to equilibrium radiative heat fluxes. Good agreement is seen between the experimental data and the present calculation except for the vibrational temperature. A possible reason for the discrepancy is given. 26 Refs.

66) Title: Aerodynamic and thermal characteristics of modified raked-off blunted cone

Author: Davies, C. B.; Park, C.

Corp: Informatics General Corporation, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 4th, Boston, MA, June 2-4, 1986, AIAA Paper 86-1309, 16 p. (see A86-39914)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AERODYNAMIC CHARACTERISTICS/*AEROTHERMODYNAMICS /*BLUNT BODIES/*CONES/*HEAT TRANSFER

Minor Term: / AEROBRAKING/ DRAG COEFFICIENTS/ ELLIPTICITY / LIFT DRAG RATIO/ PITCHING MOMENTS / RADIATIVE HEAT TRANSFER/ STAGNATION POINT

Abstract: One of the leading candidate concepts of aeroassisted orbital transfer vehicles incorporates an aerobrake in the shape of a raked-off ellipsoidally blunted elliptic cone. The present paper proposes modifying this geometry to a spherically blunted circular cone to avoid flow impingement on the afterbody. In addition, the vehicle components are arranged axially so that the vehicle is always aerodynamically stable and controllable. The Newtonian aerodynamic characteristics of the modified aerobrake geometry are determined and are shown to be nearly identical to those of the elliptic cone described above. Flight regimes and heat transfer rates, both convective and nonequilibrium radiative, are calculated using the most up-to-date methods. It is shown that the total heat transfer rates for a noncatalytic heat shield will remain below tolerable limits. 26 Refs.

67) Title: Theory of idealized two-dimensional ballute in Newtonian hypersonic flow

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 24th, Reno, NV, January 6-9, 1986, AIAA Paper 86-0301, 11 p. (see A86-22689)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*BALLUTES/*DESIGN ANALYSIS/*HYPERSONIC FLOW /*ORBIT TRANSFER VEHICLES

Minor Term: / BOUNDARY CONDITIONS/ BOUNDARY VALUE PROBLEMS / CENTER OF GRAVITY/ DIFFERENTIAL EQUATIONS

Abstract: A differential equation governing the geometry of a two-dimensional ballute in hypersonic flow and its constraining boundary conditions are derived under idealized assumptions. By solving these equations, the shape of the ballute is determined over a range of conditions. Lift, drag, pitching moment, and the allowed limit of center-of-gravity location for stability (meta-center) are then calculated using Newtonian hypersonic approximation. It is shown that the meta-center occurs near the forward end because of compliance of the ballute membrane to the shock layer pressures, especially at low free-stream densities. In order for the vehicle employing the ballute to be stable at all densities, the center of gravity must be within approximately the forward 20 percent of overall length of the vehicle. However, typical flight trajectories of an aeroassisted orbital transfer vehicle employing the ballute for aerobraking show that the vehicle may be able to complete its atmospheric flight without tumbling provided that the center of gravity is located within the forward 43 percent of the vehicle length because of the relatively short duration of flight through the destabilizing low-density regime. 15 Refs.

68) Title: Convergence of computation of chemical reacting flows
Author: Park, Chul
Corp: Ames Research Center, NASA, Moffett Field, CA, USA
Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Thermophysical aspects re-entry flows, vol. 103, AIAA, Washington, D. C., 1986, p. 478-513. (see also AIAA, Aerospace Sciences Meeting, 23rd, Reno, NV, January 14-17, 1985, AIAA Paper 85-0247, 17 p. (see A85-20863))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*COMPUTATIONAL FLUID DYNAMICS/*CONVERGENCE /*GAS DISSOCIATION/*NONEQUILIBRIUM FLOW /*REENTRY PHYSICS/*SUBSONIC FLOW/*TIME MARCHING
Minor Term: / CONSERVATION EQUATIONS/ DUCTED FLOW/ GAS FLOW / HYPERSONIC REENTRY/ IONIZATION / ONE DIMENSIONAL FLOW/ PRESSURE OSCILLATIONS / SHOCK WAVES
Abstract: The computational problems associated with high-temperature flows undergoing finite-rate chemical reactions is investigated. The conservation equations governing chemical species and vibrational and electron energies are solved simultaneously with those for overall mass, momentum and energy for a one-dimensional, viscous, subsonic flow through a constant-area duct, originating behind a normal shock wave, using an implicit time-marching technique. Boundary conditions are imposed in the form of characteristic wave variables accounting for the effects of chemical reactions on the speed of sound. Converging solutions are obtained by removing artificial damping, and by using double-precision arithmetic for inverting matrices. Convergence is faster when chemical reactions are introduced gradually, and when an inviscid, steady, reacting flow solution is used as the starting solution. The possible causes for these behaviors are discussed. 28 Refs.

69) Title: Problems of rate chemistry in the flight regimes of aeroassisted orbital transfer vehicles

Author: Park, Chul

Corp: Ames Research Center, NASA, Moffett Field, CA, USA

Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Thermal design of aeroassisted orbital transfer vehicles, vol. 96, AIAA, Washington, D. C., 1985, p. 511-37. (see AIAA, Thermophysics Conference, 19th, Snowmass, CO, June 25-28, 1984, AIAA Paper 84-1730, 11 p. (see A84-39369))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROASSIST/*COMPUTATIONAL CHEMISTRY /*NONEQUILIBRIUM FLOW/*ORBIT TRANSFER VEHICLES /*RADIATIVE HEAT TRANSFER/*REACTION KINETICS

Minor Term: / COMPUTATIONAL FLUID DYNAMICS/ HEAT FLUX / HEAT SHIELDING/ NORMAL SHOCK WAVES / ONE DIMENSIONAL FLOW

Abstract: The dissociating and ionizing nonequilibrium flows behind a normal shock wave are calculated for the density and vehicle regimes appropriate for aeroassisted orbital transfer vehicles; the departure of vibrational and electron temperatures from the gas temperature as well as viscous transport are accounted for. From the thermodynamic properties so determined, radiative power emission is calculated using an existing code. The resulting radiation characteristics are compared with the available experimental data. Chemical parameters are varied to investigate their effect on the radiation characteristics. It is concluded that the current knowledge of rate chemistry leads to a factor-of-4 uncertainty in nonequilibrium radiation intensities. The chemical parameters that must be studied to improve the accuracy are identified. 26 Refs.

70) Title: Calculation of nonequilibrium radiation in the flight regimes of aeroassisted orbital transfer vehicles

Author: Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Thermal design of aeroassisted orbital transfer vehicles, vol. 96, AIAA, Washington, D. C., 1985, p. 395-418. (see also AIAA, Aerospace Sciences Meeting, 22nd, Reno, NV, January 9-12, 1984, AIAA Paper 84-0306, 13 p. (see A84-18011)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROASSIST/*COMPUTERIZED SIMULATION /*ENVIRONMENT SIMULATION/*NONEQUILIBRIUM RADIATION /*ORBIT TRANSFER VEHICLES/*RADIATIVE TRANSFER

Minor Term: / ABSORPTION SPECTRA/ AIR/ ATOMIC EXCITATIONS / EMISSION SPECTRA/ FLIGHT SIMULATION/ GAS DENSITY / MOLECULAR EXCITATION / NONEQUILIBRIUM THERMODYNAMICS

Abstract: A computer code has been developed that calculates radiative properties of nonequilibrium air in the low-density regimes expected during the flight of aeroassisted, orbital transfer vehicles. From the given nonequilibrium thermodynamic state variables, the code calculates number densities of internal states and the accompanying emission and absorption characteristics. In addition, the code calculates the number density of the hypothetical gas in radiative equilibrium that produces the same radiation emission as the given nonequilibrium gas. Sample results are shown to demonstrate how the code predicts the nonlinear variation of radiation with density at low densities. 38 Refs.

71) Title: Radiometer experiment for the aeroassist flight experiment --- Thermal protection data for Orbital Transfer Vehicle design

Author: Davy, W. C.; Park, C.; Arnold, J. O.; Balakrishnan, A.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Eloret Institute, Sunnyvale, CA, USA

Source: AIAA, Thermophysics Conference, 20th, Williamsburg, VA, June 19-21, 1985, AIAA Paper 85-0967, 9 p. (see A85-38943)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*AEROTHERMODYNAMICS/*FLIGHT TESTS /*ORBIT TRANSFER VEHICLES/*RADIOMETERS /*THERMAL PROTECTION

Minor Term: / ATMOSPHERIC ENTRY/ HEAT SHIELDING/ RADIANT HEATING / SPACE SHUTTLE PAYLOADS/ SPACEBORNE EXPERIMENTS / SPACECRAFT DESIGN/ SPACECRAFT SHIELDING

Abstract: A forthcoming NASA flight experiment is described that provides an opportunity to obtain a large base of radiometric data for high-altitude, high-velocity thermochemically nonequilibrated flow conditions. As a preliminary to the design of a radiometer for this experiment, an approximate method for predicting both equilibrium and nonequilibrium radiative surface fluxes is described. Spectral results for one trajectory state, a velocity of 10 km/sec at an altitude of 85 km, are presented. These results are then used to develop some of the instrument parameters that will be needed for designing of the three genre of radiometers that are proposed for this experiment. 14 Refs.

72) Title: Radiative viscous-shock-layer analysis of Fire, Apollo, and PAET flight data

Author: Balakrishnan, A.; Park, C.; Green, M. J.

Corp: Eloret Institute, Sunnyvale, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics Conference, 20th, Williamsburg, VA, June 19-21, 1985, AIAA Paper 85-1064, 13 p. (see A85-37676)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AERODYNAMIC HEATING/*CONVECTIVE HEAT TRANSFER /*RADIATIVE HEAT TRANSFER/*SHOCK LAYERS /*SPACECRAFT REENTRY/*VISCOUS FLOW

Minor Term: / APOLLO FLIGHTS/ ORBIT TRANSFER VEHICLES / STAGNATION POINT/ THERMODYNAMIC EQUILIBRIUM

Abstract: Equilibrium, radiating viscous-shock-layer solutions are obtained for a number of trajectory points of the Fire II, Apollo 4, and PAET experimental flight vehicles. Convective heating rates calculated by a benchmark code agree well, except at high altitudes corresponding to low densities, with two engineering correlations. Calculated radiation intensities are compared with the flight radiometer data and with inviscid flow results. Differences as great as 70 percent are observed between measured data and the viscous calculations. Viscous effects reduce the intensity toward the wall, because of boundary-layer absorption, by as much as 30 percent, compared with inviscid intensities. Preliminary chemical and thermal nonequilibrium flow calculations along a stagnation streamline for a PAET trajectory predict enhancement of radiation owing to chemical relaxation. Stagnation point solutions are also presented for future air-assisted orbital transfer vehicle geometries with nose radii ranging from 0.3 to 15 m. 26 Refs.

73) Title: Optimum configuration of high-lift aeromaneuvering orbital transfer vehicles in viscous flow

Author: Davies, C. B.; Park, C.

Corp: Informatics General Corporation, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics Conference, 20th, Williamsburg, VA, June 19-21, 1985, AIAA Paper 85-1059, 16 p. (see A85-37673)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*AEROMANEUVERING /*ORBIT TRANSFER VEHICLES/*SPACECRAFT CONFIGURATIONS /*VISCOUS FLOW

Minor Term: / AERODYNAMIC CHARACTERISTICS/ ANGLE OF ATTACK / DELTA WINGS/ LEADING EDGES/ SPACECRAFT DESIGN

Abstract: An aeroassisted transfer vehicle (AOTV) with a high lift-to-drag ratio (L/D) is appropriate for missions requiring a large plane inclination angle change. This paper compares the aerodynamic characteristics of three geometric configurations appropriate for such purposes and considers the need to protect and support the necessary payloads in the dead air region. The three configurations are: flat-plate delta wing, truncated straight cone, and truncated bent biconic. The analysis includes the effect of viscosity and examines the rounding of the sharp leading edges. Results indicate that, under the constraints of carrying a given volume in the dead air region, all three configurations provide similar values of L/D. However, the truncated bent biconic is the only configuration that provides the necessary stabilizing moments. Also shown is that a leading edge bluntness with a radius of 0.1 m is easily tolerated for a body length of 35 m, with little degradation of L/D. An exception to this occurs for a high-aspect-ratio delta plate, where the same radius produces up to a 40 % decrease in L/D. 13 Refs.

74) Title: Aerodynamics of generalized bent biconics for aeroassisted orbital transfer vehicles

Author: Davies, C. B.; Park, C.

Corp: Informatics General Corporation, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 22, no. 2, March-April 1985, p. 104-111. (see A85-29302, see also AIAA, Thermophysics Conference, 18th, Montreal, Canada, June 1-3, 1983, AIAA Paper 83-1512, 15 p. (see A83-32749))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*AEROASSIST/*AEROBRAKING/*AERODYNAMIC CHARACTERISTICS /*ORBIT TRANSFER VEHICLES/*SPACECRAFT DESIGN

Minor Term: / AERODYNAMIC DRAG/ AEROMANEUVERING / COMPUTER PROGRAMS/ CONICAL BODIES/ LIFT

Abstract: A method was developed to generate the surface coordinates of body shapes suitable for aero-assisted, orbital-transfer vehicles (AOTVs) by extending bent biconic geometries. Lift, drag, and longitudinal moments were calculated for the bodies using Newtonian flow theory. These techniques were applied to symmetric and asymmetric aerobraking vehicles, and to an aeromaneuvering vehicle with high L/D. Results for aerobraking applications indicate that a 70 degree, fore half cone angle with a spherically blunted nose, rounded edges, and a slight asymmetry would be appropriate. Moreover, results show that an aeromaneuvering vehicle with L/D > 2.0, and with sufficient stability, is feasible. 11 Refs.

75) Title: Ablation of Galileo Probe heat-shield models in a ballistic range
Author: Park, C.; Balakrishnan, A.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; PEDA Corporation, Palo Alto, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 23, no. 2, February 1985, p. 301-308. (see A85-21872)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABLATIVE MATERIALS/*ATMOSPHERIC ENTRY /*GALILEO PROBE/*HEAT SHIELDING /*SPACE ENVIRONMENT SIMULATION
Minor Term: / BALLISTIC RANGES/ CARBON/ PHENOLIC RESINS / REENTRY SHIELDING/ SCALE MODELS/ STAGNATION POINT
Abstract: Several 1/24-scale models of the Galileo Probe made of carbon-phenolic materials were flown in a ballistic range to test their ablation characteristics. Mostly radiative or all-convective heating environments were produced by using argon or air as the test gas, respectively, to simulate the Jovian entry heating environments. The experimental results were compared with the theoretical predictions made using the computer codes of radiating shock layer environment (RASLE) and charring materials ablation (CMA). The experimental data obtained in argon agreed approximately with the theoretical predictions. The data for air agreed approximately with the theory when turbulence and surface roughness effects were accounted for. The data imply that the Galileo Probe heat shield was adequately designed. 25 Refs.

76) Title: Radiation enhancement by nonequilibrium in earth's atmosphere
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 22, no. 1, January-February 1985, p. 27-36. (see A85-21828, see also AIAA, Aerospace Sciences Meeting, 21st, Reno, NV, January 10-13, 1983, AIAA Paper 83-0410, 13 p. (see A83-16698))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROASSIST/*EARTH ATMOSPHERE /*NONEQUILIBRIUM RADIATION/*ORBIT TRANSFER VEHICLES /*RADIATIVE HEAT TRANSFER/*SHOCK LAYERS
Minor Term: / APOLLO FLIGHTS/ BALLISTIC RANGES/ DATA ACQUISITION / MATHEMATICAL MODELS/ RATES (PER TIME)/ SHOCK TUBES
Abstract: The status of knowledge of shock-layer radiation in the low-density nonequilibrium regime, as appropriate to the flight of the proposed aeroassisted orbital transfer vehicle, is surveyed. The existing laboratory data and the flight data from Apollo and Fire are scrutinized. Nonequilibrium radiation is found to be significant in the flight regime of the vehicle, but a factor-of-three uncertainty is found in its magnitude. The available theoretical models are reviewed, their weaknesses are pointed out, a computer code that approximately reproduces the existing data is introduced, and recommendations are made for future research. 34 Refs.

77) Title: Determination of atmospheric density using a space-launched projectile
Author: Menees, G. P.; Park, C.; Brown, K. G.; Wilson, J. F.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Department of the Air Force, Washington, D. C., USA; Informatics General Corporation, Palo Alto, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 23rd, Reno, NV, January 14-17, 1985, AIAA Paper 85-0327, 12 p. (see A85-20866)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROASSIST/*AERODYNAMIC CHARACTERISTICS /*ATMOSPHERIC DENSITY/*FLIGHT CHARACTERISTICS /*HYPERVELOCITY PROJECTILES/*ORBITAL LAUNCHING
Minor Term: / AEROTHERMODYNAMICS/ DECELERATION / DENSITY DISTRIBUTION/ ORBITAL MANEUVERING VEHICLES / TRAJECTORY ANALYSIS/ TRANSFER ORBITS
Abstract: A method is proposed that provides advance information about unpredictable atmospheric density dispersions that must be accommodated during random operations of aeroassisted-orbital-transfer vehicles (AOTVs). The principal feature is that a test or 'scout' projectile precedes the AOTV through the same region of the atmosphere as that of the predicted transatmospheric flight trajectory. The atmospheric density structure is determined from the vehicle's aerodynamic deceleration characteristics by on-board or ground-based tracking equipment. The time lag between passage of the projectile and the AOTV can be adjusted to only that time necessary to implement required guidance, navigation, and control (GN&C) corrections. The various strategies available to control the projectile's flight characteristics are analyzed in detail. The results are correlated with aerothermodynamic heating and materials requirements to ensure the survival of the projectile and, consequently, the capability of the AOTV to navigate a variable upper atmosphere within specified limits. 17 Refs.

78) Title: On convergence of computation of chemically reacting flows
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 23rd, Reno, NV, January 14-17, 1985, AIAA Paper 85-0247, 17 p. (see A85-20863)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*COMPUTATIONAL FLUID DYNAMICS/*CONVERGENCE /*GAS DISSOCIATION/*NONEQUILIBRIUM FLOW /*REENTRY PHYSICS/*SUBSONIC FLOW/*TIME MARCHING
Minor Term: / CONSERVATION EQUATIONS/ DUCTED FLOW/ GAS FLOW / HYPERSONIC REENTRY/ IONIZATION / ONE DIMENSIONAL FLOW/ PRESSURE OSCILLATIONS / SHOCK WAVES

Abstract: The computational problems associated with high-temperature flows undergoing finite-rate ionization reactions is investigated. The conservation equations governing chemical species and vibrational and electron energies are solved simultaneously with those for overall mass, momentum, and energy for a one-dimensional subsonic flow, through a constant-area duct, originating behind a normal shock wave, using an implicit time-marching technique. Boundary conditions are imposed in the form of characteristic wave variables accounting for the effects of chemical reactions on the speed of sound. Converging solutions are obtained for cases in which chemical reactions are weak, but difficulty is encountered in other cases. The cause of the difficulty is investigated and shown to be the sharp pressure disturbances produced by such reactions. 30 Refs.

79) Title: A review of shock waves around aeroassisted orbital transfer vehicles
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-86760, June 1985, 33 p. (see N85-33177)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*AERODYNAMIC FORCES/*ATMOSPHERIC EFFECTS /*EARTH ATMOSPHERE/*ORBIT TRANSFER VEHICLES
Minor Term: / AERODYNAMIC BRAKES/ ATMOSPHERIC ENTRY / HIGH TEMPERATURE/ NONEQUILIBRIUM FLOW / SHOCK HEATING/ SHOCK WAVES/ SPACE STATIONS / SPACE TRANSPORTATION

Abstract: Aeroassisted orbital transfer vehicles (AOTVs) are a proposed type of reusable spacecraft that would be used to transport cargoes from one Earth-bound orbit to another. Such vehicles could be based on the proposed space station and used to transport commercial satellites from the space station to geostationary orbits or to polar orbits and return. During a mission, AOTVs would fly through Earth's atmosphere, thus generating aerodynamic forces that could be used for decelerating the vehicles or changing their direction. AOTV research findings were concerned with the shock-wave-induced, high-temperature airflows that would be produced around these vehicles during atmospheric flight. Special emphasis was placed on the problems of: (1) the chemical physics of multi-temperature, ionizing, nonequilibrium air flows, and (2) the dynamics of the flows in the base region of a blunt body with complex afterbody geometry. 54 Refs.

80) Title: Nonequilibrium air radiation (NEQAIR) program: User's manual
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-86707, July 1985, 133 p. (see N85-30780)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*AEROASSIST/*COMPUTER PROGRAMS
/*LOW DENSITY RESEARCH/*NONEQUILIBRIUM CONDITIONS
/*NONEQUILIBRIUM RADIATION
/*ORBIT TRANSFER VEHICLES/*RAREFIED GASES
/*USER MANUALS (COMPUTER PROGRAMS)
Minor Term: / DENSITY (NUMBER/VOLUME)/ MOLECULAR ROTATION
/ THERMODYNAMIC PROPERTIES/ TRANSITION TEMPERATURE
/ VIBRATIONAL SPECTRA
Abstract: This supplement to the paper entitled "Calculation of Nonequilibrium Radiation in the Fight Regimes of Aeroassisted Orbital Transfer Vehicles," AIAA Paper 84-0306, January, 1984, contains listings of the computer code NEQAIR (Nonequilibrium Air Radiation), its primary input data, and explanation of the user-supplied input variables. The user-supplied input variables are the thermodynamic variables of air at a given point, i.e., number densities of various chemical species, translational temperatures of heavy particles and electrons, and vibrational temperature. These thermodynamic variables do not necessarily have to be in thermodynamic equilibrium. The code calculates emission and absorption characteristics of air under these given conditions. 7 Refs.

81) Title: Ablation of carbonaceous materials in a hydrogen-helium arcjet flow
Author: Park, C.; Lundell, J. H.; Green, M. J.; Winovich, W.; Covington, M. A.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 22, no. 10, October 1984, p. 1491-1498. (see A84-48149, see also AIAA, Thermophysics Conference, 18th, Montreal, Canada, June 1-3, 1983, AIAA Paper 83-1561, 12 p. (see A83-32778))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABLATION/*CARBONACEOUS MATERIALS/*HEAT SHIELDING /*HELIUM HYDROGEN ATMOSPHERES/*JET FLOW /*SPACECRAFT SHIELDING
Minor Term: / BLUNT BODIES/ FLOW VISUALIZATION/ HEAT TRANSFER / STAGNATION POINT/ STATIC PRESSURE/ WIND TUNNEL TESTS
Abstract: The stagnation-point ablation rates of a graphite, a carbon-carbon composite, and four carbon-phenolic materials are measured in an arcjet wind tunnel with a 50% hydrogen/50% helium mixture as the test gas. Flow environments are determined through measurements of static and impact pressures, heat-transfer rates to a calorimeter, and radiation spectra, and through numerical calculation of the flow through the wind tunnel, spectra, and heat-transfer rates. The environments so determined are: impact pressure approximately 3 atm, Mach number approximately 2.1, convective heat-transfer rate approximately 14 kW/cm**2, and radiative heat-transfer rate approximately 7 kW/cm**2 in the absence of ablation. Ablation rates are determined from the measured rates of mass loss and recession of the ablation specimens. 16 Refs.

82) Title: Problems of rate chemistry in the flight regimes of aeroassisted orbital transfer vehicles

Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics Conference, 19th, Snowmass, CO, June 25-28, 1984, AIAA Paper 84-1730, 11 p. (see A84-39369)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*COMPUTATIONAL CHEMISTRY /*NONEQUILIBRIUM FLOW/*ORBIT TRANSFER VEHICLES /*RADIATIVE HEAT TRANSFER/*REACTION KINETICS

Minor Term: / COMPUTATIONAL FLUID DYNAMICS/ HEAT FLUX / HEAT SHIELDING/ NORMAL SHOCK WAVES / ONE DIMENSIONAL FLOW

Abstract: The dissociating and ionizing nonequilibrium flows behind a normal shock wave are calculated for the density and vehicle regimes appropriate for aeroassisted orbital transfer vehicles; the departure of vibrational and electron temperatures from the gas temperature as well as viscous transport phenomena are accounted for. From the thermodynamic properties so determined, radiative power emission is calculated using an existing code. The resulting radiation characteristics are compared with the available experimental data. Chemical parameters are varied to investigate their effect on the radiation characteristics. It is concluded that the current knowledge of rate chemistry leads to a factor-of-4 uncertainty in nonequilibrium radiation intensities. The chemical parameters that must be studied to improve the accuracy are identified. 26 Refs.

83) Title: Injection-induced turbulence in stagnation-point boundary layers
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 22, no. 2, February 1984, p. 219-225. (see A84-21509)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABLATIVE NOSE CONES/*AERODYNAMIC HEAT TRANSFER /*INJECTION/*POROUS BOUNDARY LAYER CONTROL /*STAGNATION POINT/*TURBULENT BOUNDARY LAYER
Minor Term: / CARBON-CARBON COMPOSITES/ GRAPHITE / MIXING LENGTH FLOW THEORY/ TURBULENT HEAT TRANSFER / WALL FLOW
Abstract: A theory is developed for the stagnation point boundary layer with injection under the hypothesis that turbulence is produced at the wall by injection. From the existing experimental heat transfer rate data obtained in wind tunnels, the wall mixing length is deduced to be a product of a time constant and an injection velocity. The theory reproduces the observed increase in heat transfer rates at high injection rates. For graphite and carbon-carbon composite, the time constant is determined to be 0.0002 sec from the existing ablation data taken in an arc-jet tunnel and a ballistic range. 26 Refs.

84) Title: Design and performance analysis of a conical-aerobrake, orbital-transfer vehicle concept

Author: Menees, G. P.; Park, C.; Wilson, J. F.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Informatics General Corporation, Palo Alto, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 22nd, Reno, NV, January 9-12, 1984, AIAA Paper 84-0410, 13 p. (see A84-19253)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper

Major Term: /*AEROBRAKING/*CONICAL BODIES/*ORBIT TRANSFER VEHICLES /*SPACECRAFT DESIGN

Minor Term: / AERODYNAMIC HEATING/ COMPUTATIONAL FLUID DYNAMICS / PERFORMANCE PREDICTION/ STRUCTURAL ANALYSIS / THERMAL PROTECTION/ TRAJECTORY ANALYSIS

Abstract: A Shuttle-compatible systems design based on the core concept of attachable modules for the major vehicle components is proposed. The principal features include a disposable cargo/extra-propellant tank module; a porous, radiative, backscattering drag-brake surface material of thin silica cloth; and a lightweight carbon-composite support structure. The mission payload capability for delivery, retrieval, and combined operations is determined for a broad range of missions including NASA/DOD requirements and extending through cis-lunar space. The effects of finite-rate surface catalysis, negative lift, and multiple atmospheric passes in reducing the aerothermal heating rates are also investigated. In addition, the structural and thermal-protection problems of the drag-brake support apparatus are analyzed and recommendations are proposed for future design refinements.
17 Refs.

85) Title: Calculation of nonequilibrium radiation in the flight regimes of aeroassisted orbital transfer vehicles

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 22nd, Reno, NV, January 9-12, 1984, AIAA Paper 84-0306, 13 p. (see A84-18011)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*COMPUTERIZED SIMULATION /*ENVIRONMENT SIMULATION/*NONEQUILIBRIUM RADIATION /*ORBIT TRANSFER VEHICLES/*RADIATIVE TRANSFER

Minor Term: / ABSORPTION SPECTRA/ AIR/ ATOMIC EXCITATIONS / EMISSION SPECTRA/ FLIGHT SIMULATION/ GAS DENSITY / MOLECULAR EXCITATION / NONEQUILIBRIUM THERMODYNAMICS

Abstract: A computer code has been developed that calculates radiative properties of nonequilibrium air in the low-density regimes expected during the flight of aeroassisted, orbital transfer vehicles. From the given nonequilibrium thermodynamic state variables, the code calculates number densities of internal states and the accompanying emission and absorption characteristics. In addition, the code calculates the number density of the hypothetical gas in radiative equilibrium that produces the same radiation emission as the given nonequilibrium gas. Sample results are shown to demonstrate how the code predicts the nonlinear variation of radiation with density at low densities. 38 Refs.

86) Title: Stagnation-point ablation of carbonaceous flat disks. II Experiment
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 21, no. 12, December 1983, p. 1748-1754. (see A84-13584)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABLATION/*CARBON-CARBON COMPOSITES/*DISKS (SHAPES) /*FLAT PLATES/*PHENOLIC RESINS/*STAGNATION POINT
Minor Term: / ARGON/ CARBONACEOUS MATERIALS/ FLOW VISUALIZATION / HEAT SHIELDING/ SHADOWGRAPH PHOTOGRAPHY / SHOCK WAVES/ WALL TEMPERATURE
Abstract: Six flat-disk models made of carbon-carbon and carbon-phenolic materials were launched in an argon-filled track-range facility to test ablation characteristics in a radiation-dominated, massive-blowing environment. The shock standoff distances deduced from the shadowgraphs agree with theoretical predictions during the earlier portion of the flight, while the wall temperatures determined by the image-converter photographs agree with predictions during the later portion. The measured surface recessions exceed the calculated values by about 60 percent for carbon-phenolic and 30 percent for carbon-carbon. The discrepancies are attributed to spallation. The measured char thicknesses agree with theoretical predictions. 11 Refs.

87) Title: Stagnation-point ablation of carbonaceous flat disks. I Theory
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 21, no. 11, November 1983, p. 1588-1594. (see A84-10143)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABLATION/*BOUNDARY LAYER EQUATIONS /*CARBONACEOUS MATERIALS/*RADIATIVE TRANSFER /*STAGNATION POINT
Minor Term: / BLUNT BODIES/ TEST FACILITIES/ WALL TEMPERATURE
Abstract: The process of ablation is calculated for the stagnation region of a flat disk in a radiation-dominated, massive-blowing environment produced in a ballistic range filled with argon. Flow environments are determined by solving the boundary-layer equations while radiative transfer is calculated through a line-by-line spectral computation. The resulting wall heat-transfer rates are coupled with an existing material's response code to determine surface recession and char thickness. The calculation is performed for six, 5 cm diameter models made of carbon-phenolic and carbon-carbon composite launched in the Track-G facility at the Arnold Engineering Development Center. Significant surface recessions are predicted to occur for these models due mostly to radiative heating. 28 Refs.

88) Title: Transatmospheric flight vehicles and the utilization of cislunar space
Author: Menees, G. P.; Park, C.; Howe, J. T.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Langley Research Center, Advances in TPS and Structures for Space Transportation Systems, p. 79-102. (see X84-10361, see also NASA CP-2315, Advances in TPS and Structures for Space Transportation Systems (see X84-10356))
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROASSIST/*AEROTHERMODYNAMICS/*CISLUNAR SPACE /*ORBIT TRANSFER VEHICLES/*SPACE TRANSPORTATION SYSTEM
Minor Term: / AEROBRAKING/ HEAT TRANSFER/ LEADING EDGES/ LIFT / PRESSURE DISTRIBUTION/REENTRY TRAJECTORIES / STAGNATION TEMPERATURE/ THERMAL PROTECTION
Abstract: Examinations of many aeroassist orbit transfer vehicle (AOTV)/sortie concepts are summarized. Schematics are given for an AOTV in coplanar maneuver between LEO and GEO and for a hypothetical mission from libration center to polar LEO. The aerothermodynamics environment and chemistry are explored and an arc three degree asymmetric conical lifting brake is analyzed. Other aspects covered include the conical lifting brake environment; nonequilibrium radiative heating data base; thermal protection and structural weight estimates; performance capability; multiple pass trajectories, loads, and convective heating; and nonequilibrium heating. Preliminary considerations are given for a high lift aeromaneuvering concept for near Earth missions and for Earth-based sortie missions. Hypersonic sharp leading edges in a rarefied flow are examined. 18 Refs. (edited)

89) Title: Trajectories of solid particles spalled from a carbonaceous heat shield
Author: Davies, C. B.; Park, C.
Corp: Informatics, Inc., Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Entry vehicle heating and thermal protection systems: Space Shuttle, Solar Starprobe and Jupiter Galileo Probe, vol. 85, AIAA, Washington, D. C., 1983, p. 472-95. (see also AIAA, Aerospace Sciences Meeting, 20th, Orlando, FL, January 11-14, 1982, AIAA Paper 82-0200, 12 p. (see A82-17838))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*CARBONACEOUS MATERIALS/*HEAT SHIELDING /*MATHEMATICAL MODELS/*PARTICLE TRAJECTORIES /*SPALLATION
Minor Term: / AERODYNAMIC DRAG/ CARBON/ CONSERVATION EQUATIONS / FLOW DISTRIBUTION/ GALILEO PROBE/ MOMENTUM THEORY / NUSSELT NUMBER/ PARTICLE MASS/ SOLIDS / THERMAL CONDUCTIVITY
Abstract: Trajectories are calculated of solid carbon particles that spall from a carbonaceous heat shield and travel through a given flowfield. The mathematical model takes into account mass, momentum, and energy conservation during evaporation of the particles in an effort to understand spallation phenomena and their consequences in a physical way. The solution technique is applied to available Galileo Probe flowfield solutions. Plots of trajectories and other particle parameters are presented for a range of initial particle sizes and velocities. It is shown that a significant amount of gaseous carbon is deposited in the inviscid region and ahead of the bow shock as well as in the ablation layer. Possible enhancement of radiation due to this phenomena is discussed. 25 Refs.

90) Title: Computation of nonequilibrium, supersonic three-dimensional inviscid flow over blunt-nosed bodies

Author: Rakich, J. V.; Bailey, H. E.; Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA Journal (ISSN 0001-1452), vol. 21, no. 6, June 1983, p. 834-841. (see A83-32980, see also AIAA, Fluid and Plasma Dynamics Conference, 8th, Hartford, CN, June 16-18, 1975, AIAA Paper 75-835, 13 p. (see A75-33931))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*BLUNT BODIES/*CONICAL BODIES/*INVISCID FLOW /*NONEQUILIBRIUM FLOW/*SUPERSONIC FLIGHT /*THREE DIMENSIONAL FLOW

Minor Term: / ANGLE OF ATTACK/ BOW WAVES/ CHEMICAL EQUILIBRIUM / COMPUTER TECHNIQUES/ ENTROPY / FINITE DIFFERENCE THEORY/ REENTRY PHYSICS / SHOCK WAVES/ SPACE SHUTTLES

Abstract: A computer code based on the method of characteristics is applied to the study of two- and three-dimensional chemical nonequilibrium flow over sharp- and blunt-nosed bodies. Nonequilibrium flow over a wedge is used to show the approach to equilibrium flow and to demonstrate the nature of the reaction zone behind the bow shock wave. The structure and development of a blunt-body entropy layer in nonequilibrium flow is examined for a blunt cone at zero incidence. Three dimensional computations for the Space Shuttle body at 30 degree angle of attack are presented. A nondimensional scaling parameter, the Damkohler number (the ratio of flow time to chemical reaction time) is calculated and its significance discussed. 22 Refs.

91) Title: Ablation of carbonaceous materials in a hydrogen-helium arc-jet flow
Author: Park, C.; Lundell, J. H.; Green, M. J.; Winovich, W.; Covington, M. A.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Thermophysics Conference, 18th, Montreal, Canada, June 1-3, 1983, AIAA Paper 83-1561, 12 p. (see A83-32778)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ABLATION/*CARBONACEOUS MATERIALS/*HEAT SHIELDING /*HELIUM HYDROGEN ATMOSPHERES/*JET FLOW /*SPACECRAFT SHIELDING
Minor Term: / BLUNT BODIES/ FLOW VISUALIZATION/ HEAT TRANSFER / STAGNATION POINT/ STATIC PRESSURE/ WIND TUNNEL TESTS
Abstract: The stagnation-point ablation rates of a graphite, a carbon-carbon composite, and four carbon-phenolic materials are measured in an arc-jet wind tunnel with a 50 percent hydrogen, 50 percent helium mixture as the test gas. Flow environments are determined through measurements of static and impact pressures, heat-transfer rates to a calorimeter, and radiation spectra, and through numerical calculation of the flow through the wind tunnel, spectra, and heat-transfer rates. The environments so determined are: impact pressure approximately equal to 3 atm, Mach number approximately equal to 2.1, convective heat-transfer rate approximately equal to 14 kW/sq cm, and radiative heat-transfer rate approximately equal to 7 kW/sq cm in the absence of ablation. Ablation rates are determined from the measured rates of mass loss and recession of the ablation specimens. Compared with the predicted ablation rates obtained by running RASLE and CMA codes, the measured rates are higher by about 15 percent for all tested materials. 16 Refs.

92) Title: Aerodynamic characteristics of generalized bent biconic bodies for aero-assisted, orbital-transfer vehicles

Author: Davies, C. B.; Park, C.

Corp: Informatics General Corporation, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Thermophysics Conference, 18th, Montreal, Canada, June 1-3, 1983, AIAA Paper 83-1512, 15 p. (see A83-32749)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*AEROBRAKING /*AERODYNAMIC CHARACTERISTICS /*ORBIT TRANSFER VEHICLES/*SPACECRAFT DESIGN

Minor Term: / AERODYNAMIC DRAG/ AEROMANEUVERING / COMPUTER PROGRAMS/ CONICAL BODIES/ LIFT

Abstract: A method was developed to generate the surface coordinates of body shapes suitable for aero-assisted, orbital-transfer vehicles (AOTVs) by extending bent biconic geometries. Lift, drag, and longitudinal moments were calculated for the bodies using Newtonian flow theory. These techniques were applied to symmetric and asymmetric aerobraking vehicles, and to an aeromaneuvering vehicle with high L/D. Results for aerobraking applications indicate that a 70 degree, fore half cone angle with spherically blunted nose, rounded edges, and a slight asymmetry would be appropriate. Moreover, results show that an aeromaneuvering vehicle with L/D greater than 2.0, and with sufficient stability, is feasible. 8 Refs.

93) Title: Radiation enhancement by nonequilibrium in earth's atmosphere --- for aero-assisted OTV

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 21st, Reno, NV, January 10-13, 1983, AIAA Paper 83-0410, 13 p. (see A83-16698)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROASSIST/*EARTH ATMOSPHERE /*NONEQUILIBRIUM RADIATION/*ORBIT TRANSFER VEHICLES /*SHOCK LAYERS

Minor Term: / APOLLO FLIGHTS/ BALLISTIC RANGES/ DATA ACQUISITION / MATHEMATICAL MODELS/ RADIATIVE HEAT TRANSFER / RATES (PER TIME)/ SHOCK TUBES

Abstract: The status of knowledge of shock-layer radiation in the low-density, nonequilibrium regime, as appropriate to the flight of the proposed aero-assisted orbital transfer vehicle, is surveyed. The existing laboratory data and the flight data from Apollo and Fire are scrutinized. Nonequilibrium radiation is found to be significant in the flight regime of the vehicle, but a factor of 3 uncertainty is found in its magnitude. The available theoretical models are reviewed, their weaknesses are pointed out, a computer code that approximately reproduces the existing data is introduced, and recommendations are made for future research. 34 Refs.

94) Title: The satellite power system: assessment of the environmental impact on middle atmosphere composition and on climate

Author: Whitten, R. C.; Borucki, W. J.; Park, C.; Pfister, L.; Woodward, H. T.; Turco, R. P.; Capone, L. A.; Riegel, C. A.; Kropp, T.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; R and D Associates, Marina del Rey, CA, USA; San Jose State University, San Jose, CA, USA; Informatics, Inc., Palo Alto, CA, USA

Source: Space Solar Power Review (ISSN 0191-9067), vol. 3, no. 3, 1982, p. 195-221. (see A83-14517)

Sponsor: Pergamon Press, Oxford, Great Britain

Doc. Type: Journal Article

Major Term: /*AIR POLLUTION/*ATMOSPHERIC COMPOSITION /*CLIMATOLOGY/*MIDDLE ATMOSPHERE /*PHOTOCHEMICAL REACTIONS /*SATELLITE SOLAR POWER STATIONS

Minor Term: / ATMOSPHERIC CHEMISTRY/ CARBON DIOXIDE / CARBON MONOXIDE/ CLIMATE CHANGE / ENVIRONMENT POLLUTION/ ENVIRONMENTAL CHEMISTRY / HEAVY LIFT LAUNCH VEHICLES / HYDROGEN/ NITRIC OXIDE / OZONE DEPLETION/ ROCKET EXHAUST/ SULFUR DIOXIDES / THERMOSPHERE/ TWO DIMENSIONAL MODELS / WATER VAPOR

Abstract: The heavy lift launch vehicles (HLLV) proposed for use in constructing a satellite solar power system (SPS) would deposit various contaminants in the middle atmosphere, contaminants that could have an adverse effect on the upper air structure and climate. The contaminants consist primarily of water vapor, hydrogen, carbon dioxide, carbon monoxide, and traces of silicon dioxide and nitric oxide. Large quantities of nitric oxide are also formed during reentry. To assess the effects of such effluents, we constructed new models of modified existing models of the upper atmosphere: a one-dimensional and two-dimensional photochemical model, a rocket plume model, and a reentry model. All are described here. Using an SPS scenario of 400 launches per year for 10 years, our calculations lead to the following conclusions: (1) the build-up of water vapor, nitric oxide, CO2, CO, or sulfur dioxide, including a possible "corridor" effect (zonal enhancement centered on the launch latitude) is not likely to be significant; (2) ozone perturbations should not be significant - the ozone total column density decreases would probably be less than 0.1%; (3) although significant perturbations of odd-hydrogen (H, OH, HO2) are not predicted for the stratosphere and mesosphere, thermosphere hydrogen could be doubled in concentration; and (4) with respect to climate, none of the SPS-induced changes mentioned would lead to measurable changes in climate. 56 Refs.

95) Title: Aerodynamic characteristics of generalized bent biconic bodies for aero-assisted, orbital-transfer vehicles

Author: Davies, C. B.; Park, C.

Corp: Informatics General Corporation, Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-84362, April 1983, 18 p. (see N83-26918)

Sponsor: NASA, Washington, D. C., USA

Doc. Type: Report

Major Term: /*AERODYNAMIC CONFIGURATIONS/*COORDINATES /*ORBIT TRANSFER VEHICLES/*SHAPES/*SURFACE GEOMETRY

Minor Term: / AERODYNAMIC CHARACTERISTICS/ ALTITUDE/ ASYMMETRY / MANEUVERABILITY

Abstract: A method was developed to generate the surface coordinates of body shapes suitable for aeroassisted, orbital-transfer vehicles (AOTVs) by extending bent biconic geometries. Lift, drag, and longitudinal moments were calculated for the bodies using Newtonian flow theory. These techniques were applied to symmetric and asymmetric aerobraking vehicles, and to an aeromaneuvering vehicle with high L/D. Results for aerobraking applications indicate that a 70 degree, fore half cone angle with a spherically blunted nose, rounded edges, and a slight asymmetry would be appropriate. Moreover, results show that an aeromaneuvering vehicle with L/D of 2.0, and with sufficient stability, is feasible. 8 Refs.

96) Title: Ablation of carbonaceous materials in a hydrogen-helium arc-jet flow
Author: Park, C.; Lundell, J. H.; Green, M. J.; Winovich, W.; Covington, M. A.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-84346, March 1983, 14 p. (see N83-23346)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*ABLATION/*CARBON COMPOUNDS/*COMPOSITE MATERIALS /*GRAPHITE/*HELIUM/*HYDROGEN/*JET FLOW /*WIND TUNNEL TESTS
Minor Term: / COMPUTER PROGRAMS/ FLOW VISUALIZATION / HEAT TRANSFER/ STAGNATION FLOW
Abstract: The stagnation-point ablation rates of a graphite, a carbon-carbon composite, and four carbon-phenolic materials are measured in an arc-jet wind tunnel with a 50% hydrogen-50% helium mixture as the test gas. Flow environments are determined through measurements of static and impact pressures, heat-transfer rates to a calorimeter, and radiation spectra, and through numerical calculation of the flow through the wind tunnel, spectra, and heat-transfer rates. The environments so determined are: impact pressure approximately 3 atm, Mach number approximately 2.1, convective heat-transfer rate approximately 14 kW/sq cm, and radiative heat-transfer rate approximately 7 kW/sq cm in the absence of ablation. Ablation rates are determined from the measured rates of mass loss and recession of the ablation specimens. Compared with the predicted ablation rates obtained by running RASLE and CMA codes, the measured rates are higher by about 15% for all tested materials. 16 Refs.

97) Title: An analysis of the physical, chemical, optical, and historical impacts of the 1908 Tunguska meteor fall

Author: Turco, R. P.; Toon, O. B.; Park, C.; Whitten, R. C.; Pollack, J. B.; Noerdlinger, P.

Corp: R and D Associates, Marina del Rey, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA; Los Alamos National Laboratory, Los Alamos, NM, USA

Source: Icarus (ISSN: 0019-1035), International Journal of Solar System Studies, vol. 50, no. 1, April 1982, p. 1-52. (see A82-40362)

Sponsor: Academic Press, New York, NY, USA

Doc. Type: Journal Article

Major Term: /*AIRGLOW/*ENVIRONMENT EFFECTS/*NITRIC OXIDE/*OZONE /*PHOTOCHEMICAL REACTIONS/*TUNGUSK METEORITE

Minor Term: / ATMOSPHERIC ATTENUATION/ ATMOSPHERIC CHEMISTRY / ATMOSPHERIC COMPOSITION/ ATMOSPHERIC ENTRY / CHEMILUMINESCENCE/ CLIMATE CHANGE / METEORITIC COMPOSITION/ MICROMETEOROIDS / NOCTILUCENT CLOUDS/ OZONE DEPLETION

Abstract: An analysis is presented of the physical characteristics and photochemical aftereffects of the 1908 Tunguska explosive cometary meteor, whose physical manifestations are consistent with a five million ton object's entry into the earth's atmosphere at 40 km/sec. Aerodynamic calculations indicate that the shock waves emanating from the falling meteor could have generated up to 30 million tons of nitric oxide in the stratosphere and mesosphere. A fully interactive one-dimensional chemical-kinetics model of atmospheric trace constituents is used to estimate the photochemical consequences of such a large NO injection. The 35 to 45% hemispherical ozone depletion predicted by the model is in keeping with the 30 ± 15% ozone variation reported for the first year after the Tunguska fall. Attention is also given to the optical anomalies which followed the event for indications of NO(x) - O(x) chemiluminescent emissions, NO2 solar absorption, and meteoric dust turbidity, along with possible climate changes due to the nearly one million tons of pulverized dust deposited in the mesosphere and stratosphere by the meteor. 153 Refs.

98) Title: Calculation of radiation from argon shock layers
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 28, no. 1, July 1982, p. 29-40. (see A82-36542)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*ARGON PLASMA/*BLUNT BODIES/*PLASMA RADIATION /*PLASMA SPECTRA/*RADIATIVE HEAT TRANSFER /*SHOCK LAYERS
Minor Term: / GAS IONIZATION/ HEAT FLUX/ HYPERSONIC FLIGHT / LINE SPECTRA/ SHOCK TUBES/ STAGNATION POINT
Abstract: The accuracy of calculations of the radiation emissions from argon plasmas produced by the shock layers over blunt bodies is assessed. The existing theoretical and experimental spectroscopic data on argon are collated. A set of such data is selected for use in the radiative transfer calculations. Calculations are performed for the stagnation regions of the shock layers over laboratory-sized models using these data, and the results are compared with the existing experimental results obtained in a shock-tube. Through this comparison and a parametric study it is shown that radiative heat fluxes at the stagnation point in an argon environment can be calculated within an uncertainty of about 15%. It is shown also that radiative heat fluxes of the order of 100 kW/sq cm can be produced in the existing laboratory facilities. 68 Refs.

99) Title: Large ozone perturbations caused by the 1908 Tunguska meteor fall --- Were there related weather effects

Author: Turco, R. P.; Toon, O. B.; Park, C.; Whitten, R. C.; Noerdlinger, P.

Corp: R and D Associates, Marina del Rey, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: Quadrennial International Ozone Symposium, Boulder, CO, August 4-9, 1980 (see A82-36532); Proceedings of the Quadrennial International Ozone Symposium, vol. 2, 1981, p. 1067-1073. (see A82-36401)

Sponsor: International Association of Meteorology and Atmospheric Physics

Doc. Type: Conference Paper

Major Term: /*ATMOSPHERIC CHEMISTRY/*ATMOSPHERIC EFFECTS /*ENVIRONMENT EFFECTS/*OZONE/*OZONE DEPLETION /*PHOTOCHEMICAL REACTIONS/*TUNGUSK METEORITE

Minor Term: / ATMOSPHERIC OPTICS/ METEOROLOGY/ NITROGEN OXIDES / SHOCK WAVES/STRATOSPHERE

Abstract: The magnitude of the ozone depletion due to the 1908 Tunguska meteor fall is estimated and observational evidence of such a depletion is presented. Calculated stratospheric ozone and NO(x) perturbations caused by the meteor are shown, with the hemispherically averaged model giving total stratospheric ozone reductions as large as 45 percent in the first year, with significant reductions persisting for at least three more years. Ozone depletion above 10 km altitude is found to be about 85 percent for several months, and higher yet at 20, 30, and 40 km. Data from the early1900s to calculate the variability of the solar constant is used to calculate the ozone column concentration for 1909-11. The results are in close agreement with the model prediction. Weather records of the early 1900s show a cooling trend in the Northern Hemisphere for almost a decade after Tunguska. 24 Refs. (edited)

100) Title: Radiation enhancement by nonequilibrium during flight through the Titan atmosphere

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA and ASME, Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, 3rd, St. Louis, MO, June 7-11, 1982, AIAA Paper 82-0878, 15 p. (see A82-31883)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*AEROTHERMODYNAMICS/*ATMOSPHERIC CHEMISTRY /*INTERPLANETARY FLIGHT/*NONEQUILIBRIUM RADIATION /*SATELLITE ATMOSPHERES/*TITAN

Minor Term: / AEROTHERMOCHEMISTRY/ CHEMICAL EQUILIBRIUM / CHEMICAL REACTIONS/EQUILIBRIUM FLOW / RADIATIVE TRANSFER/ SHOCK LAYERS

Abstract: The chemical reactions occurring in the adiabatic inviscid shock layer over a two-dimensional wedge flying through Titan's atmosphere are calculated. Radiative transfer through the shock layer is calculated, accounting for the deviation of electronic state populations from the equilibrium distributions, to determine the heat flux reaching the edge of the boundary layer of the proposed Titan Aerocapture vehicle. The heat fluxes are found to be larger by a ratio of up to 100,000 than those calculated under the assumption of equilibrium flow. For a typical flight, the radiative heat load reaching the edge of the boundary layer is 3.4 x 10 to the 5th J/sq cm, which is 5.7 times the equilibrium value. 40 Refs.

101) Title: Trajectories of solid particles spalled from a carbonaceous heat shield
Author: Davies, C. B.; Park, C.
Corp: Informatics, Inc., Palo Alto, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 20th, Orlando, FL, January 11-14, 1982, AIAA Paper 82-0200, 12 p. (see A82-17838)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*CARBONACEOUS MATERIALS/*HEAT SHIELDING /*MATHEMATICAL MODELS/*PARTICLE TRAJECTORIES /*SPALLATION
Minor Term: / AERODYNAMIC DRAG/ CARBON/ CONSERVATION EQUATIONS / FLOW DISTRIBUTION/ GALILEO PROBE/ MOMENTUM THEORY / NUSSELT NUMBER/ PARTICLE MASS/ SOLIDS / THERMAL CONDUCTIVITY
Abstract: Trajectories are calculated of solid carbon particles that spall from a carbonaceous heat shield and travel through a given flow field. The mathematical model takes into account mass, momentum, and energy conservation during evaporation of the particles in an effort to understand spallation phenomena and their consequences in a physical way. The solution technique is applied to available Galileo Probe flow field solutions. Plots of trajectories and other particle parameters are presented for a range of initial particle sizes and velocities. It is shown that a significant amount of gaseous carbon is deposited in the inviscid region and ahead of the bow shock as well as in the ablation layer. 23 Refs.

102) Title: Environmental effects of SPS: The middle atmosphere

Author: Whitten, R. C.; Borucki, W. J.; Park, C.; Woodward, H. T.; Turco, R. P.; Prasad, S. S.; Capone, L. A.; Riegel, C. A.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; R and D Associates, Marina del Rey, CA, USA; Jet Propulsion Laboratory, Pasadena, CA, USA; San Jose State University, San Jose, CA, USA

Source: NASA, Washington, D. C., NASA-TM-84183, July 1980, The Final Proceedings of the Solar Power Satellite Program Review, Lincoln, NE, April 22-25, 1980, p. 458-459. (see N82-22760)

Sponsor: Department of Energy, Washington, D. C., USA; NASA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ATMOSPHERIC MODELS/*HEAVY LIFT LAUNCH VEHICLES /*MIDDLE ATMOSPHERE/*ROCKET EXHAUST

Minor Term: / ATMOSPHERIC CHEMISTRY/ ENVIRONMENT EFFECTS / NOCTILUCENT CLOUDS/PHOTOCHEMICAL REACTIONS / SOLAR POWER SATELLITES

Abstract: The heavy lift launch vehicle associated with the solar power satellite (SPS) would deposit in the upper atmosphere exhaust and reentry products which could modify the composition of the stratosphere, mesosphere, and lower ionosphere. In order to assess such effects, atmospheric model simulations were performed, especially considering a geographic zone centered at the launch and reentry latitudes. 0 Refs. (edited)

103) Title: Preliminary design study of solar probe heat shields
Author: Park, Chul
Corp: Ames Research Center, NASA, Moffett Field, CA, USA
Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Spacecraft Radiative Transfer and Temperature Control, vol. 83, AIAA, Washington, D. C., 1982, p. 439-71. (see also AIAA, Aerospace Sciences Meeting, 19th, St. Louis, MO, January 12-15, 1981, AIAA Paper 81-0352, 13 p. (see A81-20772))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*HEAT SHIELDING/*SILICON DIOXIDE/*SOLAR PROBES /*SPACECRAFT DESIGN/*TUNGSTEN
Minor Term: / HEAT TRANSFER/ PERFORMANCE PREDICTION/ PERIHELIONS / SLIP CASTING/ SOLAR RADIATION/ SOLAR WIND
Abstract: The requirements, constraints, design guidelines, and expected performances of heat-shield systems for a solar probe are analyzed. A multiple-stage, asymmetric, right-angle radiation cascade configuration is used as the basis for comparison, Output-to-input radiative heat flux ratios are first calculated for a system employing gray surfaces. Assuming that the temperature of the inner surface of the payload bus is allowed to reach 400 K, it is shown that four-and five-stage cascade systems employing graphite can approach, respectively, to within 5.5 and 4 solar radii of the sun. The systems using slip-cast silica and tungsten are then analyzed accounting for the degradation of the surface-optical performance caused by the solar wind. It is shown that two-and three-stage silica-tungsten systems can approach, respectively, to within 4 and 3 solar radii of the sun. 16 Refs.

104) Title: Ablation and deceleration of mass driver-launched projectiles for space disposal of nuclear wastes

Author: Park, C.; Bowen, S. W.

Corp: Ames Research Center, NASA, Moffett Field, CA, USA

Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Thermophysics of Atmospheric Entry, vol. 82, AIAA, Washington, D. C., 1982, p. 201-25. (see also AIAA, Aerospace Sciences Meeting, 19th, St. Louis, MO, January 12-15, 1981, AIAA Paper 81-0355, 11 p. (see A81-20774))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ABLATION/*DECELERATION/*MASS DRIVERS/*PROJECTILES /*RADIOACTIVE WASTES/*WASTE DISPOSAL

Minor Term: / ABLATIVE NOSE CONES/ CONVECTIVE HEAT TRANSFER / COST EFFECTIVENESS/ FLOW DISTRIBUTION / HEMISPHERE CYLINDER BODIES/ INVISCID FLOW / RADIATIVE HEAT TRANSFER/ SPACECRAFT DESIGN / STAGNATION POINT

Abstract: Ablation and deceleration characteristics are analyzed for a hemisphere-cylinder-shaped projectile protected by a graphite nose tip and launched vertically upward with a velocity in excess of 17 km/s. It is shown that ablation and deceleration of the projectile are in tolerable ranges for a scheme in which such projectiles are packed with nuclear wastes and launched with a mass driver to dispose of nuclear wastes outside the solar system. 18 Refs.

105) Title: The Tunguska meteor: effects on stratospheric ozone, ultraviolet radiation, and climate

Author: Turco, R. P.; Toon, O. B.; Park, C.; Whitten, R. C.; Noerdlinger, P.

Corp: R and D Associates, Marina del Rey, CA, USA, NASA, Ames Research Center, Moffett Field, CA, USA

Source: Lunar and Planetary Institute Contributions (ISSN: 0161-5297), vol. 449, 1981, p. 57.

Sponsor: Lunar and Planetary Institute, Houston, TX, USA

Doc. Type: Journal Article

Major Term: /*ATMOSPHERIC CHEMISTRY/*ATMOSPHERIC EFFECTS /*ENVIRONMENT EFFECTS/*OZONE/*OZONE DEPLETION /*PHOTOCHEMICAL REACTIONS/*TUNGUSK METEORITE

Minor Term: / ATMOSPHERIC OPTICS/ METEOROLOGY/ NITROGEN OXIDES / SHOCK WAVES/STRATOSPHERE

Abstract: The Tunguska meteor collided with Earth on June 30, 1908, devastating nearly 2000 square kilometers of forest land in Siberia. Air waves and ground tremors were detected over distances of several thousand kilometers. However, no impact craters and very little meteoric material were found at the impact site. These circumstances are explained in terms of the flight and disintegration in the atmosphere of a small comet or comet fragment composed of ice intermingled in dust. The effects of the Tunguska meteor on the upper atmosphere are investigated based on the results of detailed aerodynamic calculations of the event as constrained by the physical record. The major effects involve the dust and water vapor ablated from the cometary body, and the nitric oxides (NOx) generated in the air heated by the meteor. 3 Refs. (edited)

106) Title: Tunguska meteor fall of 1908 --- Effects on stratospheric ozone

Author: Turco, R. P.; Toon, O. B.; Park, C.; Whitten, R. C.; Pollack, J. B.; Noerdlinger, P.

Corp: R and D Associates, Marina del Rey, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA; Michigan State University, East Lansing, MI, USA

Source: Science (ISSN: 0036-8075), vol. 214, no. 4516, October 2, 1981, p. 19-23. (see A81-48223)

Sponsor: American Association for the Advancement of Science, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ATMOSPHERIC COMPOSITION/*OZONE DEPLETION /*OZONOMETRY/*STRATOSPHERE/*TUNGUSK METEORITE

Minor Term: / ABUNDANCE/ LONG TERM EFFECTS/ NITRIC OXIDE / PHOTOCHEMICAL REACTIONS/ TIME RESPONSE

Abstract: In 1908, when the giant Tunguska meteor disintegrated in the Earth's atmosphere over Siberia, it may have generated as much as 30 million metric tons of nitric oxide (NO) in the stratosphere and mesosphere. The photochemical aftereffects of the event are simulated using a comprehensive model of atmospheric trace composition. Calculations are made which indicate that up to 45% of the ozone in the Northern Hemisphere may have been depleted by the meteor's nitric oxide cloud early in 1909 and that large ozone reductions may have persisted until 1912. Measurements of atmospheric transparency by the Smithsonian Astrophysical Observatory for the years 1909-1911 reveal evidence of a steady ozone recovery from unusually low levels in early 1909, implying a total ozone deficit of 30 ± 15%. The coincidence in time between the observed ozone recovery and the Tunguska meteor fall suggests that the event may provide a test of current ozone depletion theories. 47 Refs.

107) Title: Ablation and deceleration of mass-driver launched projectiles for space disposal of nuclear wastes

Author: Park, C.; Bowen, S. W.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Beam Engineering, Inc., Sunnyvale, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 19th, St. Louis, MO, January 12-15, 1981, AIAA Paper 81-0355, 11 p. (see A81-20774)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ABLATION/*DECELERATION/*MASS DRIVERS/*PROJECTILES /*RADIOACTIVE WASTES/*WASTE DISPOSAL

Minor Term: / ABLATIVE NOSE CONES/ CONVECTIVE HEAT TRANSFER / COST EFFECTIVENESS/ FLOW DISTRIBUTION / HEMISPHERE CYLINDER BODIES/ INVISCID FLOW / RADIATIVE HEAT TRANSFER/ SPACECRAFT DESIGN / STAGNATION POINT

Abstract: The energy cost of launching a projectile containing nuclear waste is two orders of magnitude lower with a mass driver than with a typical rocket system. A mass driver scheme will be feasible, however, only if ablation and deceleration are within certain tolerable limits. It is shown that if a hemisphere-cylinder-shaped projectile protected thermally with a graphite nose is launched vertically to attain a velocity of 17 km/sec at an altitude of 40 km, the mass loss from ablation during atmospheric flight will be less than 0.1 ton, provided the radius of the projectile is under 20 cm and the projectile's mass is of the order of 1 ton. The velocity loss from drag will vary from 0.4 to 30 km/sec, depending on the mass and radius of the projectile, the smaller velocity loss corresponding to large mass and small radius. Ablation is always within a tolerable range for schemes using a mass driver launcher to dispose of nuclear wastes outside the solar system. Deceleration can also be held in the tolerable range if the mass and diameter of the projectile are properly chosen. 18 Refs. (edited)

108) Title: Preliminary design study of solar probe heat shields
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 19th, St. Louis, MO, January 12-15, 1981, AIAA Paper 81-0352, 13 p. (see A81-20772)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*HEAT SHIELDING/*SILICON DIOXIDE/*SOLAR PROBES /*SPACECRAFT DESIGN/*TUNGSTEN
Minor Term: / HEAT TRANSFER/ PERFORMANCE PREDICTION/ PERIHELIONS / SLIP CASTING/ SOLAR RADIATION/ SOLAR WIND
Abstract: The requirements, constraints, design guidelines, and expected performances of heat-shield systems for a solar probe are analyzed. A multiple-stage, asymmetric, right-angle radiation cascade configuration is used as the basis for comparison. Output-to-input radiative flux ratios are first calculated for a system employing gray surfaces. Assuming that the temperature of the inner surface of the payload bus is allowed to reach 400 K, it is shown that four- and five-stage cascade systems employing graphite can approach, respectively, to within about 5.5 and 4 solar radii of the sun. The systems using slip-cast silica and tungsten are then analyzed accounting for the degradation of surface-optical performance caused by the solar wind. It is shown that two- and three-stage silica-tungsten systems can approach, respectively, to within 4 and 3 solar radii of the sun. 16 Refs.

109) Title: Line-by-line transport calculations for Jupiter entry probes
Author: Arnold, J. O., Cooper, D. M., Park, Chul; Prakash, S. G.
Corp: Ames Research Center, NASA, Moffett Field, CA, USA
Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Entry Heating and Thermal Protection, vol. 69, AIAA, Washington, D. C., 1980, p. 52-82. (see also AIAA, Thermophysics Conference, 14th, Orlando, FL, June 4-6, 1979, AIAA Paper 79-1082, 16 p. (see A79-38562))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ATMOSPHERIC ENTRY/*GALILEAN SATELLITES /*GALILEO PROJECT/*JUPITER PROBES/*RADIATIVE TRANSFER
Minor Term: / ATMOSPHERIC BOUNDARY LAYER/ CARBON/ CARBON DIOXIDE / CHEMICAL BONDS/ DIATOMIC MOLECULES/ HEAT SHIELDING / MOLECULAR COLLISIONS/ STAGNATION POINT/ THICKNESS / TRIATOMIC MOLECULES
Abstract: Line-by-line calculations of the radiative transport for a condition near peak heating for entry of the Galileo probe into the Jovian atmosphere are described. The discussion includes a thorough specification of the atomic and molecular input data used in the calculations that could be useful to others working in the field. The results show that the use of spectrally averaged cross sections for diatomic absorbers such as CO and C2 in the boundary layer can lead to an underestimation (by as much as 29%) of the spectral flux at the stagnation point. On the other hand, for the turbulent region near the cone frustum on the probe, the flow tends to be optically thin, and the spectrally averaged results commonly used in coupled radiative transport-flow field calculations are in good agreement with the present line-by-line results. It is recommended that these results be taken into account in sizing the final thickness of the Galileo's heat shield. 44 Refs.

110) Title: Modeling of radiative heating of base region of Jovian entry probe
Author: Park, Chul
Corp: Ames Research Center, NASA, Moffett Field, CA, USA
Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Entry Heating and Thermal Protection, vol. 69, AIAA, Washington, D. C., 1980, p. 124-147. (see also AIAA, Aerospace Sciences Meeting, 17th, New Orleans, LA, January 15-17, 1979, AIAA Paper 79-0039, 14 p. (see A79-23540))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*AEROTHERMODYNAMICS/*ATMOSPHERIC ENTRY /*BASE HEATING/*JUPITER ATMOSPHERE/*JUPITER PROBES /*MATHEMATICAL MODELS/*RADIATIVE HEAT TRANSFER
Minor Term: / ANGULAR DISTRIBUTION/ BASE FLOW/ COMPUTER PROGRAMS / CONSERVATION EQUATIONS/ HYDROGEN IONS / MACH NUMBER/ NONEQUILIBRIUM RADIATION / PRANDTL-MEYER EXPANSION/ RECIRCULATIVE FLUID FLOW / THERMODYNAMIC EQUILIBRIUM/ VELOCITY DISTRIBUTION
Abstract: The mechanism of radiative heating of the afterbody region of Jovian entry probe is analyzed. A theoretical model is derived to determine the average thermodynamic properties in the expanding region, recirculating region, recompression region, and neck region through application of one-dimensional conservation equations. Flow parameters are obtained from the shadowgraphs of a free-flight test. Radiative transfer is calculated using spectrally detailed computer codes accounting for nonequilibrium. The results show that the most severe heating occurs immediately behind the frustum, and that the recompression and neck regions are the major sources of radiation that heats the base stagnation point. The radiation flux to the base point is slightly stronger with ablation than without, its value being 0.11*(43*Pb/Ps)**2 times that to the front stagnation point, where Pb/Ps is the ratio of base-to-front stagnation point pressures and its value is in the range 0.023-0.066. The time-integrated heat load to the base point is 18*(43*Pb/Ps)**2 kJ/sq cm. Existing experimental data are shown to agree with the theoretical prediction. 22 Refs.

111) Title: Curves of growth for van der Waals broadened spectral lines
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 24, no. 4, October 1980, p. 289-292. (see A80-51378)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*LINE SPECTRA/*SPECTRAL LINE WIDTH /*VAN DER WAALS FORCES
Minor Term: / SPACECRAFT REENTRY/ VOIGT EFFECT
Abstract: Curves of growth are evaluated for a spectral line broadened by the van der Waals interactions during collisions. The growth of the equivalent widths of such lines is shown to be dependent on the product of the perturber density and the 6/10 power of the van der Waals potential coefficient. When the parameter is small, the widths grow as the 1/2 power of the optical depth as they do for the Voigt profile: but when the parameter is large, they grow as 2/3 power and, hence, faster than the Voigt profile. An approximate analytical expression for the computed growth characteristics is given. 6 Refs.

112) Title: Equivalent-cone calculation of nitric oxide production rate during Space Shuttle re-entry
Author: Park, Chul; Rakich, John V.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Atmospheric Environment (ISSN: 0004-6981), vol. 14, no. 8, 1980, p. 971-972. (see A80-45359)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*ENVIRONMENT EFFECTS/*NITRIC OXIDE /*SPACE SHUTTLE ORBITERS/*SPACECRAFT REENTRY
Minor Term: / ANGLE OF ATTACK/ FLIGHT CHARACTERISTICS
Abstract: The amount of nitric oxide likely to be produced in the shock layer around a Space Shuttle orbiter vehicle during its reentry is calculated at one point on the trajectory. An equivalent-cone is defined as one that produces the same amount of nitric oxide as the orbiter. The amounts of nitric oxide produced by the cone are calculated at points along the trajectory to determine their total and altitudinal distribution. The results show that about 14 tonne nitric oxide is produced at each entry, the peak occurring at 68 km altitude. 3 Refs.

113) Title: Shock-tube studies of radiative base heating of Jovian probe
Author: Shirai, H.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Symposium on Shock Tubes and Waves, 12th, Jerusalem, Israel, July 16-19, 1979 (see A80-38114); Shock tubes and waves, Magnes Press, Jerusalem, Israel, 1980, p. 419-428. (see A80-38078)
Sponsor: Air Force Office of Scientific Research, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ATMOSPHERIC ENTRY/*BASE HEATING/*JUPITER ATMOSPHERE /*RADIATIVE HEAT TRANSFER/*SHOCK HEATING /*SPACE PROBES
Minor Term: / GAS FLOW/ GAS PRESSURE/ HEAT FLUX/ MISSION PLANNING / PRESSURE SENSORS/ RADIOMETERS/ SCALE MODELS / SHOCK TUBES/ SHOCK WAVE PROPAGATION / STAGNATION POINT
Abstract: A 6.4-cm-diameter scale model of the Jovian entry vehicle is tested in an electric-arc-driven shock tube and a 5-cm-diameter sphere model is tested in a combustion-driven shock tube and in an electric-arc-driven shock tunnel. The radiative heat-transfer rate and pressure on the front and the base regions are measured in the absence of ablation with sensors imbedded in the models in a stream consisting of 10% hydrogen in a bath of either neon or argon. The measured radiative heat-transfer rates and pressures range to about 22 kW/sq cm and 12 atm, respectively, at the front stagnation point. The ratio of the radiative heat-transfer rate at the base stagnation point to that at the front stagnation point is found to be about 1/4 for the sphere at Mach 1.8, about 1/30 for the sphere at Mach 4.8, and about 1/6 for the scale model at Mach 1.7. The present experimental results agree well with the theoretical predictions of Park, thus indicating that Park's theory is valid. 7 Refs.

114) Title: Shape change of Galileo Probe models in free-flight tests
Author: Park, C.; De Rose, C. E.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-81209, June 1980, 41 p. (see N80-27418)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*ABLATION/*CARBON-CARBON COMPOSITES /*GALILEO PROJECT/*PHENOLIC RESINS/*POLYMERS /*SCALE MODELS
Minor Term: / FLIGHT TESTS/ JUPITER (PLANET)/ JUPITER PROBES / SHADOWGRAPH PHOTOGRAPHY/ SPACECRAFT
Abstract: Scale models of the Galileo Probe made of polycarbonate, AXF5Q graphite, carbon-carbon composite, and carbon-phenolic were flown in a free flight range in an ambient gas of air, krypton, or xenon. Mach numbers varied between 14 and 24, Reynolds numbers between 300,000 and 1,000,000, stagnation pressures between 31 and 200 atm, and stagnation point heat transfer rates between 10 and 1,000 kW/sq cm. Shadowgraphs indicate gouging ablation of the aft portion of the frustum; the gouging was moderate in air and severe in the noble gases. The graphite models break in the same region. An explanation of the phenomena is offered in terms of the strong compression and shear caused by the reattachment of a turbulent separated flow. Conditions are calculated for similar tests appropriate for Von Karman Facility of the Arnold Engineering Development Center in which a larger model can be flown in argon. 19 Refs.

115) Title: Shock-tube studies of atomic silicon emission in the spectral range 180 to 300 nm

Author: Prakash, S. G.; Park, Chul

Corp: Ames Research Center, NASA, Moffett Field, CA, USA

Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Outer Planet Entry Heating and Thermal Protection, vol. 64, AIAA, Washington, D. C., 1979, p. 245-64. (see also AIAA, Aerospace Sciences Meeting, 16th, Huntsville, AL, January 16-18, 1978, AIAA Paper 78-234, 10 p. (see A78-22602)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*EMISSION SPECTRA/*HEAT SHIELDING/*JUPITER PROBES /*SHOCK TUBES/*SILICON/*SPACE ENVIRONMENT SIMULATION

Minor Term: / ELECTRON DENSITY (CONCENTRATION)/ HYDROGEN ATOMS / LORENTZ FORCE/ RADIATIVE TRANSFER/ SHOCK LAYERS / SPECTRAL LINE WIDTH/ STARK EFFECT / VAN DER WAALS FORCES

Abstract: Emission spectroscopy of shock-heated atomic silicon was performed in the spectral range 180 to 300 nm, in an environment simulating the ablation layer expected around a Jovian entry probe with a silica heat shield. From the spectra obtained at temperatures from 6000 to 10,000 K and electron number densities from 10**15 to 10**17 cm-3, the Lorentzian line widths were determined. The results showed that the silicon lines are broadened significantly by both electrons (Stark broadening) and hydrogen atoms (Van der Waals broadening), and the combined line widths are much larger than previously assumed. From the data, the Stark and Van der Waals line widths were determined for 34 silicon lines. Radiative transport through a typical shock layer was computed using the new line-width data. The computations showed that silicon emission in the hot region is large, but it is mostly absorbed in the colder region adjacent to the wall. 17 Refs.

116) Title: Calculation of radiative properties of nonequilibrium hydrogen plasma
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 22, no. 1, July 1979, p. 101-112. (see A79-47514)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*COMPUTER PROGRAMS/*HYDROGEN PLASMA /*NONEQUILIBRIUM PLASMAS/*RADIATIVE TRANSFER
Minor Term: / COMPUTER TECHNIQUES/ JUPITER ATMOSPHERE / PLASMA SLABS/ TRANSPORT PROPERTIES
Abstract: A computer program called NEQRAP is described that calculates the radiative properties of nonequilibrium ionized hydrogen. From the given electron temperature, electron density, and atom density values (which do not necessarily satisfy the equilibrium relationship) and intensities of incident radiation, the non-Boltzmann populations of electronic states are computed by solving the equation of quasi-steady-state population distribution. Emission and absorption coefficients are determined as functions of wavelength by invoking the principle of detailed balance between the upper and lower states of each radiative transition. Radiative transport through the medium is computed assuming a one-dimensional uniform slab. The rate of ionic reaction is also computed. When used on a sample case, the program shows that there is a large difference between the calculated intensities of radiation emitted by a bulk of equilibrium and nonequilibrium hydrogen. The accuracy of the program is estimated to be better than 10%. 24 Refs.

117) Title: Line-by-line transport calculations for Jupiter entry probes --- of radiative transfer

Author: Arnold, J. O.; Cooper, D. M.; Park, C.; Prakash, S. G.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Stanford University, Stanford, CA, USA

Source: AIAA, Thermophysics Conference, 14th, Orlando, FL, June 4-6, 1979, AIAA Paper 79-1082, 16 p. (see A79-38562)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ATMOSPHERIC ENTRY/*GALILEAN SATELLITES /*GALILEO PROJECT/*JUPITER PROBES/*RADIATIVE TRANSFER

Minor Term: / ATMOSPHERIC BOUNDARY LAYER/ CARBON/ CARBON DIOXIDE / CHEMICAL BONDS/ DIATOMIC MOLECULES/ HEAT SHIELDING / MOLECULAR COLLISIONS/ STAGNATION POINT/ THICKNESS / TRIATOMIC MOLECULES

Abstract: Line-by-line calculations of the radiative transport for a condition near peak heating for entry of the Galileo probe into the Jovian atmosphere are described. The discussion includes a thorough specification of the atomic and molecular input data used in the calculations that could be useful to others working in the field. The results show that the use of spectrally averaged cross sections for diatomic absorbers such as CO and C2 in the boundary layer can lead to an underestimation (by as much as 29%) of the spectral flux at the stagnation point. On the other hand, for the turbulent region near the cone frustum on the probe, the flow tends to be optically thin, and the spectrally averaged results commonly used in coupled radiative transport-flow field calculations are in good agreement with the present line-by-line results. It is recommended that these results be taken into account in sizing the final thickness of the Galileo's heat shield. 44 Refs.

118) Title: Problems of radiative base heating
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, NASA, Conference on Advanced Technology for Future Space Systems, Hampton, VA, May 8-11, 1979, AIAA Paper 79-0919, 9 p.
Sponsor: AIAA, Washington, D. C., USA; NASA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ATMOSPHERIC ENTRY/*BASE HEATING/*GAS GIANT PLANETS /*JUPITER ATMOSPHERE/*PLANETARY ATMOSPHERES /*RADIATIVE HEAT TRANSFER/*SHOCK HEATING /*SHOCK TUBES/*SPACE PROBES
Minor Term: / BASE FLOW/ GAS FLOW/ GAS PRESSURE/ HEAT FLUX / PRESSURE SENSORS/ RADIOMETERS/ SCALE MODELS / STAGNATION POINT
Abstract: The origin, magnitude, and main uncertainties associated with the problem of radiative heating of the base region of an entry body - for the regime of entry flights into Jupiter - are examined. A one-dimensional analysis of the base flow employing Newtonian hypersonic concepts is presented to demonstrate the intrinsic nature of the radiation phenomon in the region. The earlier calculations of Park are repeated with the same base pressure held at 1 percent of the front stagnation point pressure, Ps, but the pressure in the neck region, Pn, allowed to vary up to 25 percent of Ps, the maximum value predicted by the Chapman-Korst theory. The base-to-front stagnation-point radiative heat flux is derived as qb/qs = 2.4 (Pn/Ps)**1.5 in the presence of ablation, the maximum possible value being 0.3. Current efforts to experimentally determine the heat flux ratio are described. 12 Refs.

119) Title: Shock-tube determination of absorption cross sections and A 2 Delta - X 2Pi band transition moments of SiH

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 21, no. 4, April 1979, p. 373-385. (see A79-32120)

Sponsor: Pergamon Press, Oxford, Great Britain

Doc. Type: Journal Article

Major Term: /*ABSORPTION CROSS SECTIONS/*ABSORPTION SPECTRA /*ELECTRON TRANSITIONS/*HYDRIDES/*SHOCK TUBES /*SILICON COMPOUNDS

Minor Term: / ABSORPTION SPECTROSCOPY/ DISTRIBUTION MOMENTS / METASTABLE STATE/ MOLECULAR ABSORPTION / ULTRAVIOLET ABSORPTION

Abstract: The overall absorption cross sections and electronic transition moments of the A 2 Delta - X 2 Pi band system of SiH have been determined by using an absorption technique with a shock tube at temperatures of 2600-3800 K over the wavelengths of 150-160 nm. Absorption cross sections are shown to be dominated by continua. The possible contributions to the overall cross sections by a low-lying 4 Sigma minus and a high-lying 4 Sigma minus state are discussed. At 200, 228, 340, 445, and 505 nm, the continuum cross sections are (2.9 ± 1.0)**10**minus 17, (2.0 ± 0.5)**10**minus 17, (3.2 ± 0.5)**10**minus 18, (3.8 ± 0.6)**10**minus 18, and (1.8 ± 0.8)**10**minus 18 cm-2, respectively. The overall emission intensity and the Si + H - SiH + photon radiative recombination rate are ((6.7 ± 2.3)**10**minus 35) x (3500/T)**0.7 (Si)(H) watt-cm-3 and ((1.3 ± 0.4)**10**minus 17) x (3500/T)**1.1 (Si)(H) cm-3 s-1, respectively. The A - X transition moments are 0.12 ± 0.04 a. u. for the (0,0) and (1,1) bands. The intensity of each branch in the A - X (0,0) band follows approximately the prediction based on the Hönl-London factors of Kovacs. The data are applied to the study of the flow field around a spacecraft entering the Jovian atmosphere. 17 Refs.

120) Title: Modeling of radiative heating of base region of Jovian entry probe
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 17th, New Orleans, LA, January 15-17, 1979, AIAA Paper 79-0039, 14 p. (see A79-23540)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMODYNAMICS/*ATMOSPHERIC ENTRY /*BASE HEATING/*JUPITER ATMOSPHERE/*JUPITER PROBES /*MATHEMATICAL MODELS/*RADIATIVE HEAT TRANSFER
Minor Term: / ANGULAR DISTRIBUTION/ BASE FLOW/ COMPUTER PROGRAMS / CONSERVATION EQUATIONS/ HYDROGEN IONS / MACH NUMBER/ NONEQUILIBRIUM RADIATION / PRANDTL-MEYER EXPANSION/ RECIRCULATIVE FLUID FLOW / THERMODYNAMIC EQUILIBRIUM/ VELOCITY DISTRIBUTION
Abstract: The mechanism of radiative heating of the afterbody region of Jovian entry probe is analyzed. A theoretical model is derived to determine the average thermodynamic properties in the expanding region, recirculating region, recompression region, and neck region through application of one-dimensional conservation equations. Flow parameters are obtained from the shadowgraphs of a free-flight test. Radiative transfer is calculated using spectrally detailed computer codes accounting for nonequilibrium. The results show that the most severe heating occurs immediately behind the frustum, and that the recompression and neck regions are the major sources of radiation that heats the base stagnation point. The radiation flux to the base point is slightly stronger with ablation than without, its value being 0.11*(43*Pb/Ps)**2 times that to the front stagnation point, where Pb/Ps is the ratio of base-to-front stagnation point pressures and its value is in the range 0.023 to 0.066. The time-integrated heat load to the base point is 18*(43*Pb/Ps)**2 kJ/cm-2. Existing experimental data are shown to agree with the theoretical prediction. 21 Refs.

121) Title: A shock-tube measurement of the SiO/E 1 Sigma + - X 1 Sigma +/ transition moment

Author: Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 20, no. 5, November 1978, p. 491-498. (see A79-18547)

Sponsor: Pergamon Press, Oxford, Great Britain

Doc. Type: Journal Article

Major Term: /*ABSORPTION SPECTROSCOPY/*ELECTRON TRANSITIONS /*MOLECULAR SPECTROSCOPY/*SHOCK HEATING /*SHOCK TUBES/*SILICON OXIDES

Minor Term: / ANGULAR MOMENTUM/ FRANCK-CONDON PRINCIPLE / GAS MIXTURES/ OPTICAL TRANSITION / PHOTOGRAPHIC RECORDING/ VIBRATIONAL SPECTRA

Abstract: The sum of the squares of the electronic transition moments for the (E 1Sigma +) - (X 1 Sigma +) band system of SiO has been determined from absorption measurements conducted in the reflected-shock region of a shock tube. The test gas produced by shock-heating a mixture of SiCl4, N2O, and Ar, and the spectra were recorded photographically in the 150-230-nm wavelength range. The values of the sum of the squares were determined by comparing the measured absorption spectra with those produced by a line-by-line synthetic spectrum calculation. The value so deduced at an r-centroid value of 3.0 Bohr was 0.86 ± 0.10 atomic unit. 13 Refs.

122) Title: Experimental studies of radiative base heating of a Jovian entry model
Author: Shirai, H.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Gunma University, Maebashi, Japan
Source: AIAA, Aerospace Sciences Meeting, 17th, New Orleans, LA, January 15-17, 1979, AIAA Paper 79-0038, 11 p. (see A79-23539)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ATMOSPHERIC ENTRY/*BASE HEATING/*GAS GIANT PLANETS /*PLANETARY ATMOSPHERES/*RADIATIVE HEAT TRANSFER /*SHOCK TUBES
Minor Term: / BASE FLOW/ CALIBRATING/ HEAT FLUX/ MACH NUMBER / RADIOMETERS/ SCALE MODELS/ STAGNATION POINT / TABLES (DATA)
Abstract: A scale model of the Jovian entry vehicle of 6.4 cm diameter is tested in an electric-arc-driven shock tube while a sphere model of 5 cm diameter is tested in a combustion-driven shock tube and an electric-arc-driven shock tunnel. The radiative heat-transfer rate and pressure on the front and the base regions are measured in the absence of ablation with sensors imbedded in the models in a stream consisting of 10% hydrogen in a bath of either neon or argon. The measured radiative heat-transfer rates and pressures are up to about 22 kW/sq cm and 12 atm, respectively, at the front stagnation point. The ratio of the base-to-stagnation-point radiative heat-transfer rates is found to be about 1/4 for the sphere at Mach 1.8, about 1/30 for the sphere at Mach 4.8, and about 1/6 for the scale model at Mach 1.7. When the effects of model geometry and Mach number are accounted for, the present experimental results agree well with the theoretical prediction of Park. 8 Refs.

123) Title: Shock tube spectroscopy of C3 + C2H mixture in the 140 to 700 nm range --- for Jovian entry probe ablation layer simulation

Author: Prakash, S. G.; Park, C.

Corp: Stanford University, Stanford, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 17th, New Orleans, LA, January 15-17, 1979, AIAA Paper 79-0094, 7 p. (see A79-23530)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ABLATION/*ABSORPTION SPECTROSCOPY /*ATMOSPHERIC ENTRY/*GAS MIXTURES/*HEAT SHIELDING /*JUPITER ATMOSPHERE/*JUPITER PROBES/*SHOCK TUBES

Minor Term: / ABSORPTION CROSS SECTIONS/ ACETYLENE/ ARGON / CARBONACEOUS MATERIALS/ COMPUTER PROGRAMS / EMISSION SPECTRA/ OPTICAL EMISSION SPECTROSCOPY / RADIATIVE HEAT TRANSFER/ STAGNATION POINT / ULTRAVIOLET SPECTROSCOPY

Abstract: Absorption spectroscopy has been performed in the reflected-shock region of a shock tube. Acetylene was shock-heated to produce a mixture, at around 4000 K, rich in C3 and C2H to simulate the ablation layer over the Jovian entry probe, and the spectral range from 140 to 700 nm was surveyed with an evacuable spectrograph. The observed spectra were dominated by those of C2 and C3 and an unknown band at wavelengths below 300 nm. The cross sections of the C3 Swings band in the 300 to 450 nm range agreed with previous measurements within a factor of 1.5. No absorption was observed in the wavelength range from 550 to 700 nm. The unknown broadband absorption with a peak cross section of 4 times 10 to the minus 17/sq cm at around 170 nm was attributed tentatively to the C2H radical. A preliminary calculation showed that the newly found absorption band would reduce the radiative heat flux to the stagnation point wall by about 12.5% in a typical flight condition. 14 Refs.

124) Title: Stratospheric-related research using the shock tube
Author: Cooper, D. M.; Park, C.; Boitnott, C. A.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Symposium on Shock Tubes and Waves, 11th, Seattle, WA, July 11-14, 1977 (see A79-15225); Shock tube and shock wave research, University of Washington Press, Seattle, WA, 1978, p. 193-199. (see A79-15207)
Sponsor: Air Force Office of Scientific Research, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AIR POLLUTION/*HALOCARBONS/*OZONE /*POLLUTION MONITORING/*SHOCK TUBES/*STRATOSPHERE
Minor Term: / ABSORPTION CROSS SECTIONS/ ATMOSPHERIC CHEMISTRY / ELECTRON TRANSITIONS/ OZONE DEPLETION / PHOTOABSORPTION/ REACTION KINETICS / SCHUMANN-RUNGE BANDS/ THERMODYNAMIC PROPERTIES / WAVE ATTENUATION
Abstract: The capabilities of shock tubes used in stratospheric-related research are considered, and the results of three independent shock tube research projects are reported. The studies are concerned with the evaluation of stratospheric ozone depletion. In the first experiment, photoabsorption cross sections of Freon 11 and 12 at stratospheric temperatures were measured using rarefaction waves. In the second experiment, reaction-rate coefficients were determined from measurements made behind reflected shock waves. In the third experiment, electronic-transition moments of the O2 Schumann-Runge system and the A2Pi-X2Pi system of ClO were deduced from intensity measurements made behind the incident shock. 20 Refs.

125) Title: Spectral studies of SiCl4 + N2O + Ar and SiH4 + Ar mixtures in a shock tube in 160-550 nm range

Author: Park, Chul; Fujiwara, Toshitaka

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: International Symposium on Shock Tubes and Waves, 11th, Seattle, WA, July 11-14, 1977 (see A79-15220); Shock tube and shock wave research, University of Washington Press, Seattle, WA, 1978, p. 148-155. (see A79-15207)

Sponsor: Air Force Office of Scientific Research, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ABSORPTION SPECTROSCOPY/*GAS MIXTURES /*GAS SPECTROSCOPY/*HEAT SHIELDING/*SHOCK HEATING /*SHOCK TUBES/*SILICON COMPOUNDS

Minor Term: / ABSORPTION CROSS SECTIONS/ ARGON/ CHLORIDES / HYDRIDES/ NITROUS OXIDES/ SILICON DIOXIDE / SILICON OXIDES/ THERMODYNAMIC EQUILIBRIUM

Abstract: By heating SiCl4 + N2O + Ar and SiH4 + Ar mixtures with shock waves, test gases containing SiO, SiO2, SiH, and Si2 were produced in the reflected-shock region of a shock tube. Spectral absorption characteristics were measured for the gases and compared with theoretical characteristics for the wavelength range between 160 and 550 nm, at gas temperatures between 2800 and 3600 K. The sums of the squares of electronic transition moments at equilibrium separation were deduced from tests as: 1.0 ± 0.3 a. u. for the SiO (A1Pi - X1Sigma+) band system; 0.8 ± 0.26 a. u. for that or SiO (E1Sigma+ - X1Sigma+); 1.3 ± 0.4 a. u. for SiH (A2Delta - X2Pi); 0.52 ± 0.2 a. u. for SiH (B2Sigma+ - X2Pi); 0.73 ± 0.25 a. u. for Si2 (K3Sigma u- - X3Sigma g-); and 1.5 ± 0.5 a. u. for Si2 (L3Piu - D3Pig). Absorption by SiO2 and other known bands of SiO, SiH, and Si2 were found to be too weak to be measurable. The cross sections of absorption by a continuum, believed due to SiH, varied from 2.5 x 10** minus 17 sq cm at 280 nm to 1.6 x 10** minus 18 sq cm at 440 nm. 16 Refs.

126) Title: Nitric oxide production by Tunguska meteor
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Acta Astronautica (ISSN 0094-0701), Journal of the International Academy of Astronautics, vol. 5, no. 7-8, July-August 1978, p. 523-542.
(see A78-51811)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*GAS EVOLUTION/*METEORITIC COMPOSITION/*NITRIC OXIDE /*REACTION KINETICS/*TUNGUSK METEORITE
Minor Term: / ABLATION/ ATMOSPHERIC CHEMISTRY/ FLOW DISTRIBUTION / OPTICAL THICKNESS/ OZONE/ WAKES
Abstract: The nonequilibrium chemical processes of nitric oxide formation are computed for the wake of the Tunguska meteor of 1908. The wake characteristics are derived by carrying out an optically-thick radiation field analysis for ablation of the meteoroid. The wake flow field is approximated by a one-dimensional, well-stirred reactor model. Known characteristics of the Tunguska event are imposed as constraints, and three controlling parameters, chemical composition, density, and velocity, are varied over a range around the values derived by Korobeinikov et al. (1976) and Petrov and Stulov (1975). The calculation shows that at least 19 million tons of nitric oxide is produced between the altitudes of 10 and 50 km. The anomalous atmospheric phenomena following the event are attributed to the reactions involving nitric oxide thus produced and atmospheric ozone. It is speculated that the nitric oxide produced by the event fertilized the area near the fall, causing the observed rapid plant growth.
40 Refs.

127) Title: Odd nitrogen production by meteoroids
Author: Park, Chul; Menees, Gene P.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Geophysical Research (ISSN: 0148-0227), vol. 83, no. c8, August 20, 1978, p. 4029-4035. (see A78-48063)
Sponsor: American Geophysical Union, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ATMOSPHERIC ENTRY/*METEOROIDS/*NITRIC OXIDE /*NITROGEN ATOMS
Minor Term: / ABLATION/ ATMOSPHERIC CHEMISTRY/ ELECTRON ENERGY / NUMERICAL INTEGRATION/ REACTION KINETICS
Abstract: The process by which odd nitrogen species (atomic nitrogen and nitric oxide) are formed during atmospheric entry of meteoroids is analyzed theoretically. An ablating meteoroid is assumed to be a point source of mass with a continuum regime evolving in its wake. The amounts of odd nitrogen species, produced by high-temperature reactions of air in the continuum wake, are calculated by numerical integration of chemical rate equations. Flow properties are assumed to be uniform across the wake, and 29 reactions involving five neutral species and five singly ionized species are considered, as well as vibrational and electron temperature nonequilibrium phenomena. The results, when they are summed over the observed mass, velocity, and entry-angle distribution of meteoroids, provide odd-nitrogen-species annual global production rates as functions of altitude. The peak production of nitric oxide is found to occur at an altitude of about 85 km; atomic nitrogen production peaks at about 95 km. The total annual rate for nitric oxide is 40 million kg; for atomic nitrogen it is 170 million kg. 29 Refs.

128) Title: Shock tube studies of atomic silicon emission in the spectral range 180 to300 nm ~ environment simulation for Jupiter probes

Author: Prakash, S. G.; Park, C.

Corp: Stanford University, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 16th, Huntsville, AL, January 16-18, 1978, AIAA Paper 78-234, 10 p. (see A78-22602)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*EMISSION SPECTRA/*HEAT SHIELDING/*JUPITER PROBES /*SHOCK TUBES/*SILICON/*SPACE ENVIRONMENT SIMULATION

Minor Term: / ELECTRON DENSITY (CONCENTRATION)/ HYDROGEN ATOMS / LORENTZ FORCE/ RADIATIVE TRANSFER/ SHOCK LAYERS / SPECTRAL LINE WIDTH/ STARK EFFECT / VAN DER WAALS FORCES

Abstract: Emission spectroscopy of shock-heated atomic silicon was performed in the spectral range 180 to 300 nm, in an environment simulating the ablation layer expected around a Jovian entry probe with a silica heat shield. From the spectra obtained at temperatures from 6000 to 10,000 K and electron number densities from 1 quadrillion to 100 quadrillion per cu cm, the Lorentzian line-widths were determined. The results showed that silicon lines are broadened significantly by both electrons (Stark broadening) and hydrogen atoms (Van der Waals broadening), and the combined line-widths are much larger than previously assumed. From the data, the Stark and the Van der Waals line-widths were determined for 34 silicon lines. Radiative transport through a typical shock layer was computed using the new line-width data. The computations showed that silicon emission in the hot region is large, but it is mostly absorbed in the colder region adjacent to the wall.
17 Refs.

129) Title: A shock-tube determination of the SiO /A 1 Pi - X 1 Sigma +/ transition moment

Author: Park, C.; Arnold, J. O.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 19, no. 1, January 1978, p. 1-10. (see A78-18432)

Sponsor: Pergamon Press, Oxford, Great Britain

Doc. Type: Journal Article

Major Term: /*ABSORPTION SPECTROSCOPY/*ELECTRON TRANSITIONS /*SHOCK TUBES/*SILICON OXIDES

Minor Term: / LINE SPECTRA/ SHOCK HEATING / THERMODYNAMIC PROPERTIES

Abstract: The sum of the squares of the electronic transition moments for the A 1 Pi - X 1 Sigma + band system of SiO has been determined from absorption measurements conducted in the reflected-shock region of a shock tube. The test gas was produced by shock-heating a mixture of N2O, SiCl4, and Ar, and the spectra were recorded photographically in the 260-290 nm wavelength range. The values of the sum as a function of internuclear distance between 2.8 and 3.3 Bohr were determined by comparing the measured absorption spectrum with that produced by a line-by-line synthetic-spectrum calculation which accounted for instrumental broadening. The value of the sum so deduced at an internuclear distance of 3.0 Bohr was $1.0 \pm 0.3$ atomic units. 23 Refs.

130) Title: Shock-tube studies of silicon-compound vapors
Author: Park, Chul; Fujiwara, Toshitaka
Corp: Ames Research Center, NASA, Moffett Field, CA, USA
Source: Progress in Astronautics and Aeronautics (ISSN: 0079-6050), Aerodynamic Heating and Thermal Protection Systems, vol. 59, AIAA, Washington, D. C., 1978, p. 137-55. (see also AIAA, Thermophysics Conference, 12th, Albuquerque, NM, June 27-29, 1977, AIAA Paper 77-769, 8 p. (see A77-37277))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABSORPTION SPECTRA/*GAS MIXTURES/*GAS SPECTROSCOPY /*SHOCK TUBES/*SHOCK WAVE PROPAGATION /*SILICON COMPOUNDS
Minor Term: / CHLORIDES/ FORBIDDEN TRANSITIONS/ HEAT SHIELDING / HYDRIDES/ SILICON OXIDES/ VAPORS/ WAVE REFLECTION
Abstract: Test gas mixtures containing SiO, SiO2, Si2, and SiH were produced in a 5 cm ID shock tube by processing shock waves through a mixture of SiCl4 + N2O + Ar, SiH4 + Ar, or SiH4 + O2 + Ar. Absorption spectra of the test gases were studied photographically in the reflected shock region using a xenon flash lamp as the light source in the range of wavelengths between 250 and 600 nm. SiO was found to be a dominant species in the vapors produced by the SiCl4 + N2O and SiH4 + O2 mixture prior to then shock arrival, and the resulting solid SiO2 particles evaporated behind the shock wave. Spectral absorption characteristics of SiO, SiO2, Si2, and SiH were determined by studying the test gases. 18 Refs.

131) Title: Shock-tube studies of silicon-compound vapors
Author: Park, C.; Fujiwara, T.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Thermophysics Conference, 12th, Albuquerque, NM, June 27-29, 1977, AIAA Paper 77-769, 8 p. (see A77-37277)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ABSORPTION SPECTRA/*GAS MIXTURES/*GAS SPECTROSCOPY /*SHOCK TUBES/*SHOCK WAVE PROPAGATION /*SILICON COMPOUNDS
Minor Term: / CHLORIDES/ FORBIDDEN TRANSITIONS/ HEAT SHIELDING / HYDRIDES/ SILICON OXIDES/ VAPORS/ WAVE REFLECTION
Abstract: Test gas mixtures containing SiO, SiO2, Si2, and SiH were produced in a shock tube by processing shock waves through a mixture of SiCl4 + N2O + Ar, SiH4 + Ar, or SiH4 + O2 + Ar. Absorption spectra of the test gases were studied photographically in the reflected shock region using a xenon flash lamp as the light source in the range of wavelengths between 250 and 600 nm. SiO was found to be a dominant species in the vapors produced by the SiCl4 + N2O and SiH4 + O2 mixtures. Spontaneous combustion was observed in the SiH4 + O2 + Ar mixture prior to the shock arrival, and the resulting solid SiO2 particles evaporated behind the shock wave. Spectral absorption characteristics of SiO, SiO2, Si2, and SiH were determined by studying the test gases. 18 Refs.

132) Title: Reaction rates for O3 + HCl yielding O + O2 + HCl, Cl + O3 yielding ClO +O2, and HCl + O yielding OH + Cl at elevated temperatures

Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Physical Chemistry (ISSN: 0022-3654), vol. 81, no. 6, March 24, 1977, p. 499-504. (see A77-29725)

Sponsor: American Chemical Society, Washington, D. C., USA
Doc. Type: Journal Article

Major Term: /*HYDROGEN CHLORIDES/*OZONE/*PYROLYSIS /*REACTION KINETICS/*SHOCK HEATING

Minor Term: / CHEMICAL REACTIONS/ HIGH PRESSURE / HIGH TEMPERATURE TESTS/ PRESSURE EFFECTS / TEMPERATURE EFFECTS

Abstract: Ozone and a much greater quantity of hydrogen chloride, slightly diluted by oxygen and argon, were heated by a shock wave process to temperatures in the range 480-1300 K at pressures from four to eight atmospheres. From variations in ozone concentration, determined by the attenuation of 2537 Å radiation, the rate coefficient for the reaction O3 + HCl yielding O + O2 + HCl was determined to be k1 = ((4.0 ± 1.5) x 10**minus 10) exp(-10,408/T) cm3 s-1 for temperatures of 480-720 K. From the concentration of ClO remaining at the end of ozone decomposition the rate coefficients for the reactions Cl + O3 yielding ClO + O2 and HCl + O yielding OH + Cl were also deduced to be k4 = (1.35 ± 0.4) x 10**minus 11 and k2 = (2.0 ± 1.0) x 10** minus 14 cm3/s, respectively, at a temperature of about 1100 K. 12 Refs.

133) Title: Effects of atomic oxygen on graphite ablation
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 14, no. 11, November 1976, p. 1640-1642. (see A77-13723)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABLATIVE MATERIALS/*GRAPHITE/*OXYGEN ATOMS /*REENTRY PHYSICS
Minor Term: / ABLATIVE NOSE CONES/ CHEMICAL REACTIONS / CONVECTIVE HEAT TRANSFER/ISOTROPIC MEDIA / REACTION KINETICS/ STAGNATION POINT / THERMOCHEMISTRY
Abstract: It is shown that a previously derived semi-empirical equation for describing observed ablation rates of isotropic graphites cannot be applied to low-density flows containing dissociated oxygen. Experimentally determined reaction probabilities of isotropic graphites to molecular and atomic oxygen are used to calculate heat-transfer rates and stagnation-point ablation rates for typical conditions. Integrated mass losses are computed for a group of flight trajectories which start from geosynchronous orbit and enter earth's atmosphere in a skipping motion following near-elliptic decaying orbits. A comparison of the results with those obtained by the equation under question shows excellent agreement for steep trajectories, but large discrepancies for shallow trajectories. The differences are attributed to surface oxidation by atomic oxygen. 23 Refs. (edited)

134) Title: High temperature reformation of aluminum and chlorine compounds behind the Mach disk of a solid-fuel rocket exhaust

Author: Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Atmospheric Environment (ISSN: 0004-6981), vol. 10, no. 9, 1976, p. 693-702. (see A76-44597)

Sponsor: Pergamon Press, Oxford, Great Britain

Doc. Type: Journal Article

Major Term: /*ALUMINUM OXIDES/*CHEMICAL REACTIONS /*CHLORINE COMPOUNDS/*HIGH TEMPERATURE PROPELLANTS /*ROCKET EXHAUST/*SOLID ROCKET PROPELLANTS

Minor Term: / AIR POLLUTION/ ATMOSPHERIC EFFECTS/ FLOW DISTRIBUTION / GAS DYNAMICS/ SEPARATED FLOW / SPACE SHUTTLE BOOSTERS

Abstract: Chemical reactions expected to occur among the constituents of solid-fuel rocket engine effluents in the hot region behind a Mach disk are analyzed theoretically. With the use of a rocket plume model that assumes the flow to be separated in the base region, and a chemical reaction scheme that includes evaporation of alumina and the associated reactions of 17 gas species, the reformation of the effluent is calculated. It is shown that AlClO and AlOH are produced in exchange for a corresponding reduction in the amounts of HCl and Al2O3. For the case of the space shuttle booster engines, up to 2% of the original mass of the rocket fuel can possibly be converted to these two new species and deposited in the atmosphere between the altitudes of 10 and 40 km. No adverse effects on the atmospheric environment are anticipated with the addition of these two new species. 39 Refs.

135) Title: Nitric oxide formation by meteoroids in the upper atmosphere
Author: Menees, Gene P.; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Atmospheric Environment (ISSN: 0004-6981), vol. 10, no. 7, 1976, p. 535-545. (see A76-37678)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*ATMOSPHERIC CHEMISTRY/*ATMOSPHERIC ENTRY /*METEOROIDS/*NITRIC OXIDE/*UPPER ATMOSPHERE
Minor Term: / ABLATIVE MATERIALS/ HIGH TEMPERATURE ENVIRONMENTS / REACTION KINETICS
Abstract: The process of nitric oxide formation during atmospheric entry of meteoroids is analyzed theoretically. An ablating meteoroid is assumed to be a point source in a uniform flow with a continuum regime evolving in its wake. The amount of nitric oxide produced by high-temperature reactions of air in the continuum regime is calculated by numerical integration of chemical-rate equations. This is accomplished by assuming that flow properties are constant across the reacting region, the radius of the region being determined from considerations of shock-wave formation and molecular diffusion. The results, when summed over the observed mass, velocity, and entry-angle distributions of meteoroids, provide annual global production rates of nitric oxide as a function of altitude. The peak production of nitric oxide is found to occur at altitudes between 90 and 100 km, the total annual rate being about 40 million kg. The present results suggest that the large concentration of nitric oxide observed below 95 km could be attributed to meteoroids instead of photodissociation of nitrogen into metastable, 2D-state atoms, as has been previously hypothesized. 11 Refs.

136) Title: Estimates of nitric oxide production for lifting spacecraft reentry
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Atmospheric Environment (ISSN: 0004-6981), vol. 10, no. 4, 1976, p. 309-313. (see A76-37657)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*CHEMICAL REACTIONS/*HYPERSONIC REENTRY /*LIFTING REENTRY VEHICLES/*NITRIC OXIDE /*REENTRY EFFECTS
Minor Term: / ATMOSPHERIC COMPOSITION/ NUMERICAL INTEGRATION / REACTION KINETICS/ TRAILING EDGES/ TURBULENT WAKES
Abstract: An approximate analysis to estimate the quantity of nitric oxide that could be formed in the wake of a reentering lifting spacecraft is reported. Three different approaches are undertaken: two simplified analytical models utilizing the sudden-freezing concept named the 'trailing-edge-freezing' and 'wake-freezing' approximations, and a computer calculation involving numerical integration of chemical rate equations. The three methods predict a maximum nitric oxide production equivalent to 6, 9.5 and 8% of the mass of the spacecraft, respectively. Thus, the amount of nitric oxide expected to be produced by future space activities is negligibly small compared with that produced by the natural processes. 14 Refs.

137) Title: Shock tube study of ionization rates of NaCl-contaminated argon
Author: Schneider, Claus-Peter; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Shock Tube Symposium, 10th, Kyoto, Japan, July 14-16, 1975 (see A76-35582); Modern developments in shock tube research, Shock Tube Research Society, Kyoto, 1975, p. 757-779. (see A76-35505)
Sponsor: Shock Tube Research Society, Kyoto, Japan
Doc. Type: Conference Paper
Major Term: /*ARGON PLASMA/*ELECTRON DENSITY (CONCENTRATION) /*ION PRODUCTION RATES/*PLASMA DIAGNOSTICS /*SHOCK TUBES/*SODIUM CHLORIDES
Minor Term: / ARGON PLASMA/ ELECTRON ENERGY / MICROWAVE PLASMA PROBES/ RADIOMETERS / REACTION KINETICS/ SHOCK HEATING/ SHOCK WAVES / SPECTRAL RESOLUTION
Abstract: Electron density, electron temperature, and concentration of excited sodium atoms are measured in the weakly ionized regime behind a shock wave in an impure argon shock tube using microwave technique and spectrally-resolved radiometry. Evidence is presented to show that an apparent increase in the rate of ionization due to electron detachment of negative chlorine ions produced from sodium chloride vapor contained as an impurity. To be consistent with this chemical model, rate coefficients are found for 5500 < T < 8600 K to be as follows: for NaCl + A + 5.8 eV - Na+ + Cl- + A, k4 = (0.082) exp(-67,315/T)*T**2 cm3 s-1; for Cl- + A + 3.61 eV - Cl + e + A, k5 = (6 x 10**minus 12) exp(-41,900/T) cm3 s-1; and for the branching ratio between the reaction NaCl + A + 5.8 eV - Na+ + Cl- + A(k4) and reaction NaCl + A + 4.27 eV - Na+ + Cl- + A(k3), k4/k3 = (1.6 x 10**4) exp(-17,760/T). Electron temperature is lower that heavy particle temperature roughly by 1000 K. The electron-argon impact ionization rate coefficient is a weak function of electron temperature in contradiction to expectation. 43 Refs.

138) Title: Rates of reactions ClO + ClO yields Cl2 + O2 and ClO + O yields Cl + O2 at elevated temperatures --- atmospheric ozone-chlorine reactions

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Physical Chemistry (ISSN: 0022-3654), vol. 80, no. 6, March 11, 1976, p. 565-571. (see A76-33470)

Sponsor: American Chemical Society, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ATMOSPHERIC CHEMISTRY/*CHLORINE OXIDES /*GAS DISSOCIATION/*HIGH TEMPERATURE/*OZONE /*REACTION KINETICS

Minor Term: / ABSORPTION CROSS SECTIONS/ ABSORPTION SPECTRA / CHLORINE/ OXYGEN ATOMS/ SHOCK HEATING/ SHOCK TUBES

Abstract: Results are reported for an experiment in which a shock tube was employed to measure the reaction rates of chlorine-oxygen systems at high temperatures. In this experiment, a mixture of chlorine and ozone, diluted by oxygen and argon, was heated by two consecutive shock waves (primary and reflected) to produce a temperature in the range from 1000 to 1400 K and a pressure of between 3.5 and 9 atm. The reflected shock thermally decomposed the ozone; the resulting atomic oxygen reacted with molecular chlorine to produce ClO; and the variation in ClO concentration after passage of the reflected shock was observed by monitoring the intensity of 2537 Å radiation passing through the test gas. The rates of the two cited reactions are deduced from the variation pattern. The rate coefficient values are found to be compatible with existing data obtained in lower pressure and temperature ranges. 17 Refs.

139) Title: Shock tube study of ionization rates of NaCl-contaminated argon
Author: Schneider, K. -P.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Physics of Fluids (ISSN: 0899-8213), vol. 18, no. 8, August 1975, p. 969-981. (see A75-41710)
Sponsor: American Institute of Physics, New York, NY, USA
Doc. Type: Journal Article
Major Term: /*ARGON PLASMA/*IONIZATION COEFFICIENTS /*PLASMA DIAGNOSTICS/*SHOCK HEATING /*SODIUM CHLORIDES
Minor Term: / ELECTRON ENERGY/ HYPERVELOCITY IMPACT / MICROWAVE RADIOMETERS/ SHOCK TUBES
Abstract: Electron density, electron temperature, and concentration of excited sodium atoms are measured in the weakly ionized regime behind a shock wave in impure argon in a shock tube using microwave techniques and spectrally resolved radiometry. Evidence is presented to show that an apparent increase in the rate of ionization is due to electron detachment of negative chlorine ions produced from sodium chloride vapor contained as an impurity. To be consistent with this chemical model, rate coefficients are found in the temperature range between 5500 and 8600 K for the dissociation of NaCl into an ion pair, dissociation of NaCl into a neutral pair, and electron detachment of a negative chlorine ion. Electron temperature is lower than heavy-particle temperature by roughly 1000 K. The electron-argon impact-ionization rate coefficient is a weak function of electron temperature in contradiction to expectation. 44 Refs.

140) Title: Computation of nonequilibrium three-dimensional inviscid flow over blunt-nosed bodies flying at supersonic speeds

Author: Rakich, J. V.; Bailey, H. E.; Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Fluid and Plasma Dynamics Conference, 8th, Hartford, CN, June 16-18, 1975, AIAA Paper 75-835, 13 p. (see A75-33931)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Article

Major Term: /*BLUNT BODIES/*CONICAL BODIES/*INVISCID FLOW /*NONEQUILIBRIUM FLOW/*SUPERSONIC FLIGHT /*THREE DIMENSIONAL FLOW

Minor Term: / ANGLE OF ATTACK/ BOW WAVES/ CHEMICAL EQUILIBRIUM / COMPUTER TECHNIQUES/ ENTROPY / FINITE DIFFERENCE THEORY/ REENTRY PHYSICS / SHOCK WAVES/ SPACE SHUTTLES

Abstract: A computer code based on the method of characteristics is described and applied to the study of two- and three-dimensional chemical nonequilibrium flow over sharp and blunt-nosed bodies. Nonequilibrium flow over a wedge is used to show the approach to equilibrium flow, and to demonstrate the nature of the reaction zone behind the bow shock wave. The structure and development of a blunt-body entropy layer in nonequilibrium flow is examined for a blunt cone at zero incidence. Three-dimensional computations for the space shuttle body at 30 degree angle of attack are presented. A nondimensional scaling parameter, the Damkohler number, which is the ratio of flow time to chemical reaction time, is calculated and its significance discussed. 22 Refs.

141) Title: Nitric oxide formation by meteoroids in the upper atmosphere
Author: Menees, Gene P.; Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Fluid and Plasma Dynamics Conference, 7th, Palo Alto, CA, June 17-19, 1974, AIAA Paper 74-591, 10 p. (see A74-33170)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*AEROTHERMOCHEMISTRY/*ATMOSPHERIC CHEMISTRY /*ATMOSPHERIC ENTRY/*METEOROIDS/*NITRIC OXIDE /*UPPER ATMOSPHERE
Minor Term: / ABLATION/ BOLIDES/ CONTINUUM FLOW / FLOW DISTRIBUTION/ KNUDSEN FLOW/ LAMINAR WAKES / POINT SOURCES/ REACTION KINETICS
Abstract: The process of nitric oxide formation during atmospheric entry of meteoroids is analyzed theoretically. An ablating meteoroid is assumed to be a point source in a uniform flow with a continuum regime evolving in its wake. The amount of nitric oxide produced by high-temperature reactions of air in the continuum regime is calculated by numerical integration of chemical-rate equations. This is accomplished by assuming that flow properties are constant across the reacting region, its radius being determined from considerations of shock-wave formation and molecular diffusion. The results, when summed over the observed mass, velocity, and entry-angle distributions of meteoroids, provide annual global production rates of nitric oxide as a function of altitude. The peak production is found to occur between 90- and 100-km altitude, the total annual rate being around 40 million kg. The present results suggest that the large concentration of nitric oxide observed below 95 km could be attributed to meteoroids instead of photodissociation of nitrogen into metastable, 2D-state atoms, as has been previously been hypothesized. 13 Refs.

142) Title: Shock tube measurements of soot oxidation rates at combustion temperatures and pressures

Author: Park, C.; Appleton, J. P.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Massachusetts Institute of Technology, Cambridge, MA, USA

Source: International Shock Tube Symposium, 9th, Stanford, CA, July 16-19, 1973 (see A74-16441); Recent developments in shock tube research, Stanford University Press, Stanford, CA, 1973, p. 793-803. (A74-1637505-12)

Sponsor: Stanford University, Stanford, CA, USA; Air Force Office of Scientific Research, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*COMBUSTION TEMPERATURE/*HYDROCARBON COMBUSTION /*OXIDATION/*SHOCK TUBES/*SOOT

Minor Term: / AEROSOLS/ AIR POLLUTION/ COMBUSTION CHAMBERS / DIFFUSION FLAMES/ FUEL COMBUSTION / PRESSURE DISTRIBUTION/ TIME DEPENDENCE / WAVE ATTENUATION

Abstract: A new technique has been developed for measuring the specific surface oxidation rate of soot particles. It employs an aerosol process for initially dispersing the soot particles and a time-resolved light-attenuation measurement for determining the particle concentration in the reaction zone. Using two types of carbon black, which are typical of the soot formed in hydrocarbon fuel combustion, the technique is applied to measure the oxidation rate in the range of temperature and pressure prevailing in practical fuel combustors. The test results indicate that the soot particles can be considered completely dispersed in the reflected-shock region where the oxidation rate measurement was made. The oxidation rate of soot is found to be nearly equal to that for a pyrolytic graphite. 24 Refs.

143) Title: Ledge spacings in evaporation of molecular solids
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Massachusetts Institute of Technology, Cambridge, MA, USA
Source: Journal of Chemical Physics (ISSN: 0021-9606), vol. 59, no. 6, 1973, p. 3427-8.
Sponsor: American Institute of Physics, New York, NY, USA
Doc. Type: Journal Article
Major Term: /*EVAPORATION/*EVAPORATION RATE/*IODINE
Minor Term: / COMPUTER SIMULATION/ SOLIDS
Abstract: A recent computer simulation elucidates that the evaporation coefficient 'alpha' of an ideal solid is a function mainly of the average ledge spacing, 'lambda1'. Experimental evidences on monatomic solids give the upper limit on the ledge spacing as 'lambda1' < L, where L is the "diffusion-jump" distance. The lower limit of 'lambda1' cannot be determined from monatomic solid data because the evaporation coefficient is insensitive to the ledge spacing in the lower range of 'lambda1'/L. This work offers a means of estimating the lower limit of the ledge spacing from experimental evaporation rate data on simple molecular solids. 11 Refs.

144) Title: Comparison of electron and electronic temperatures in recombining nozzle flow of ionized nitrogen-hydrogen mixture. I. Theory, II. Experiment

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Plasma Physics (ISSN: 022-3778), vol. 9, pt. 2, April 1973, p. 187-215 (pt. I), 217-234 (pt. II). (see A73-37441)

Sponsor: Cambridge University Press, Cambridge, Great Britain

Doc. Type: Journal Article

Major Term: /*ELECTRON ENERGY/*GAS MIXTURES/*IONIZED GASES /*NOZZLE FLOW/*RECOMBINATION REACTIONS

Minor Term: / ELECTRON STATES/ GAS EXPANSION/ HYDROGEN / MOLECULAR RELAXATION/ NITROGEN / NONEQUILIBRIUM CONDITIONS/ POPULATION INVERSION / QUANTUM MECHANICS/ RADIATION ABSORPTION / TEMPERATURE EFFECTS

Abstract: Relaxation of the population distribution of electronic states is studied theoretically for a highly ionized nitrogen-hydrogen mixture expanding through a nozzle wherein the hydrogen content is less than 0.1%. The analysis incorporates quantum-mechanical rate coefficients, and considers the effects of wall cooling and absorption of radiation. Calculations are carried out for a condition produced experimentally. Visible and infrared line radiation from nitrogen and hydrogen were measured with a spectrograph. The geometry and stagnation conditions were those calculated theoretically. The experiment confirms quantitatively the predictions that the electronic excitation temperatures of hydrogen and (3P) core states of nitrogen are higher than the electron temperature, and that (3P) excitation temperatures exhibit maxima within the nozzle. 30 Refs. (part I); 10 Refs. (Part II)

145) Title: Shock-tube measurements of soot oxidation rates
Author: Park, C.; Appleton, J. P.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA; Massachusetts Institute of Technology, Cambridge, MA, USA
Source: Combustion and Flame (ISSN: 0010-2180), Journal of the Combustion Institute, vol. 20, no. 3, June 1973, p. 369-379. (see A73-33344)
Sponsor: American Elsevier, New York, NY, USA
Doc. Type: Journal Article
Major Term: /*BURNING RATE/*HYDROCARBON COMBUSTION/*OXIDATION /*REACTION KINETICS/*SHOCK TUBES/*SOOT
Minor Term: / AIR POLLUTION/ PARTICLE SIZE DISTRIBUTION / POLYMERIZATION/ PYROLYSIS/SEMIEMPIRICAL EQUATIONS / STOICHIOMETRY
Abstract: Surface oxidation rates of two types of carbon black, which are representative of soot formed during the combustion of hydrocarbon fuels, have been measured in a shock tube over the range of temperature 1700-4000 K and of pressure 0.05-13 atm of oxygen. The results illustrate that the specific surface reaction rate is nearly the same as that which has previously been measured for the oxidation of pyrolytic graphite samples, and can be approximately correlated by a semiempirical formula for pyrolytic graphite oxidation proposed by Nagle and Strickland-Constable. 24 Refs.

146) Title: Population inversion of atomic carbon in recombining plasma flow
Author: Bowen, S. W.; Park, C.
Corp: University of Michigan, Ann Arbor, MI, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 10, no. 4, April 1972, p. 522-524.
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ABSORPTION SPECTRA/*ATOMIC SPECTRA/*NOZZLE FLOW /*PLASMA HEATING/*POPULATION INVERSION
Minor Term: / ARC HEATING/ ARGON/ CARBON/ HELIUM/ LINE SPECTRA / MAGNETOHYDRODYNAMIC FLOW/ METHANE / PLASMA DIAGNOSTICS/ SELF ABSORPTION
Abstract: Recent theoretical calculations and experimental measurements have indicated that a large overpopulation of upper neutral atom excited states with respect to the ground state can exist in an arc-heated plasma expanding through a nozzle. It is shown experimentally that such an overpopulation results ultimately in a population inversion between a pair of states corresponding to a visible or infrared spectral line. Literature predicts that a population inversion may occur also for an ultraviolet line. The purpose of the present work is to examine experimentally the population inversion of an ultraviolet line. Here, spectroscopic measurements made on high-pressure high-temperature, arc-heated helium-methane or argon-methane mixtures expanding through a nozzle show a population inversion in the neutral carbon line at 2478.6 Å corresponding to the 2p2 1S0 - 2p 3s 1(P1)0 transition. 8 Refs.

147) Title: Atomic recombination rate determination through heat-transfer measurement.
Author: Park, C.; Anderson, L. A.; Sheldahl, R. E.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 11, no. 3, March 1973, p. 372-374. (see A73-23449)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ATOMIC RECOMBINATION/*GAS DISSOCIATION/*HEAT FLUX /*HEAT TRANSFER/*RECOMBINATION COEFFICIENT
Minor Term: / ARGON/ BOUNDARY VALUE PROBLEMS / LAMINAR BOUNDARY LAYER/ NITROGEN/ PIPE FLOW / REACTION KINETICS/ SUBSONIC FLOW
Abstract: A theoretical and experimental demonstration is presented which shows that under suitable conditions the volume recombination coefficient can be determined by measuring the heat transfer rate into the wall of a cylinder through which a dissociated stream is passing. The experimental results obtained are in agreement with those of other investigators. 7 Refs. (edited)

148) Title: Shock-tube measurements of soot oxidation rates
Author: Park, C.; Appleton, J. P.
Corp: Massachusetts Institute of Technology, Cambridge, MA, USA
Source: Fluid Mechanics Laboratory, Publication No. 72-8, July 1972, 32 p. (see N73-10176)
Sponsor: Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA
Doc. Type: Report
Major Term: /*HYDROCARBON COMBUSTION/*OXIDATION/*SHOCK TUBES /*SOOT
Minor Term: / MATHEMATICAL MODELS/ PRESSURE EFFECTS / REACTION KINETICS/ SURFACE REACTIONS / TEMPERATURE EFFECTS
Abstract: Surface oxidation rates of two types of carbon black, which are representative of soot formed during the combustion of hydrocarbon fuels, have been measured in a shock tube over the ranges of temperature between 1700 and 4000 K and pressure between 0.05 and 13 atm of oxygen. The results illustrate that the specific surface reaction rate is nearly the same as that which has previously been measured for the oxidation of polycrystalline pyrographite, and that the results can be approximately correlated by a semi-empirical formula for pyrographite oxidation proposed by Nagle and Strickland-Constable. 22 Refs.

149) Title: Electrical conductivity and velocity of highly ionized plasma flows - Theory and experiment.

Author: Vendell, E. W.; Park, C.; Posch, R. E.

Corp: Utah State University of Agriculture and Applied Science, Logan, UT, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Fluid and Plasma Dynamics Conference, 5th, Boston, MA, June 26-28, 1972, AIAA Paper 72-671, 6 p. (see A72-34069)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*FLOW VELOCITY/*NITROGEN/*PLASMA CONDUCTIVITY /*PLASMA DIAGNOSTICS/*PLASMA JETS

Minor Term: / BOW WAVES/ CONFERENCES/ ELECTRICAL RESISTIVITY / ELECTRON DENSITY(CONCENTRATION)/ ELECTRON ENERGY / IONIZED GASES/ MAGNETIC PROBES /MAGNETOHYDRODYNAMIC FLOW/ PLASMA PROBES / SHOCK WAVES

Abstract: Use of an immersible, three-coil, magnetic-induction probe, previously tested in a low-density supersonic argon jet, to measure electrical conductivity and velocity profiles of a highly ionized high-density nitrogen jet in the continuum flow regime where effects due to probe bow shocks and boundary layers might not be negligible. Measured centerline values of electrical conductivity and velocity were compared with predictions based on a theoretical analysis previously developed to study the gas as it expanded adiabatically and inviscidly from an equilibrium sonic state to the nozzle exit. The resulting numerical exit plane values for electron density and electron temperature were then substituted into the Spitzer-Haerm conductivity formula to compute a theoretical conductivity which agreed within 40% of the measured conductivity, while the calculated and experimental velocity values differed by as much as 50%. The lack of agreement was attributed to the possible use of invalid assumptions and boundary conditions in the computer analysis or to the unknown effects of shocks on the probe data. 30 Refs.

150) Title: Propellant flow rate through simulated liquid-core nuclear rocket fuel bed
Author: McGuirk, James P.; Park, Chul
Corp: University of Santa Clara, Santa Clara, CA, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 9, no. 5, May 1972, p. 375-376. (see A72-30923)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*FLUIDIZED BED PROCESSORS/*NUCLEAR ROCKET ENGINES /*ROCKET PROPELLANTS/*ROTATING LIQUIDS /*TWO PHASE FLOW
Minor Term: / CENTRIFUGING/ HYDROGEN/ MASS FLOW RATE / NUCLEAR FUELS/ NUCLEAR PROPULSION/ SIMULATION
Abstract: Experimental investigation of the validity of Zuber and Finlay's (1965) gas flow-rate formula for a two-phase flow in a rotating cylinder under high centrifugal acceleration. This formula was originally derived from tests in a 1-g environment in pipes. In the light of the investigation results obtained, the formula is valid also for a high-g environment in the rotating chamber tested. 4 Refs. (edited)

151) Title: Hydrogen line ratios as electron temperature indicators in nonequilibrium plasmas
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 12, no. 3, March 1972, p. 323-370. (see A72-22666)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*BALMER SERIES/*ELECTRON ENERGY/*H LINES /*NONEQUILIBRIUM PLASMAS
Minor Term: / H ALPHA LINE/ H BETA LINE/ SAHA EQUATIONS
Abstract: The ratio of intensities of hydrogen Balmer lines H-alpha/H-beta is proposed as an indicator of electron temperature in a nonequilibrium plasma. Although different from the equilibrium case, the intensity ratio is a unique function of electron temperature provided that the optical depth is small for the visible lines and the plasma is far out of equilibrium. For such a plasma, the H-alpha/H-beta intensity ratios are computed. The results are tabulated in the form of a conversion table between the measured excitation temperature and the true electron temperature. The ranges of applicability of the conversion table are also computed and are presented in separate tables. An example is shown in which particle densities are consistent with the Saha equilibrium condition at the apparent excitation temperature even though the plasma is in nonequilibrium at a different true electron temperature. 23 Refs.

152) Title: Estimates of nitric oxide production for lifting spacecraft reentry
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-X-62052, July 1971, 37 p. (see N72-31862)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*LIFTING REENTRY VEHICLES/*NITRIC OXIDE /*SPACECRAFT REENTRY
Minor Term: / APPROXIMATION/ NUMERICAL INTEGRATION / REACTION KINETICS
Abstract: The amount of nitric oxide which may be produced by heating of air during an atmospheric reentry of a lifting spacecraft is estimated by three different methods. Two assume nitrogen fixation by the process of sudden freezing, and the third is a computer calculation using chemical rate equations. 16 Refs.

153) Title: Population inversion of A. U. V. atomic line in recombining plasma nozzle flow self-absorption UV atomic line
Author: Bowen, S. W.; Park, C.
Corp: University of Michigan, Ann Arbor, MI, USA; NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Fluid and Plasma Dynamics Conference, 4th, Palo Alto, CA, June 21-23, 1971, AIAA Paper 71-592, 4 p. (see A71-31537)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*ABSORPTION SPECTRA/*ATOMIC SPECTRA/*NOZZLE FLOW /*PLASMA HEATING/*POPULATION INVERSION /*ULTRAVIOLET RADIATION
Minor Term: / ARC HEATING/ ARGON/ CARBON/ CONFERENCES/ HELIUM / LINE SPECTRA/ MAGNETOHYDRODYNAMIC FLOW/ METHANE / PLASMA DIAGNOSTICS/ SELF ABSORPTION
Abstract: The self-absorption of the neutral carbon line at 2478.6 Å (2p2 1S0 - 2p 3s 1P1) has been experimentally measured by placing a concave mirror behind expanding, high pressure arc heated plasmas issuing from a 1.27 cm constricted arc tunnel. Negative absorption coefficients indicating population inversions were observed in both helium-methane and argon-methane plasmas. To date the largest absorption coefficient has been $k_o^* \approx -0.292/cm$ using a mole fraction of carbon of 0.333 in a helium-methane mixture, with total mass flow 2.5 gm/sec, 4.75 atm cathode pressure, and enthalpy about 190 MJ/kg. The effective area ratio at the observation station was approximately 50. 8 Refs.

154) Title: Electron impact excitation rate coefficients for hydrogen, helium and alkali atoms

Author: Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 11, no. 1, January 1971, p. 7-36. (see A71-24543)

Sponsor: Pergamon Press, Oxford, Great Britain

Doc. Type: Journal Article

Major Term: /*ALKALI METALS/*ATOMIC EXCITATIONS/*ELECTRON IMPACT /*HELIUM ATOMS/*HYDROGEN ATOMS

Minor Term: / CHANNEL FLOW/ CROSS SECTIONS / MAGNETOHYDRODYNAMICS/ PLASMA DIAGNOSTICS / QUANTUM THEORY

Abstract: The rates of electron impact excitation of bound electronic states are calculated by interpolating the existing quantum-mechanical theories and applying an empirical correction. The calculation is done for hydrogen, helium, lithium, sodium, potassium, rubidium, and cesium. The resulting rate coefficients are expressed by two parameters, the values of which are presented in tables. The error of the present calculations is estimated by comparing with the available experimental data to be within a factor of approximately 2. 26 Refs.

155) Title: Computer study of nonequilibrium excitation in recombining nitrogen plasma nozzle flows

Author: Bowen, S. W.; Park, C.

Corp: University of Michigan, Ann Arbor, MI, USA; NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA Journal (ISSN 0001-1452), vol. 9, no. 3, p. 493-499. (see A71-22093, see also AIAA, Aerospace Sciences Meeting, 8th, New York, NY, January 19-21, 1970, AIAA Paper 70-44, 15 p. (see A70-18061))

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*ATOMIC EXCITATIONS/*ATOMIC RECOMBINATION /*NITROGEN PLASMA/*NONEQUILIBRIUM PLASMAS /*NOZZLE FLOW

Minor Term: / COMPUTER PROGRAMS/ CONFERENCES / ELECTRON DENSITY (CONCENTRATION)/ FLOW THEORY / NUMERICAL ANALYSIS/ PARTICLE COLLISIONS

Abstract: The nonequilibrium neutral atom excited state densities, electron densities, electron and heavy particle temperatures are computed for a fully dissociated partially ionized nitrogen plasma expanding in a nozzle starting from equilibrium in the settling chamber. The degree of excitation nonequilibrium at the exit of a convergent-divergent nozzle having an area ratio of 22 is systematically investigated for chamber pressures between 0.01 and 1000 atm and chamber temperatures between 6000 and 18,000 K. Thermal nonequilibrium at the exit rises to a maximum in the settling chamber pressure range between 1 and 10 atm, due to competing effects of the three-body recombination and collisional coupling terms in the electron energy equation. Increasing chamber pressure above 10 atm produces increasingly severe and unexpected departure from excitation equilibrium. 27 Refs.

156) Title: Gas core nuclear rocket with fuel separation by MHD driven rotation
Author: Love, W. L.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Symposium on Research on Uranium Plasmas and their Technological Applications, Gainesville, FL, January 7-8, 1970 (see N71-33641); NASA, Washington, D. C., NASA CP-236, 1971, p. 139-148. (see N71-33626)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*FUEL FLOW/*GASEOUS FISSION REACTORS /*MAGNETO-HYDRODYNAMICS/*NUCLEAR ROCKET ENGINES /*SEPARATED FLOW
Minor Term: / CENTRIFUGAL FORCE/ CONFERENCES / PERFORMANCE PREDICTION/ RADIATIVE HEAT TRANSFER / ROTATING FLUIDS
Abstract: A gas-core nuclear rocket is described in which fuel containment is achieved through the application of an MHD-centrifuge scheme. Solid-body rotation of the gas would be developed in a cylindrical cavity in order to obtain maximum separation of the fuel gas from the propellant gas. Heating of the propellant gas would be accomplished by radiative heat transfer from the fuel region near the wall as the propellant flows axially through the center region of the cavity. Encouraging results were obtained from a preliminary experiment to test the effectiveness of MHD-driven rotation for separating two gas species in a closed cylindrical chamber. The operating characteristics and projected performance of a gas-core nuclear rocket engine using this scheme for fuel containment were calculated and typical results presented. 17 Refs.

157) Title: Stagnation-point heat-transfer rate in nitrogen plasma flows: theory and experiment

Author: Okuno, A. F.; Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: Transactions of the ASME, Series C, Journal of Heat Transfer (ISSN: 0022-1481), vol. 92, no. 3, August 1970, p. 372-84. (see ASME, Winter Annual Meeting, Los Angeles, CA, November 16-20, 1969, ASME Paper 69-WA/HT-49, 15 p. (see A70-14799))

Sponsor: ASME, New York, NY, USA

Doc. Type: Journal Article

Major Term: /*HEAT TRANSFER/*HEMISPHERES /*MAGNETOHYDRODYNAMIC FLOW/*NITROGEN PLASMA /*STAGNATION POINT

Minor Term: / CONFERENCES/ DISSOCIATION/ ENTHALPY/ PLASMA DENSITY / RAREFIED PLASMAS/ SUPERSONIC FLOW

Abstract: A theory for the heat transfer to the stagnation point of a hemisphere in a supersonic, high-enthalpy, low-density nitrogen plasma flow was developed. The theory assumed a flow that is frozen with respect to molecular dissociation and relaxing with respect to ionization. The calculations for this partially frozen flow yielded heat-transfer rates that were generally lower than predicted by other theories for both frozen and equilibrium flows. Experimental heat-transfer rates from measurements in a high-enthalpy constricted- arc tunnel agreed with the theoretical value within 10 percent in the mean. 42 Refs.

158) Title: An experiment on the MHD-driven rotating flow for a gas core nuclear rocket

Author: Love, W. L.; Park, C.

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA Journal (ISSN 0001-1452), vol. 8, no. 8, August 1970, p. 1377-1385. (see A70-40256)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Journal Article

Major Term: /*CENTRIFUGAL FORCE/*GASEOUS FISSION REACTORS /*MAGNETOHYDRODYNAMIC FLOW /*NUCLEAR ROCKET ENGINES/*REACTOR CORES /*ROTATING FLUIDS

Minor Term: / FLUID DYNAMICS/ GAS DISCHARGES/ PLASMA DIAGNOSTICS / ROCKET ENGINE DESIGN/ TRANSONIC FLOW

Abstract: A fluid dynamic simulation of a gas core nuclear rocket chamber has been made with the objective of separating a light and heavy gas by means of centrifugal force produced by MHD- driven rotation. The test apparatus, a closed cylinder filled with a mixture of xenon and helium, uses a radial magnetic field configuration with an axial electric current passing between 16 pairs of electrodes. By observing the behavior of the discharge and the luminosity of the gas at different locations, the mode of discharge was found to be stable and suitable for effective separation. 16 Refs.

159) Title: Computer study of nonequilibrium excitation in recombining nitrogen plasma nozzle flows

Author: Bowen, Stewart W.; Park, Chul

Corp: Michigan, Ann Arbor, MI, USA; NASA Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Aerospace Sciences Meeting, 8th, New York, NY, January 19-21, 1970, AIAA Paper 70-44, 14 p. (see A70-18061)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ATOMIC EXCITATIONS/*ATOMIC RECOMBINATION/*NITROGEN /*NONEQUILIBRIUM PLASMAS/*NOZZLE FLOW

Minor Term: / COMPUTER PROGRAMS/ CONFERENCES / ELECTRON DENSITY (CONCENTRATION)/ FLOW THEORY / NUMERICAL ANALYSIS/ PARTICLE COLLISIONS

Abstract: The nonequilibrium neutral atom excited state densities, electron densities, electron and heavy particle temperatures are computed for a fully dissociated partially ionized nitrogen plasma expanding in a nozzle starting from equilibrium in the settling chamber. The degree of excitation nonequilibrium at the exit of a convergent-divergent nozzle having an area ratio of 22 is systematically investigated for chamber pressures between 0.01 and 1000 atm and chamber temperatures between 6000 and 18,000 K. Thermal nonequilibrium at the exit rises to a maximum in the settling chamber pressure range between 1 and 10 atm, due to competing effects of the three-body recombination and collisional coupling terms in the electron energy equation. Increasing chamber pressure above 10 atm produces increasingly severe and unexpected departure from excitation equilibrium. 24 Refs.

160) Title: Stagnation-point heat-transfer rate in nitrogen plasma flows - Theory and experiment

Author: Okuno, A. F.; Park, C.

Corp: NASA Ames Research Center, Moffett Field, CA, USA

Source: ASME, Winter Annual Meeting, Los Angeles, CA, November 16-20, 1969, ASME Paper 69-WA/HT-49, 15 p. (see A70-14799)

Sponsor: ASME, New York, NY, USA

Doc. Type: Conference Paper

Major Term: /*HEAT TRANSFER/*HEMISPHERES /*MAGNETOHYDRODYNAMIC FLOW/*NITROGEN PLASMA /*STAGNATION POINT

Minor Term: / CONFERENCES/ DISSOCIATION/ ENTHALPY/ PLASMA DENSITY / RAREFIED PLASMAS/ SUPERSONIC FLOW

Abstract: Theory for heat transfer to stagnation point of hemisphere in supersonic, high-enthalpy, low- density nitrogen plasma flow; assumed flow that is frozen with respect to molecular dissociation and relaxing with respect to ionization; calculations for this partially frozen flow yielded heat- transfer rates generally lower than predicted by other theories for frozen and equilibrium flows; experimental heat-transfer rates generally lower than predicted by other flows; experimental heat- transfer rates from measurements in high-enthalpy constricted-arc-tunnel agreed with theoretical value within 10% in mean. 42 Refs.

161) Title: A polynomial method for determining local emission intensity by Abel inversion
Author: Moore, D.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TN-D-5677, February 1970, 19 p. (see N70-19310)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*ABEL FUNCTION/*OPTICAL MEASUREMENT /*PLASMA DIAGNOSTICS/*POLYNOMIALS /*RADIANT FLUX DENSITY
Minor Term: / APPROXIMATION/ AXISYMMETRIC FLOW / BOUNDARY VALUE PROBLEMS/ FORMULAS (MATHEMATICS)
Abstract: The Abel inversion is applied to the transformation of the measured line-of-sight integrated radiation intensity from an axially symmetric plasma light source into local emission intensity. Consideration of the physical features of the plasma light source shows that the most appropriate approximation of the radial variation of emission is an even-powered polynomial. Thus, the measured light integrated intensity is represented by a linear combination of Abel transforms of even powers. The formula is precise near the axis of symmetry even when the integrated intensity is known at only two or three lateral positions. The formula becomes inaccurate at large radial distances and is suitable mainly when the emission intensity decreases monotonically toward the boundary. 10 Refs.

162) Title: Collisional ionization and recombination rates of atomic nitrogen.
Author: Park, Chul
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 7, no. 8, August 1969, p. 1653-4. (see A69-43700)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ATOMIC COLLISIONS/*ELECTRON DENSITY (CONCENTRATION) /*GAS IONIZATION/*NITROGEN ATOMS /*RECOMBINATION COEFFICIENT
Minor Term: / CHARGED PARTICLES/ ELASTIC SCATTERING/ ELECTRON PLASMA/ ENERGY LEVELS/ MONATOMIC GASES
Abstract: The exact fundamental dependence of a chemical reaction rate on temperature has always been a subject of debate. This work intends to show that, under the assumption of a quasi-steady nonequilibrium distribution of electronic state populations, the (collisional) ionization-rate equation reduces to a simple form even when the energy-level structure and inelastic cross sections involved are fairly complex. 6 Refs. (edited)

163) Title: An experiment on the MHD-driven flow for a gas core nuclear rocket.
Author: Love, W. L.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Fluid and Plasma Dynamics Conference, San Francisco, CA, June 16-18, 1969, AIAA Paper 69-727, 13 p. (see A69-33483)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*CORE FLOW/*FLUID DYNAMICS /*MAGNETOHYDRODYNAMIC FLOW /*NUCLEAR ROCKET ENGINES/*ROTATING FLUIDS
Minor Term: / CONFERENCES/ CROSSED FIELDS/ ELECTRIC FIELDS/ GAS FLOW / LORENTZ FORCE/ MACH NUMBER/ MAGNETIC FIELDS / SPECTROSCOPY
Abstract: A fluid-dynamic simulation of a gas core nuclear rocket chamber has been made with the objective of separating a light and heavy gas by means of the centrifugal force produced by MHD-driven rotation. The test apparatus, a closed cylinder filled with a mixture of xenon and helium, uses a radial magnetic field configuration with an axial electric current passing between 16 pairs of electrodes. By observing the behavior of the discharge and the luminosity of the gas at different locations, the mode of discharge was found to be stable and suitable for effective separation. A rotating flow with transonic Mach number was produced, as evidenced by the ratio (greater than 2) of the pressure at the wall of the cylinder to that at the center. Spectroscopic measurements of the plasma condition show an appreciable degree of separation of the two species. The Hall parameter was found to be less than one. 19 Refs.

164) Title: Theoretical population inversion in a decaying nitrogen plasma column.
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Aerospace Sciences Meeting, 7th, New York, NY, January 20-22, 1969, AIAA Paper 69-48, 12 p. (see A69-18145)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*PLASMA CONTROL/*PLASMA CYLINDERS/*PLASMA DECAY /*POPULATION INVERSION
Minor Term: / CIRCULAR CYLINDERS/ CONFERENCES/ ELECTRON ENERGY / ENERGY DISSIPATION/ OPTICAL THICKNESS / PARTICLE DENSITY (CONCENTRATION)/ PLASMA PHYSICS / PLASMAS (PHYSICS)/ TEMPERATURE DISTRIBUTION / THEORETICAL PHYSICS
Abstract: Theoretical analysis of a decaying plasma column of atomic nitrogen, free from external fields and confined motionless in a circular cylinder. Starting from equilibrium, the temporal changes in the plasma properties and the population of bound electronic states as a result of the energy losses by radiation and conduction are calculated on the axis of the plasma column. The radial distribution of electron temperature is assumed to be parabolic, and the plasma is assumed to be optically thin. The collisional excitation rates are derived from the Born-Ochkur approximation. The results show that a strong population inversion occurs between 2p3 2P and 3s4P states, giving rise to 1837 Å line radiation for about 10 ns under the following conditions: (1) the initial electron temperature is over 14,000 K; (2) the initial electron density is on the order of 10**16 cm-3; and (3) the radius of the containing cylinder is on the order of 0.1 cm. 22 Refs.

165) Title: Spectral line intensities in a nonequilibrium nitrogen plasma.
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: Journal of Quantitative Spectroscopy and Radiative Transfer (ISSN: 0022-4073), vol. 8, no. 10, October 1968, p. 1633-1653. (see A69-10960)
Sponsor: Pergamon Press, Oxford, Great Britain
Doc. Type: Journal Article
Major Term: /*GROUND STATE/*NITROGEN PLASMA /*NONEQUILIBRIUM PLASMAS/*OPTICAL THICKNESS /*SPECTRAL LINE WIDTH
Minor Term: / ELECTRON ENERGY/ LINE SPECTRA/ PLASMA TEMPERATURE
Abstract: For given ratios of nonequilibrium ground state number density to equilibrium ground state number density, and given electron temperatures, the relative populations of excited states of atomic nitrogen in a collision-dominated nonequilibrium plasma, consisting of atoms, singly charged ions, and electrons, are calculated by the method of Bates, Kingston, and McWhirter (1962). This method uses Gryzinski's (1959) semiclassical cross sections for the collisional excitation of electronic states of an atom. From the resulting populations, the spectral intensities of two prominent visible lines are calculated assuming the plasma to be optically thin for these lines. It is shown that, with the exception of a decaying plasma at temperatures greater than 8000 degrees K, the calculated nonequilibrium intensities disagree with the equilibrium spectral line intensities that would be conventionally employed to determine the temperature of a plasma in equilibrium. 31 Refs.

166) Title: Measurement of ionic recombination rate of nitrogen
Author: Park, Chul
Corp: NASA Ames Research Center, Moffett Field, CA, USA
Source: AIAA Journal (ISSN 0001-1452), vol. 6, no. 11, p. 2090-2094.
(see A68-44713, see also AIAA, Electric Propulsion and Plasma Dynamics Conference, Colorado Springs, CO, September 11- 13, 1967, Paper 67-703, 7 p. (see A67-38730))
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*DECAY RATES/*ELECTRON-ION RECOMBINATION /*NITROGEN IONS/*NONEQUILIBRIUM PLASMAS /*PLASMA SPECTRA/*THREE BODY PROBLEM
Minor Term: / ELECTRON DENSITY (CONCENTRATION)/ PLASMA DENSITY / PLASMA JET WIND TUNNELS/ SPECTRAL LINE WIDTH
Abstract: The rate of the three-body recombination of electrons and atomic ions of nitrogen in a dense plasma is measured spectroscopically. A nonequilibrium plasma is produced by expanding nitrogen through a supersonic nozzle of an electric-arc plasma wind tunnel. Electron density is measured utilizing the hydrogen-beta line broadening technique. The results show that the rate coefficient is 1.0**minus 26 ± 0.5 cm6/sec at a temperature of 10,000 K. This value agrees with that calculated by semiclassical theory. 12 Refs.

167) Title: Relaxation of electronic state populations in expanding flows of ionized nitrogen

Author: Park, Chul

Corp: NASA, Ames Research Center, Moffett Field, CA, USA

Source: AIAA, Fluid and Plasma Dynamics Conference, Los Angeles, CA, June 24-26, 1968, AIAA Paper 68-734, 13 p. (see A68-33232)

Sponsor: AIAA, Washington, D. C., USA

Doc. Type: Conference Paper

Major Term: /*ATOMIC EXCITATIONS/*GAS EXPANSION/*NITROGEN IONS /*POPULATION INVERSION/*RELAXATION (MECHANICS) /*SUPERSONIC NOZZLES

Minor Term: None

Abstract: The relaxation of the population distribution of atomic electronic states in a fully dissociated and partially ionized nitrogen stream expanding supersonically is studied both theoretically and experimentally. The nonequilibrium population of excited states is calculated theoretically by combining two existing theories; i.e., the nozzle flow theory of Bray and the electronic transition theory of Bates, Kingston and McWhirter based on Gryzinski's semi-classical cross-sections. In the experiment, the electron density and the populations of the excited states are inferred from spectroscopic measurements of the light emission along a nozzle. Both theory and experiment show that the excited state populations deviate significantly from the equilibrium distribution. Furthermore, the intensity ratios of certain pairs of spectral lines may not change monotonically along the nozzle, but may reverse their trend at certain positions. The theory and experiment disagree, however, on the locations of the reversal points. 17 Refs.

168) Title: Convective stagnation-point heat transfer in partially equilibrium flow of highly ionized nitrogen
Author: Okuno, A. F.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: NASA, Ames Research Center, Moffett Field, CA, NASA-TM-X-61187, 1968, 17 p. (see N68-34754, see also Heat Transfer and Fluid Mechanics Conference, Seattle, June 17-19, 1968)
Sponsor: NASA, Washington, D. C., USA
Doc. Type: Report
Major Term: /*CONVECTIVE HEAT TRANSFER/*EQUILIBRIUM FLOW /*IONIZED GASES/*STAGNATION POINT
Minor Term: None
Abstract: Measurements of stagnation-point heat-transfer rate in a nitrogen stream at high ionization levels were made in a continuously operated arc-heated wind tunnel. The stream was thought to be frozen for molecular dissociation and in equilibrium for ionization in the boundary layer, and an analysis was made of this partially equilibrium flow. The results of both theory and experiment show that when the flow is partially in equilibrium, the total heat-transfer rate is appreciably lower than would be predicted by previous theories. The new theory provides a lower limit on heat-transfer rates attainable by a noncatalytic surface in the ionized regime. 19 Refs.

169) Title: Measurement of ionic recombination rate of nitrogen
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: AIAA, Electric Propulsion and Plasma Dynamics Conference, Colorado Springs, CO, September 11- 13, 1967, Paper 67-703, 6 p. (see A67-38730)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Conference Paper
Major Term: /*CONFERENCES/*DECAY RATES/*DENSE PLASMAS /*ELECTRON-ION RECOMBINATION/*NITROGEN /*NITROGEN IONS/*NITROGEN PLASMA /*NONEQUILIBRIUM PLASMAS/*PLASMA SPECTRA /*THREE BODY PROBLEM
Minor Term: None
Abstract: The rate of the three-body recombination of electrons and atomic ions of nitrogen in a dense plasma is measured spectroscopically. A nonequilibrium plasma is produced by expanding nitrogen through a supersonic nozzle of an electric-arc plasma wind tunnel. Electron density is measured utilizing the hydrogen-beta line broadening technique. The results show that the rate coefficient is 10**minus (26 ± 0.5) cm6/sec at a temperature of 10,000 K. This value agrees with that calculated by semiclassical theory. 11 Refs.

170) Title: Real flow effects on shock attenuation in shock-tube flows
Author: Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Shock Tube Symposium, 5th, Silver Spring, MD, April 28-30, 1965 (see N67-82266); Proceedings of the 5th International Shock Tube Symposium, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, MD, 1966, p. 879-914. (see N67-82207)
Sponsor: American Physical Society, Division of Fluid Dynamics, New York, NY, USA
Doc. Type: Conference Paper
Major Term: /*CONFERENCES/*SHOCK TUBES
Minor Term: None
Abstract: The real flow effects, i.e., the effect of boundary layer growth, radiation, imperfect diaphragm rupture and contact-surface mixing, convective heat transfer, and crossed electric and magnetic fields, on shock-wave velocity attenuation in a constant-area shock-tube is evaluated. The gas is assumed to be an ideal reacting gas of Lighthill's type in chemical equilibrium, and the characteristic equations for the modified Riemann's variables for unsteady flow are derived. Assuming that the above-mentioned real flow effects are small in comparison with the ideal gas flow properties, a small-perturbation analysis is applied to the characteristic equations to derive the deviations from ideal conditions due to the real flow effects. By making a minimum number of assumptions, it is shown that (i) imperfect diaphragm rupture causes an initial lag in shock velocity, (ii) heat transfer from hot gas to cold gas through contact-surface mixing causes an overshoot in shock velocity, (iii) attenuation of shock speed due to radiation from the hot gas becomes an important effect at high density and is independent of the tube diameter. In addition, (iv) the strengths of crossed electrical and magnetic fields needed to compensate for the attenuating effect of boundary layer growth and radiation to maintain a constant shock speed are calculated. The numerical calculations are carried out for the radiation and wall heat transfer effect for a range of operating conditions and some typical values are computed for the rest of the effects. 20 Refs.

171) Title: Diagnosis of high-density, highly ionized nitrogen wind tunnel flows.
Author: Okuno, A. F.; Park, C.
Corp: NASA, Ames Research Center, Moffett Field, CA, USA
Source: International Congress on Instrumentation in Aerospace Simulation Facilities, 2nd, Stanford University, Stanford, CA, August 29-31, 1966 (see A66-42192); Proceedings of the 2nd International Congress on Instrumentation in Aerospace Simulation Facilities, Intercon, Arnold Air Force Station, TN, 1966, p. 26-1 to 26-10. (see A66-42166)
Sponsor: IEEE, Aerospace and Electronic Systems Group, New York, NY, USA
Doc. Type: Conference Paper
Major Term: /*CONFERENCES/*DIAGNOSIS/*ENTHALPY /*FLOW CHARACTERISTICS/*GAS FLOW/*IONIZED GASES /*NITROGEN/*NITROGEN PLASMA/*PLASMA ARC /*PLASMA JETS/*WIND TUNNELS
Minor Term: None
Abstract: Three techniques for diagnosing the high density, highly ionized nitrogen flow in a plasma wind tunnel are described. These are: (1) time-of-flight velocity measurement by correlating the light-signal fluctuations between two points, (2) total enthalpy determination by spectroscopic observation of a blunt-body shock layer, (3) determination of free stream kinetic energy from the angle of an oblique shock wave over a wedge. The principle and the test results of the velocity measurement by the correlation technique are described in detail. The velocity determined by the correlation technique agreed with the value deduced from the shock wave angle within the estimated ± 4 percent accuracy of the measurements. 7 Refs.

172) Title: Comparison of diagnostic methods for nonequilibrium plasma-jet wind tunnel flow

Author: Park, C.

Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain; NASA, Ames Research Center, Moffett Field, CA, USA

Source: Ph. D. Thesis, Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain; NASA, Ames Research Center, Moffett Field, CA, NASA-TM-X-56599, 1964, 35 p. (see N66-82331)

Sponsor: NASA, Washington, D. C., USA

Doc. Type: Report

Major Term: /*ENTHALPY/*NONEQUILIBRIUM FLOW /*PLASMA JET WIND TUNNELS

Minor Term: None

Abstract: Various experimental methods for determining the state of gas flow in chemical nonequilibrium throughout a plasma-jet wind tunnel are compared. These methods are (i) using energy balance to determine gross enthalpy, (ii) using stagnation chamber pressure and mass flow rate relation to determine plenum chamber enthalpy, (iii) measuring convective heat transfer with a blunt and slender model to determine test-section enthalpy, (iv) using shock-wave standoff distance to determine ionization or dissociation fractions, (v) using spectroscopy to determine electron temperature. The experimental data were obtained in a 1-inch plasma-jet wind tunnel, using argon and nitrogen as working gases, with a stagnation chamber pressure of approximately 1/3 atmosphere. Reynolds number and Mach number at the exit of the tunnel were approximately 1000 and 3, respectively. The various experimental data were compared by means of theoretical flow calculations (i) for ionized argon by solving the nozzle flow ionic relaxation problem with a computer, and (ii) for dissociated nitrogen using the frozen flow relations. The conclusions drawn include: (i) for argon, the various methods of diagnosis are consistent, (ii) in nitrogen, the sum of the kinetic energy of the gas and the dissociational energy is significantly less in a weakly dissociated regime than the total energy which is recovered by the heat transfer to a test body, and (iii) the three-body recombination rate of Hinnov and Hirschberg and the two-body recombination rate of Bond in ionized argon are accurate within the experimental accuracy in a flow expanding through a nozzle.
27 Refs.

173) Title: Dissociative relaxation in viscous hypersonic shock layers.
Author: Park, C.
Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain
Source: AIAA Journal (ISSN 0001-1452), vol. 2, July 1964, p. 1202-1207. (see A64-20409)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ATOM CONCENTRATION/*DISSOCIATION/*GAS DISSOCIATION /*HEAT TRANSFER/*HYPERSONIC SHOCK/*SHOCK LAYERS /*STAGNATION POINT/*WALLS
Minor Term: None
Abstract: The dissociative relaxation in a viscous shock layer of nonequilibrium dissociating diatomic gas in the stagnation region of a blunt hypersonic body is analyzed. The case in which the maximum local dissociation level is appreciably lower than the inviscid equilibrium value is considered. A simplified atom concentration equation is derived neglecting the recombination term in the reaction, and it is solved for a range of conditions using a digital computer. The procedure for determining the stagnation-point wall concentration for the general case of arbitrary freestream and wall conditions, including air, using the result of these solutions, is described. The approximate solution based on the simplified concentration equation is compared with the exact solution and shown to agree approximately when the maximum dissociation is less than 80% of the inviscid equilibrium value. 10 Refs.

174) Title: Computer solutions to the problem of vibrational relaxation in hypersonic nozzle flows.

Author: Park, C.; Stollery, J. L.

Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain

Source: Journal of Fluid Mechanics, vol. 19, part 1, May 1964, p. 113-123. (see A64-19462)

Sponsor: Cambridge University Press, Cambridge, Great Britain

Doc. Type: Journal Article

Major Term: /*COMPUTER TECHNIQUES/*HYPERSONIC FLOW /*HYPERSONIC NOZZLES/*MOLECULAR RELAXATION /*NOZZLE FLOW/*NUMERICAL ANALYSIS/*SIMPLIFICATION /*VIBRATIONAL RELAXATION

Minor Term: None

Abstract: This report is an extension of an earlier note in which a simple method of estimating the distribution of vibrational temperature along a hypersonic nozzle was described. Results were presented for hyperbolic, axisymmetric nozzles with reservoir conditions $1000 \leq p0 \leq 4000$ psia, $1000 \leq T0 \leq 3000$ K. The problem was subsequently programmed for the Ferranti Mercury computer at the University of London computing centre, and the results of these computations are given here. The vibrational temperatures are compared with those of the previous method. The distributions of pressure and temperature through the nozzle are also given and a simple method of estimating the vibrational temperature is described. 13 Refs.

175) Title: The effects of vibrational relaxation of hypersonic nozzle flows.
Author: Park, C.; Smith, J. E.; Stollery, J. L.
Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain
Source: NATO, AGARD, Specialist's Meeting, Technical Centre for Experimental Aerodynamics, Rhode-Saint-Genese, Belgium, April 3-6, 1962 (see A64-17713 and N64-26129); NATO, AGARD, AGARDograph 68, The High Temperature Aspects of Hypersonic Flow, MacMillan, New York, 1964, p. 49-65, discussion, p. 65-66. (see N64-26126)
Sponsor: NATO, AGARD, Neuilly sur Seine, France
Doc. Type: Conference Paper
Major Term: /*AIR FLOW/*GAS FLOW/*HYPERBOLAS/*HYPERSONIC NOZZLES /*MOLECULAR RELAXATION/*NOZZLE FLOW/*SYMMETRY /*TEMPERATURE DISTRIBUTION/*VIBRATION /*VIBRATIONAL RELAXATION
Minor Term: None
Abstract: The paper comprises two parts. Part I is a reproduction of an earlier note, already published, in which a simple method of estimating the distribution of vibrational temperature along a hypersonic nozzle is described. In Part II more exact solutions of the non-equilibrium nozzle flow of a vibrating gas are given. These solutions were obtained using the Ferranti "Mercury" computer at the University of London computing centre. 21 Refs.

176) Title: Heat transfer from nonequilibrium ionized argon gas
Author: Park, C.
Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain
Source: AIAA Journal (ISSN 0001-1452), vol. 2, no. 1, January 1964, p. 169-171. (see A64-13178)
Sponsor: AIAA, Washington, D. C., USA
Doc. Type: Journal Article
Major Term: /*ARGON/*HEAT TRANSFER/*IONIZATION/*IONIZED GASES /*TEMPERATURE EFFECTS/*TRANSPORT PROPERTIES
Minor Term: None
Abstract: The effect of ionization on boundary-layer flow and heat transfer has been a matter of considerable argument in recent years, for, apart from the scarcity of experimental data, a discrepancy was found between the result obtained by Scala and Warren and those by other researchers. Here, the effect of ionization on heat transfer is investigated for argon flow both theoretically and experimentally. 13 Refs. (edited)

177) Title: Measurement of heat transfer to a hemisphere in high enthalpy argon and nitrogen streams in a plasma jet wind tunnel

Author: Park, C.

Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain

Source: Aeronautical Research Council, London, Great Britain, ARC-24948, April 1963, 50 p. (see X64-15073)

Sponsor: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain

Doc. Type: Report

Major Term: /*ARGON/*CATALYSIS/*ENTHALPY/*HEAT MEASUREMENT /*HEAT TRANSFER/*NITROGEN PLASMA/*PLASMA JETS /*STREAMS/*WIND TUNNELS

Minor Term: None

Abstract: The effect of surface catalysis of copper, stainless steel and a boro-silicate ceramic coating on heat transfer to a hemisphere in ionized argon and dissociated nitrogen streams is investigated experimentally in a plasma jet wind tunnel using a water-cooled calorimeter. The results are compared with the existing theories. The average effective surface catalytic reaction rate constants of the three materials for nitrogen recombination are determined. A large departure of the heat transfer in ionized argon from the theoretical values for non-ionized gases is found and possible explanations are given. Two methods of determining the flow properties in a plasma jet wind tunnel are compared and correlated. 30 Refs.

178) Title: Vibrational relaxation in hypersonic nozzle flow --- Ferranti Mercury computer solutions

Author: Park, C.; Stollery, J. L.

Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain

Source: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain, Report 115, Computer Solutions to the Problem of Vibrational Relaxation in Hypersonic Nozzle Flows, January 1963, 42 p. (see N63-14830)

Sponsor: Imperial College of Science and Technology, London, Great Britain

Doc. Type: Report

Major Term: /*COMPUTER TECHNIQUES/*FERRANTI MERCURY COMPUTER /*HYPERSONIC NOZZLES/*MOLECULAR RELAXATION /*NOZZLE FLOW/*NUMERICAL ANALYSIS /*VIBRATIONAL RELAXATION

Minor Term: None

Abstract: This report is an extension of an earlier note in which a simple method of estimating the distribution of vibrational temperature along a hypersonic nozzle was described. Results were presented for hyperbolic, axisymmetric nozzles with reservoir conditions $1000 \leq P0 \leq 4000$ psia; $1000 \leq T0 \leq 3000$ K. The problem was subsequently programmed for the Ferranti Mercury computer at the University of London computing centre and the results of these computations are given here. The vibrational temperatures are compared with those of the previous simple method. The distributions of pressure and temperature through the nozzle are also given and a simple method of estimating the vibrational temperature is described. 25 Refs.

179) Title: Comparison of diagnostic methods for nonequilibrium plasma-jet wind tunnel flow

Author: Park, C.

Corp: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain

Source: Ph. D. Dissertation, Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain, 1964

Sponsor: Imperial College of Science and Technology, Department of Aeronautics, London, Great Britain

Doc. Type: Ph. D. Dissertation

Major Term: /*ENTHALPY/*NONEQUILIBRIUM FLOW /*PLASMA JET WIND TUNNELS

Minor Term: None

Abstract: The effects of dissociative and ionic nonequilibrium on nozzle flow characteristics, the flow in the stagnation region of a sphere and heat transfer rates are investigated both theoretically and experimentally. The content is divided into two parts. Part I describes the work on ionized argon, while Part II is devoted to dissociated nitrogen. The theoretical calculations for nonequilibrium nozzle flow were carried out employing the relaxing gas model suggested by Freeman and using a digital computer. Tests were made in the one-inch arc-heated wind tunnel as follows: i) stand-off distance of a hemisphere, ii) heat transfer rates to a hemisphere and a cone with catalytic and noncatalytic surfaces, and iii) heat transfer by radiation. Conclusions drawn, among others, are: i) the ionic recombination rate constant of argon is not greater than (5 x 10^27)*T^(-4.5) cm-6-mole2-sec-1 where T is in K, ii) the variations of shock wave stand-off distance for a sphere due to the frozen nature of the flow are verified, iii) copper, chromium and stainless steel have the surface catalytic reaction rate constants of the order of 10 fps for surface recombination of nitrogen, and two boro-silicate ceramics are much less catalytic than these metals, and iv) the heat transfer to a hemisphere from ionized argon is greater than that from non-ionized flow and this occurs because the boundary layer is basically frozen and the cold surface acts as a fully catalytic surface to the ionic recombination. 73 Refs.

180) Title: Theoretical Studies on Shock Attenuation and its Electro-Magnetic Compensation in Shock Tube Flow

Author: Kim, C. -S.; Park, C.
Corp: Seoul National University, Seoul, Korea

Source: Proceedings of the Third International Symposium on Rockets and Astronautics, Nippon Toshi Center, Hirakawa-Cho, Chiyoda-ku, Tokyo, Japan, 1961, S. Saito, Editor-in-Chief, Yokendo Publishing Co., Tokyo, Japan, 1962, pp. 171-188.
Sponsor: University of Tokyo, Bunkyo-ku, Tokyo, Japan
Doc. Type: Conference Paper
Major Term: None
Minor Term: None

Abstract: The possibility of compensating for the attenuation of the shock tube flow by the application of crossed electric and magnetic field is investigated theoretically. For this purpose, the generalized Riemann's characteristic equations for unsteady one-dimensional flow are derived with the consideration of boundary-layer and electro-magnetic field effects. And, using the conditions of equilibrium across the shock wave and contact-surface, the expressions for the attenuation of the shock wave and acceleration of the contact-surface are obtained in terms of boundary-layer and electro-magnetic effects. The main results obtained are: (1) the shock wave decelerates in the same power of time as the contact-surface boundary-layer thickness in the first approximation, (2) the general requirements for the electric and magnetic fields to produce uniform shock wave speed are derived from the attenuation law, (3) the conditions for the production of uniform flow throughout the whole testing time are also stated, and (4) some numerical examples of the calculation of shock wave attenuation and the optimum field strength necessary for its compensation are given. It is concluded that the production of uniform shock wave speed is always possible by applying electric and magnetic fields of proper strength. 11 Refs.

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**13. ABSTRACT** *(Maximum 200 words)*

This document contains a comprehensive bibliography of the published works, and a short biography, of Dr. Chul Park. The contents of this bibliography were compiled primarily from the NASA RECON data base. The RECON citations have been modified to appear in a uniform format with all other listed citations. These other citations were located by computer searches in the INSPEC, NTIS, COMPENDEX, and Chemical Abstracts data bases, as well as through the cooperation of Dr. Chul Park, and his associates in the Reacting Flow Environments Branch at NASA Ames Research Center. All citations are presented in an approximate reverse chronological order from the present date.

This work was created to honor the occasion of Dr. Chul Park's retirement on December 14, 1994, after 27 years of distinguished government service at the NASA Ames Research Center.

**14. SUBJECT TERMS**

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