

UNCLASSIFIED

AD 400 967

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

400967

(5) 552 850

(11)

MARTIN COMPANY
DENVER, COLORADO

Library Literature Search No. 25

LIBRARIES

(1)

AD No. —
ASTIA FILE COPY

(6)

TWO-PHASE (GAS-PARTICLE) FLOW THROUGH ROCKET NOZZLES

AN ANNOTATED BIBLIOGRAPHY OF RECENT REPORTS

Compiled January 1963

Comp. by

(8)

Clyde Briggs

(7) IVA

(10) 3p

(12) NA

(13) NA

(14) NA

(15) NA

400 967

Sources:

International Aerospace Abstracts
NASA Technical Publications Announcements
Engineering Index
Applied Science & Technology Index
ASTIA Technical Abstract Bulletin

ASTIA
APR 15 1963
RECEIVED
ASTIA

ADVANCED TECHNOLOGY LIBRARY C-107 2721
RESEARCH LIBRARY A-82 2101

Aerospace Division of Martin Marietta Corporation

MAINTENANCE

G. F. Carrier, Shock waves in a dusty gas. Journal of Fluid Mechanics, Vol. 4, 1958.

The flow of a dust-gas mixture is analyzed. The problem is reduced to a form such that the analysis can be completed by the integration of a first-order non-linear differential equation and a quadrature.

R. F. Hoglund, Recent advances in gas-particle nozzle flows. ARS Journal, Vol. 32, May 1962. ARS Paper 2331-62.

Performance loss in rocket motors caused by condensed metal-oxide combustion products is analyzed. A description of various studies is given along with a list of problems yet to be solved. A bibliography of 72 references is included.

M. Gilbert et al, Velocity lag of particles in linearly accelerated combustion gases. Jet Propulsion, Vol. 25, 1955.

The behavior of solid particles tracking combustion gases is studied. Particles lag appreciably in the reaction zone. Calculation shows that in a rocket motor a three percent loss in specific impulse can be caused by these particles.

L. Torobin and H. Gauvin, Fundamental aspects of solid-gas flow. Canadian Journal of Chemical Engineering, Vol. 37 & 38, 1959 & 1960; August 1959, p. 129-141; October 1959, p. 167-176; December 1959, p. 224-236; October 1960, p. 142-153; December 1960, p. 189-200.

Idealized sphere motion in viscous regime, drag for single spherical particles, sphere wake in steady fluids, boundary layer separation and accelerated motion of particles of fluids are discussed. An analysis of the literature of the field is included.

M. Gilbert et al, Dynamics of two-phase flow in rocket nozzles. American Rocket Society Journal, Vol. 32, December 1962.

A summary of the studies conducted at United Technology Corp. on gas particle flow.

Donald J. Carlson, Experimental determination of thermal lag in gas-particle nozzle flow. ARS Journal, July 1962.

In order to delineate the phenomena surrounding lag processes in rocket nozzles, a series of experiments has been undertaken with the object of measuring thermal lags of solids relative to gases and correlate such lags with theoretical predictions.

W. S. Bailey et al, Gas particle flow in an axisymmetric nozzle. ARS Journal, June 1961.

The problems of erosion due to particle impingement upon nozzle walls and the loss of thrust caused by velocity and thermal lag of particles flowing through thrust nozzles are studied. Thrust losses up to five percent are possible.

G. Kynch, Effective viscosity of suspension of spherical particles. Proc. Royal Society of London, Ser. A., September 25, 1956.

Development of a method for solving the hydrodynamic problem involving swarms of particles moving in an incompressible fluid.

- T. Starkey, The laminar flow of streams of suspended particles. British Journal of Applied Physics, February 1956.
- S. K. Friedlander, Behavior of suspended particles in turbulent fluid. American Institute of Chemical Engineers Journal, Vol. 3, September 1957.
Heat and mass transfer and coagulation are considered as related to mean-square relative velocity between particle and fluid and eddy diffusion.
- S. K. Friedlander and H. F. Johnstone, Deposition of suspended particles from turbulent gas streams. Industrial and Engineering Chemistry, Vol. 49, July 1957.
Dust particle deposition rates were measured by counting number of particles deposited on known area in given time from a stream.
- S. L. Soo, Determination of turbulence characteristics of solid particles in two-phase stream by optical autocorrelation. Review of Scientific Instruments, Vol. 30, September 1959.
Optical autocorrelation techniques application of which enables determination of lagrangian correlation scale, and intensity of turbulent motion of solid particles in two-phase stream.
- S. L. Soo, Experimental determination of statistical properties of two-phase turbulent motion. ASME Trans. Journal of Basic Engineering, Vol. 82, Series D, September 1960.
Methods for determination of certain statistical properties of turbulent conveyance and diffusion of solid particles in gaseous state.
- R. D. Glauz, Combined sub-sonic super-sonic gas particle flow. American Rocket Society Journal, Vol. 32, May 1962, and ARS Paper 1717-61.
Flow equations, heat and energy transfer between gases and particles. Illustrates method for obtaining correct starting velocity in the subsonic region.
- A. P. Chernov, The effect of solid admixtures on the velocity of motion of a free dusty air jet. Zhurnal Tekh Fiz, 1956. Trans. NACA TM 1430, 1957.
- S. Corrsin, On the equation of motion for a particle in turbulent fluid. Applied Scientific Research, Section A, No. 2-3, 1956.
- D. J. Carlson, Static temperature measurements in hot gas-particle flows. "Temperature its measurement and control in science and industry", Vol. 3, pt. 2. Reinhold Publishing Co., New York, 1962.
This book is to be published this winter.
- D. Dodge, Turbulence in non-newtonian systems, Univ. of Delaware, Dept. of Chem. Eng., Report AFOSR TN 58-94, AD 148143.
Analysis for turbulent flow of non-Newtonian fluids through smooth round tubes which yields a new concept of the attending relationship between the pressure loss and the mean flow rate. In addition the analysis has permitted the prediction of non-Newtonian turbulent velocity profiles. Experimental data are obtained for polymeric gels and solid liquid suspensions under turbulent flow conditions.

- S. Zabrodskii, The coefficient of resistance of a solid particle in a gas flow. Ministry of Aviation TIL/T 5196, December 1961, NASA 62-10297.
The effects of roughness of the particles is investigated. The roughness of the particles increase the resistance to the flow of gases. Trans. from the Russian Ser. Fiz.-Tekh. Nauk, Vol. 4, 1956.
- R. Sehgal, An experimental investigation of a gas particle system. Jet Propulsion Lab. TR 32-238, March 1962, NASA N62-11504, AD 274 314.
The presence of particles in the gas flow causes drag which eliminates the increase in performance caused by metal additives. Performance loss increases with particle size.
- J. R. Kliegel, One dimensional flow of a gas particle system. IAS preprint 60-5 and Journal of Aero/Space Sciences, March 1960. RL 21,305.
A mathematical analysis of the one dimensional flow of a gas-particle system through an exhaust nozzle.
- J. R. Kliegel and G. Nickerson, Flow of gas-particle mixtures in axially symmetric nozzles. American Rocket Society, Paper 1713-61, RL 15,133.
A previous one dimensional study has been expanded to treat axially symmetric nozzle flows. Theory predicts the performance of propellants and nozzles within limits of experiment and is adequate to describe the flow of the gas-particle mixture.
- Rohm and Hass, Quarterly Progress Report on Interior Ballistics (Report Confidential) P 60-7, April 1960. RL 18,959
Equations on the flow of gas containing particles through a rocket motor are given.
- F. C. Price et al, Detail design optimization of solid-propellant rocket motor aft-closure nozzle combinations. AD 325 823. Aeronutronic C-1412, 1st Quar. Prog. Rept., October 1961. Confidential. RL 18,958.
Studies of rocket motor designs based on the effects of flow of gases and particles through nozzles.
- F. C. Price et al, Detail design optimization of solid-propellant rocket motor aft-closure nozzle combinations. AD 327 512 Aeronutronic C-1512 1st Quar. Prog. Rept., January 1962. Confidential. RL 18,981.
Studies of rocket motor designs based on the effects of flow of gases and particles through nozzles.
- M. Gilbert et al, Dynamics of two-phase flow in rocket nozzle. United Technology Corp. Quarterly Progress Reports, August 1961. Report 1 - AD 264 479; Report 2 - AD 267 768; Report 3 - AD 329 094; Report 4 - AD 277 220; Report 5 - AD 284 663.
An experimental and theoretical investigation is being conducted of the axial and radial velocity lag of a dispersed solid phase in accelerating gases. Basic information for nozzle design and two-phase flow dynamics is being compiled.