

UNCLASSIFIED

AD 428706

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, 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.

TECHNICAL OPERATIONS RESEARCH

428706

SUMMARY OF
FINAL REPORT ON RESEARCH ON CIRCULATION
IN NUCLEAR CLOUDS

Contract OCD-OS-62-186

By

H. G. Norment

Report No. TO-B 63-102A

OCD Subtask No. 3113A

1 December 1963

Submitted to

The Office of Civil Defense
Department of Defense
Washington 25, D. C.

tech ops

Notice

**Qualified requestors may obtain
copies of this report from:**

**Defense Documentation Center
Cameron Station
Alexandria, Virginia 22314**

tech ops

TECHNICAL OPERATIONS RESEARCH

SUMMARY OF
FINAL REPORT ON RESEARCH ON CIRCULATION
IN NUCLEAR CLOUDS

Contract OCD-OS-62-186

By
H. G. Norment

Report No. TO-B 63-102A
OCD Subtask No. 3113A

1 December 1963

Submitted to
The Office of Civil Defense
Department of Defense
Washington 25, D. C.

Burlington, Massachusetts



TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
APPROACH	1
FINDINGS	2
THEORETICAL STUDIES	2
DATA COLLECTION AND ANALYSIS	4
COMPUTER SIMULATION	4
RECOMMENDATIONS FOR FURTHER RESEARCH	6
REFERENCES	6

LIST OF ILLUSTRATIONS

Figure

1 Relationship of the Position of an Arbitrary Fluid Parcel with Coordinates ω , z to Circulation Axis Points ω_c , z_c , and $-\omega_c$, z_c	4
2 Particle Trajectories as Determined by Computer Simulation . .	5

INTRODUCTION

This is a summary of TO-B 63-102 (SECRET-RD), the final report submitted by Technical Operations Research to the Office of Civil Defense, Department of Defense, on an extension to research contract OCD-OS-62-186. The general objective of this contract was to provide the Office of Civil Defense with an improved ability to predict patterns of fallout depositions as they relate to civil defense planning and operations. Under this contract the tasks of Technical Operations Research were defined as follows:

1. Attempt to describe mathematically the gas circulation about the rising fireball from a nuclear detonation
2. Study the trajectories of particles within the nuclear cloud as these are affected by various significant parameters
3. Program the processes developed for computer simulation and make estimates of the locations where particles start falling by gravity effects only and the time after detonation when this occurs.

It has been observed repeatedly that when a bubble of fluid surrounded by a fluid of similar composition is moved by buoyant forces, viscous shear at its surface sets up vortex ring circulation inside the bubble. A familiar example of a vortex ring is a smoke ring blown from the mouth of a tobacco smoker. The most dramatic of all vortex rings are those observed in rising fireballs produced by nuclear detonations. The vigor of circulation in these rings is impressive and leaves little doubt in the minds of observers that it must produce significant effects upon particle distributions in nuclear clouds. Accordingly, it is clear that this must be accounted for in the construction of fallout-predicting models that aspire to even reasonable accuracy.

APPROACH

The approach taken in this extension of Contract OCD-OS-62-186 represents a consistent continuation of the work accomplished in the previous contract period.¹ Research advanced in three rather broadly overlapping areas:



1. Theoretical studies
2. Data collection and analysis
3. Computer simulation.

In continuing our theoretical evaluations of circulation models, emphasis was placed on testing the models' capacities to accurately describe observed phenomena and on the feasibility of their use in a large-scale particle motion simulation computer program. Additional sources of experimental circulation data were sought and found. Data adequate to test, at least in part, the mathematical models and provide information necessary for model calibration were collected from these sources. Particle motion simulations on a pilot scale were made; trajectory stability problems encountered in the simulation calculations were studied and solutions to these problems have been found.

FINDINGS

THEORETICAL STUDIES

Studies of circulation models devised previously have indicated that all these models are rather seriously deficient in that they either lack sufficient basis or they are computationally too complex. To circumvent these difficulties, a relatively simple model has been devised that nevertheless leans heavily for support on the fluid dynamic theory. This model does appear to be compatible with observed data. With it, extrapolation into observationally inaccessible portions of the cloud can be done with increased confidence. As a bonus, this model yields important insights into vital areas of interest such as cloud boundary, cloud rise and expansion rates, and the effects of these and other variable cloud properties on strength of circulation.

The stream function for a stationary circular vortex ring is derived by Lamb (Reference 2, p. 237, Eq. 11). He assumes an axis of cylindrical symmetry perpendicular to the plane of the vortex ring and passing through its center. By taking advantage of the symmetry, one can make use of a cylindrical coordinate system ω , z , where $\omega = \sqrt{x^2 + y^2}$ and z is vertical with positive direction upward. If the

vortex ring is given a constant velocity (a) in the positive z direction, then at a point (ω, z) the stream function ψ is given by

$$\psi = -\frac{k}{2\pi} (r_1 + r_2) \lambda^2 D + \frac{a}{2} \omega^2,$$

where the coordinates of the vortex filament axis (circulation axis) are (ω_c, z_c) and

$$r_1 = \sqrt{(z - z_c)^2 + (\omega - \omega_c)^2},$$

$$r_2 = \sqrt{(z - z_c)^2 + (\omega + \omega_c)^2},$$

$$\lambda = \frac{r_2 - r_1}{r_2 + r_1},$$

$$D = \frac{1}{\lambda^2} (K - E),$$

and K and E are complete elliptic integrals of modulus λ of the first and second kinds respectively,³ and k is the vortex strength. Figure 1 gives a schematic diagram of the relationships of some of these quantities. Fluid velocity components in the ω and z directions, v_ω and v_z respectively, are determined by differentiation of the stream function to yield

$$v_\omega = \frac{z - z_c}{\omega r_1 r_2} \left(\psi - \frac{a}{2} \omega^2 \right) \left(1 - \frac{2}{1 - \lambda^2} \frac{E}{D} \right)$$

$$v_z = -a - \frac{\psi - \frac{a}{2} \omega^2}{r_1 r_2} \left\{ 1 - \beta \lambda + \frac{1}{1 - \lambda^2} \left[\left(\frac{1}{\lambda} + \lambda \right) \beta - 2 \right] \frac{E}{D} \right\}$$

where

$$\beta = \frac{\omega}{\omega_c}$$

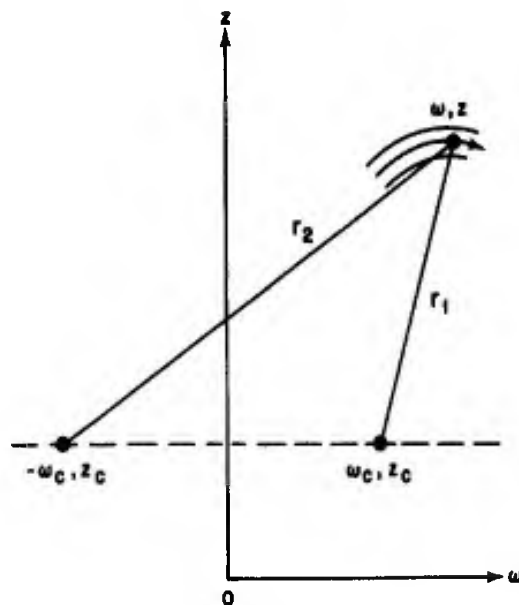


Figure 1. Relationship of the Position of an Arbitrary Fluid Parcel with Coordinates ω , z to Circulation Axis Points ω_c , z_c , and $-\omega_c$, z_c

If both position and velocity data are available for two or more points on a streamline, the constants a , k , ω_c , and z_c can be evaluated by means of a least squares analysis that has been developed and programmed for machine computation. When this is done for a real vortex ring, however, these constants will lose some or all their literal meaning as expressed by the theory. When used to describe flow in actual vortex rings, the theory becomes merely an elegant extrapolation tool.

DATA COLLECTION AND ANALYSIS

With the aid of a semiautomatic film analyzer, experimental circulation data have been obtained from cinefilms of nuclear test shots. After appropriate geometry corrections are applied, these data then should yield both position and velocity information for flow along individual streamlines. When used with the least squares analysis mentioned above, it should be possible to obtain the vital parameters necessary to quantitatively describe cloud circulation.

COMPUTER SIMULATION

The fluid dynamic circulation model has been programmed for machine computation and incorporated into a particle motion simulation program for operation on the IBM 7094 computer. Some interesting data have been obtained from pilot simulations. These are presented graphically in Figure 2 for particles of 1μ radii.

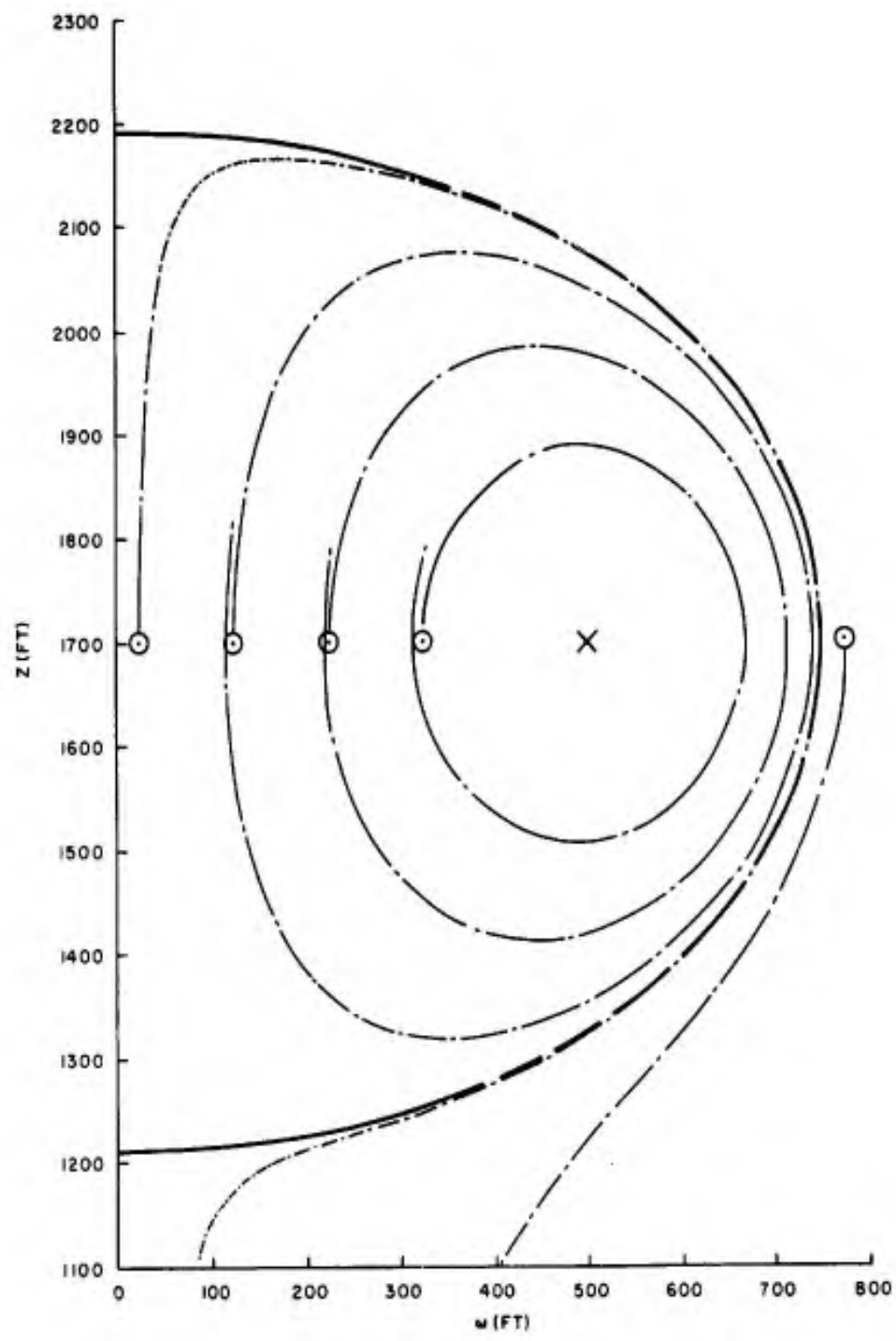


Figure 2. Particle Trajectories as Determined by Computer Simulation (Circulation is clockwise starting with circled dots)



Temperature, fluid density, ω_c , a , and k all were held constant throughout the calculations. The simulation time increment was 0.001 sec. Starting positions for each particle are indicated by the circled dots. Circulation is clockwise. Each successive dot represents the position of a particle after a 0.2 sec interval in simulated time. Translational motion of the cloud in the z direction has been subtracted from each position. The heavy solid curve represents the theoretical cloud boundary.

With the exception of the one particle starting at the point $\omega = 25$ ft, $z = 1700$ ft, the particles follow the fluid flow very closely, as would be expected for particles of their size. There is little evidence of computational instability or error accumulation. The behavior of the particle "falling out" of the cloud is typical of that observed in cinefilms and is quite relevant to the cloud stem formation.

RECOMMENDATIONS FOR FURTHER RESEARCH

In light of the considerable potential of the fluid dynamic model of circulation in nuclear clouds, it is recommended that this model be developed further to provide a simulation tool applicable to the complete time span of the dynamic nuclear cloud. To accomplish this, it will be necessary to continue development in the areas of experimental data collection, theoretical analysis, and computer simulation of particle motion.

REFERENCES

1. T. W. Schwenke, J. C. W. Rogers, J. R. Dion, P. Kugel, and M. Dwonczyk, "Research on Fallout Prediction Techniques (U)," Final Report on Contract OCD-OS-62-186, Technical Operations Research, Report TO-B 63-30 (27 June 1963).
2. H. Lamb, "Hydrodynamics," Sixth Edition (New York, N. Y.: Dover Publications, 1932).
3. E. Jahnke and F. Emde, "Tables of Functions with Formulae and Curves," Fourth Edition (New York, N. Y.: Dover Publications, 1945).



DISTRIBUTION LIST FOR CONTRACT NO. OCD-OS-62-186
FINAL REPORT
SUMMARY

<u>No. of Copies</u>	<u>Recipient</u>	<u>No. of Copies</u>	<u>Recipient</u>
214	Office of Civil Defense, DOD Pentagon, Washington, D. C. Attn: Director for Research	1	Chief, Bureau of Yards and Docks Office of Research (Code 74) Department of the Navy Washington 25, D. C.
3	Army Library Civil Defense Unit Washington 25, D. C.	1	U. S. Naval Civil Engineering Laboratory Port Hueneme, California
1	Assistant Secretary of the Army (R & D) Washington 25, D. C. Attn: Assistant for Research	20	Defense Documentation Center Cameron Station Alexandria, Virginia
1	Chief of Naval Research (Code 104) Department of the Navy Washington 25, D. C.	1	Advisory Committee on Civil Defense National Academy of Sciences 2101 Constitution Avenue, N. W. Washington 25, D. C. Attn: Mr. Richard Park
1	Chief of Naval Operations (OP-07T10) Department of the Navy Washington 25, D. C.	2	Chief, Bureau of Ships (Code 335) Department of the Navy Washington 25, D. C.
1	Chief, Bureau of Naval Weapons (Code RRRE-5) Department of the Navy Washington 25, D. C.	1	Chief, Bureau of Ships (Code 203) Department of the Navy Washington 25, D. C.
1	Chief, Bureau of Medicine and Surgery Department of the Navy Washington 25, D. C.	1	Coordin, Marine Corps Landing Force Development Activities Quantico, Virginia
1	Chief, Bureau of Supplies & Accounts (Code L12) Department of the Navy Washington 25, D. C.	1	Dr. Wayne Bell General Dynamics Corp. P. O. Box 5 Old San Diego Station San Diego 10, California



DISTRIBUTION LIST FOR CONTRACT NO. OCD-OS-62-186 (Cont'd.)

<u>No. of Copies</u>	<u>Recipient</u>	<u>No. of Copies</u>	<u>Recipient</u>
1	Dr. Eric Clarke Technical Operations, Inc. Burlington, Massachusetts	1	Dr. Edgar Parsons Research Triangle Institute P.O. Box 490 Durham, North Carolina
1	Dr. Carl F. Miller Stanford Research Institute Menlo Park, California	1	Mr. C. Herbert Wheeler Curtiss-Wright Incorporated Caldwell, New Jersey
1	Cdr. W. J. Christensen Naval Civil Engineering Laboratory Port Hueneme, California	1	Mr. Olaf Fernald Advance Research Inc. 19 Brook Road Needham Heights 94, Mass.
1	Dr. J. Laurence Kulp Isotopes Incorporated 123 Woodlawn Avenue Westwood, New Jersey	1	Mr. Harvey Ludwig Engineering Science Inc. 150 East Foothills Blvd. Arcadia, California
1	Dr. Louis Gavantman Naval Radiological Defense Laboratory San Francisco, California	1	Dr. Eugene Sevin IIT Research Institute 10 West 35th Street Chicago 16, Illinois
1	Mr. Joseph Maloney Nuclear Defense Laboratory Army Chemical Center Edgewood, Maryland	1	Dr. Paul Parrino Public Health Service, DHEW Washington 25, D.C.
1	Dr. Wayne A. McRae Ionics Incorporated 152 6th Street Cambridge, Massachusetts	1	Mr. Herman Kahn Hudson Institute Quaker Ridge Road Harmon-on-Hudson, New York
1	Mr. P. Schmidt U. S. Army Material Office Directorate of Research & Development Fort Belvoir, Virginia	1	Dr. Robert McGinnis Cornell University Ithaca, New York



DISTRIBUTION LIST FOR CONTRACT NO. OCD-OS-62-186 (Cont'd.)

<u>No. of Copies</u>	<u>Recipient</u>	<u>No. of Copies</u>	<u>Recipient</u>
1	Mr. Homer J. McConnell Civil Defense Training Program FDA/DHEW Washington 25, D. C.	1	Mr. George W. Burke, Jr. Div. of Water Supply & Pollution Control Public Health Service, DHEW Washington 25, D. C.
1	Lt. Col. Converse R. Lewis Office of the Surgeon General Main Navy Building Washington 25, D. C.	1	Prof. Thomas deS. Furman Civil Engineering Department University of Florida Gainesville, Florida
1	Col. F. H. Whitley Medical Division Hq. USAREUR APO 403 New York, New York	1	American Institute for Research 410 Amberson Avenue Pittsburgh, Pennsylvania
1	Dr. Frank Todd Assistant to the Administrator Agricultural Research U. S. Department of Agriculture Washington 25, D. C.	1	Psychological Laboratories University of Georgia Athens, Georgia
1	Dr. Luna Leopold Water Resources Division U. S. Geological Survey Washington 25, D. C.	1	Dr. Frederick Bellinger School of Engineering Georgia Institute of Technology Atlanta, Georgia
1	Col. Stanley J. Widenkaph Hq. Medical R&D Command Main Navy Building Washington 25, D. C.	1	Dr. W. Fulton Abercrombie U. S. Public Health Service Division of Health Mobilization Washington 25, D. C.
1	Water & Sewage Industry and Utilities Division U. S. Department of Commerce Washington 25, D. C.	1	Dr. Ken Kaplan 1811 Trousdale Avenue United Research Services Burlingame, California
1	Mr. Gordon E. McCallum Water Supply & Pollution Control Public Health Service, DHEW Washington 25, D. C.	1	Lt. Col. J. R. Bohannon Air Force Office of Civil Engineering Washington 25, D. C.



DISTRIBUTION LIST FOR CONTRACT NO. OCD-OS-62-186 (Cont'd.)

<u>No. of Copies</u>	<u>Recipient</u>	<u>No. of Copies</u>	<u>Recipient</u>
1	Dr. Frank Parker Health Physics Division Oak Ridge National Laboratory Oak Ridge, Tennessee	1	Mr. Walter Wood Dikewood Corp. 4805 Menaul Blvd. N. E. Albuquerque, N. M.
1	PARM Project 7th Floor 1424 16th St. , N. W. Washington, D. C.	1	U. S. Atomic Energy Commission Hdq. Reports Library G-017 Germantown, Md.
1	Dr. Joseph Coker Office of Emergency Planning Washington 25, D. C.	1	Commander, Field Command Defense Atomic Support Agency Sandia Base Albuquerque, New Mexico
1	Dr. Ray Edwards Nuclear Science & Engineering Corp. P. O. Box 10901 Pittsburgh 36, Pennsylvania	2	Defense Logistics Studies Information Exchange U. S. Army Logistics Management Center Attn: Col. L. A. Robbins Fort Lee, Virginia
1	Mr. H. Malcolm Childers 708 North West Street Alexandria 14, Virginia	1	NASA Headquarters Office of Advanced Research & Technology 1512 H Street, N. W. Washington, D. C.
1	Technical Information Service U. S. Atomic Energy Commission Oak Ridge, Tennessee	1	Commanding General Combat Developments Command Materiel Requirements Division Attn: Lt. Col. Davis Fort Belvoir, Virginia
1	Mr. Jim G. Terrell, Jr. Radiological Health Division U. S. Public Health Service, DHEW Washington 25, D. C.	1	Assistant Secretary of the Air Force (R&D) Room 4E968 The Pentagon Washington 25, D. C.
1	Dr. Werner N. Grune Professor of Civil Engineering Merrimack College North Andover, Mass.	1	Advanced Research Projects Agency Department of Defense The Pentagon Washington 25, D. C.

UNCLASSIFIED

UNCLASSIFIED