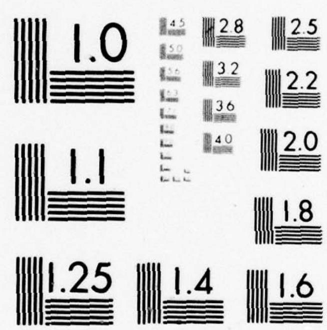
AD-A073 215 PENNSYLVANIA STATE UNIV UNIVERSITY PARK APPLIED RESE--ETC F/G 20/1
BACKSCATTERING FROM AN ABSORBENT SPHERE.(U)
JUL 79 G C LAUCHLE N00024-79-C-6043
UNCLASSIFIED ARL/PSU/TM-79-131 NL

1 OF 1

AD
A073215

END
DATE
FILMED
10-79
DDC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

BACKSCATTERING FROM AN ABSORBENT SPHERE

G. C. Lauchle

Technical Memorandum
File No. TM 79-131
10 July 1979
Contract No. N00024-79-C-6043

Copy No. 48

The Pennsylvania State University
APPLIED RESEARCH LABORATORY
Post Office Box 30
State College, PA 16801

NAVY DEPARTMENT

NAVAL SEA SYSTEMS COMMAND

Approved for Public Release
Distribution Unlimited

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TM 79-131	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9 Technical memo
4. TITLE (and Subtitle) 6 BACKSCATTERING FROM AN ABSORBENT SPHERE		5. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 G. C. Lauchle		8. CONTRACT OR GRANT NUMBER(s) 15 N00024-79-C-6043
9. PERFORMING ORGANIZATION NAME AND ADDRESS Applied Research Laboratory P.O. Box 30 State College, PA 16801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command Washington, DC 20362		12. REPORT DATE 11 10 Jul[redacted]79
		13. NUMBER OF PAGES 11
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 16p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release. Distribution Unlimited.
Per NAVSEA - August 16, 1979.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

14 ARL/PSU/TM-79-131

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

backscatter
absorbent
sphere

beta

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This letter presents a series of curves for the backscattering cross section of an absorbent sphere. The surface of the sphere is assumed to be one of local reaction of point impedance, z, or of specific admittance, β. The normalized backscattering cross section is given as a function of ka ranging from 0.2 to 21 and for β ranging from 0 to infinity.

beta

391007 Gw

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Subject: Backscattering From An Absorbent Sphere

References: See page 8.

Abstract: This letter presents a series of curves for the backscattering cross section of an absorbent sphere. The surface of the sphere is assumed to be one of local reaction of point impedance, z, or of specific admittance, β. The normalized backscattering cross section is given as a function of ka ranging from 0.2 to 21 and for β ranging from 0 to infinity.

Acknowledgement: The curves presented in this letter were generated at the suggestion of Prof. E. J. Skudrzyk. Support has been through the Naval Sea Systems Command, Code 03.

Table of Contents

List of Figures

INTRODUCTION

Backscattering cross section curves for hard and soft spheres may be found in many references, e.g., Bowman, et. al. [1]. Analogous curves for the absorbent sphere appear to be limited except for special cases of the surface impedance [2, 3]. In this letter we consider the simple case of a sphere whose surface is one of local reaction. That is, the motion of the surface at a point, due to some pressure at that point, is not coupled with the motions of other points on the surface. Many acoustical absorbents satisfy this definition. The surface is characterized in terms of the specific admittance, β, assumed independent of frequency. This admittance is related to the point impedance, z, by $\beta = \rho c/z$, where ρc is the characteristic impedance of the acoustic medium. Numerical results for the backscattering cross section are presented herein as a function of acoustic radius, ka, and for discrete values of β.

ANALYSIS

Sound scattering analyses for absorbent spheres may be found in the books by Morse and Ingard [4] and Skudrzyk [5], but neither author presents numerical examples of their analysis. We repeat the analysis here only for the sake of completeness.

The incident pressure due to a plane wave is given in the usual spherical coordinate notation by:

$$p_i = \overline{A} \sum_{n=0}^{\infty} (-i)^n (2n+1) P_n(\cos\theta) j_n(kr) \quad , \qquad (1)$$

where P_n is the Legendre polynomial and j_n the spherical Bessel function. For $\exp(-i\omega t)$ time dependence, the scattered pressure field is of the form:

$$p_s = \sum_{n=0}^{\infty} A_n P_n(\cos\theta)\, h_n^{(1)}(kr) \quad , \tag{2}$$

where $h_n^{(1)}$ is the spherical Hankel function of the first kind, and A_n is determined from the boundary condition at r=a; namely,

$$\left.\frac{\partial p}{\partial r} + ik\beta p\right|_{r=a} = 0 \ . \tag{3}$$

Solving for A_n and making the far-field approximation:

$$h_n^{(1)}(kr) \xrightarrow[kr\to\infty]{} i^{-n-1} \exp(ikr)/kr \ , \tag{4}$$

we find that

$$p_s \longrightarrow \bar{A} \exp(ikr)\, \Phi(\theta)/r \ , \tag{5}$$

where $\Phi(\theta)$ is the angle distribution function given by:

$$\Phi(\theta) = \frac{i}{k} \sum_{n=0}^{\infty} (-1)^n (2n+1) P_n(\cos\theta) \left\{ \frac{i\beta j_n(ka) + j_n'(ka)}{i\beta h_n^{(1)}(ka) + h_n^{(1)\prime}(ka)} \right\} . \tag{6}$$

The primes on the spherical functions denote differentiation with respect to the argument.

The backscattering cross section is a measure of the sound intensity scattered back in the direction of the incident plane wave. When normalized to the intensity of the incident wave, we have

$$\sigma_o = 2\pi\, |\Phi(0)|^2 \int_0^{\pi} \sin\theta d\theta = 4\pi |\Phi(0)|^2 \ . \tag{7}$$

The relative backscattering cross section is eq. (7) normalized by the area of the geometric shadow, πa^2; hence,

$$\frac{\sigma_o}{\pi a^2} = \frac{4}{(ka)^2} \left| \sum_{n=0}^{\infty} (-1)^n (2n+1) \left\{ \frac{j_n'(ka) + i\beta j_n(ka)}{h_n^{(1)\prime}(ka) + i\beta h_n^{(1)}(ka)} \right\} \right|^2 . \tag{8}$$

NUMERICAL RESULTS

Equation (8) has been evaluated for $0.2 \leq ka \leq 21$ and for a few discrete values of β including $\beta = 0$ $(z \rightarrow \infty)$ which is the rigid case, $\beta \rightarrow \infty$ $(z = 0)$ which is the pressure release case, and $\beta = 1$ $(z = \rho c)$ which is the ρc-match case. The spherical Bessel and Neumann functions were calculated on an IBM 370 digital computer using the method of Corbato' and Uretsky [6]. The series of equation (8) was found to converge in about [ka] terms when $ka > \pi$, although six terms were used when $ka \leq 6$, and [ka] terms when $ka > 6$.

Figure 1 shows the results of these computations for $0.2 \leq ka \leq 21$, while Figure 2 shows only the low-frequency behavior $(0.2 \leq ka \leq 2.4)$. We see from Figure 1 that for a large sphere (large ka), the backscattering decreases as the specific admittance is increased from zero to one. When β is increased to values greater than one, the backscattering cross section is observed to increase. Figure 3 demonstrates this behavior for $ka = 21$. We note that for $ka > 2$, the rigid and pressure release spheres reflect approximately equal energy.

At low values of ka (small spheres), the behavior is nearly reversed of what occurs for large spheres. For $ka \lesssim 0.6$, the rigid sphere is the worst reflector while the pressure release one is the best. In between, the magnitude of the backscattering cross section increases monotonically with β (Figure 3); there is no null corresponding to the case when the characteristic impedance of the absorbent matches that of the acoustic medium.

CONCLUSIONS

It has been the purpose of this letter to present a series of curves for the backscattering cross section of absorbent spheres. In the two limiting cases of the ideally rigid and pressure release spheres, this cross section asymptotically approaches the area of the geometric shadow when the wavelength becomes small. When the point impedance of the surface matches the characteristic impedance of the medium, the backscattering cross section decreases with ka by approximately a factor of four for each octave in ka (we should not assume this to be generally true for ka >21). In general, for $ka \gtrsim 5$, the backscattering cross section increases with increasing $|\beta-1|$, where $0 \leq \beta \leq \infty$. For small spheres ($ka \lesssim 0.6$), σ_o increases monotonically with β. For intermediate values of ka, corresponding to sphere radii on the order of a wavelength, the backscattering cross section oscillates with ka and no generalization regarding its dependence on β may be made.

REFERENCES

[1] J. J. Bowman, T. B. A. Senior, and P. L. E. Uslenghi (Editors) Electromagnetic and Acoustic Scattering by Simple Shapes, North-Holland Publishing Co., Amsterdam, John Wiley and Sons, Inc., New York (1969).

[2] V. Anderson, "Sound Scattering from a Fluid Sphere," J. Acoust. Soc. Am. 22, 426-431 (1950).

[3] R. Cook and P. Chrzanowski, "Absorption by Sound-Absorbent Spheres," J. Acoust. Soc. Am. 21, 167-170 (1949).

[4] P. M. Morse and K. U. Ingard, Theoretical Acoustics, McGraw-Hill Book Co., New York (1968).

[5] E. Skudrzyk, The Foundations of Acoustics: Basic Mathematics and Basic Acoustics, Springer-Verlag, New York (1971).

[6] F. J. Corbato' and J. L. Uretsky, "Generation of Spherical Bessel Functions in Digital Computers," J. Assoc. Comp. Machinery 6, 366-375 (1959).

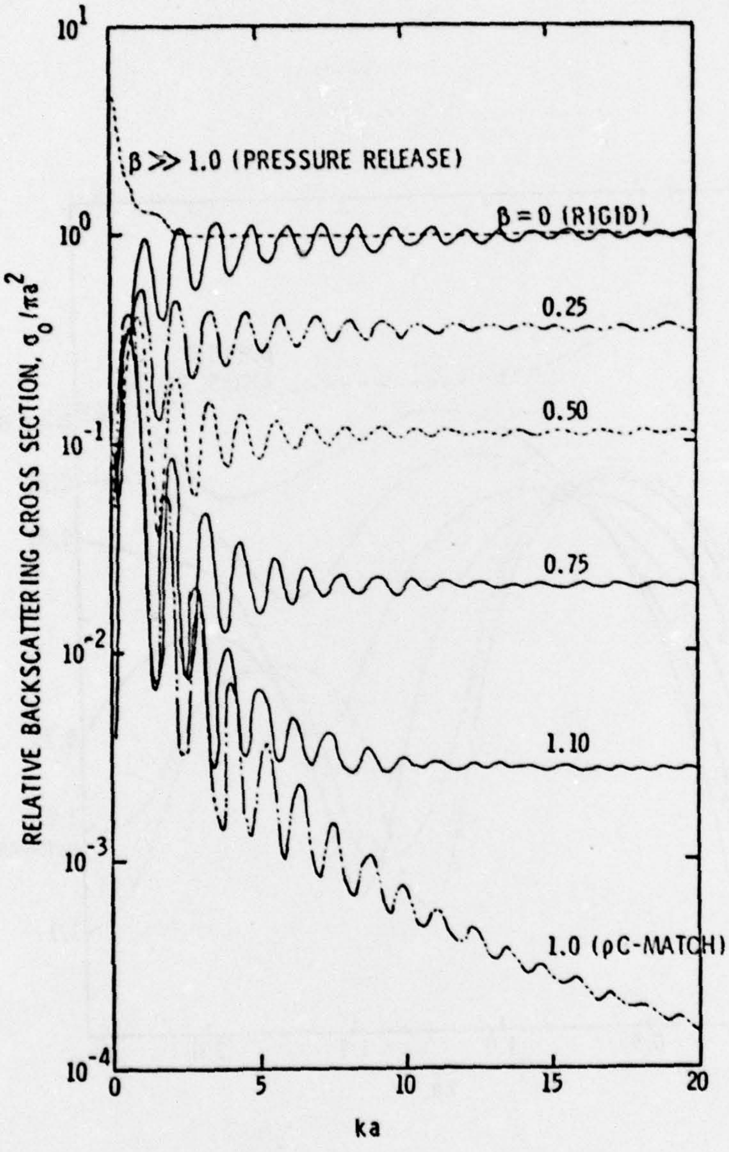


Figure 1 - Backscattering cross section curves for various values of β and for $0.2 \leq ka \leq 21$.

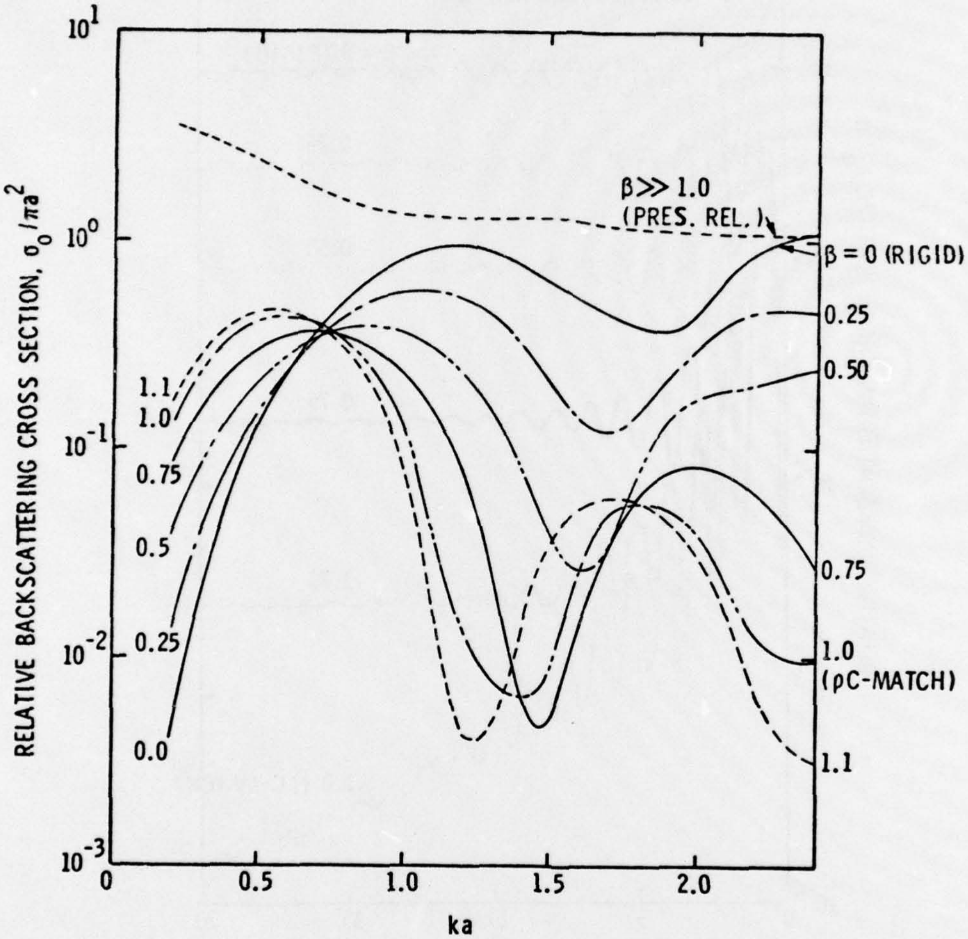


Figure 2 - Backscattering cross section curves for various values of β and for $0.2 \leq ka \leq 2.4$.

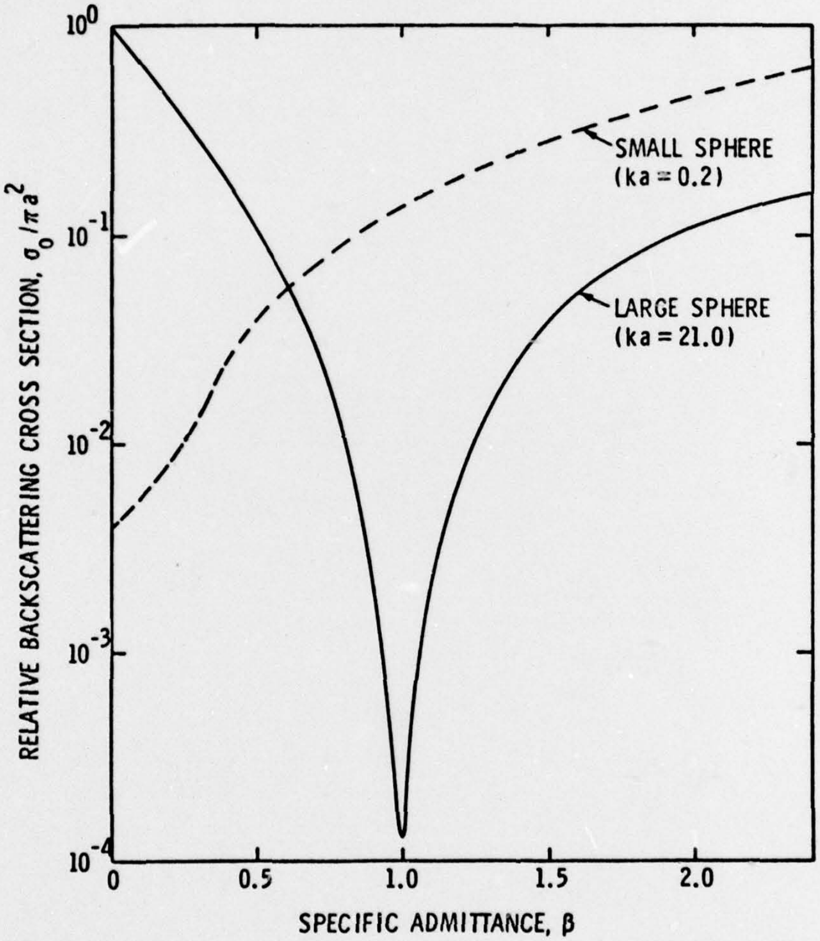


Figure 3 - The variation of the backscattering cross section with β for both large and small spheres.

DISTRIBUTION LIST FOR UNCLASSIFIED TM 79-131 by G. C. Lauchle, dated 10 July 1979.

Commander
Naval Sea Systems Command
Department of the Navy
Washington, DC 20362
Attn: Library
Code NSEA-09G32
(Copies No. 1 and 2)

Naval Sea Systems Command
Attn: C. G. McGuigan
Code NSEA-03133
(Copy No. 3)

Naval Sea Systems Command
Attn: L. Benen
Code NSEA-0322
(Copy No. 4)

Naval Sea Systems Command
Attn: E. J. McKinney
Code NSEA-0342
(Copy No. 5)

Naval Sea Systems Command
Attn: E. G. Liszka
Code NSEA-63R
(Copy No. 6)

Naval Sea Systems Command
Attn: G. Sorkin
Code NSEA 63R
(Copy No. 7)

Naval Sea Systems Command
Attn: T. E. Peirce
Code NSEA 63R-31
(Copy No. 8)

Naval Sea Systems Command
Attn: J. G. Juergens
Code NSEA 05H
(Copy No. 9)

Naval Sea Systems Command
Attn: H. C. Claybourne
Code NSEA-05H
(Copy No. 10)

Naval Sea Systems Command
Attn: A. R. Paladino
Code NSEA-05H
(Copy No. 11)

Naval Sea Systems Command
Attn: D. Creed
Code NSEA-03132A
(Copy No. 12)

Commander
Naval Ship Engineering Center
Department of the Navy
Washington, DC 20360
Attn: W. L. Louis
Code NSEC-6136B
(Copy No. 13)

Naval Ship Engineering Center
Attn: F. Welling
Code NSEC-6144
(Copy No. 14)

Commanding Officer
Naval Underwater Systems Center
Newport, RI 02840
Attn: C. N. Pryor
Code 01
(Copy No. 15)

Naval Underwater Systems Center
Attn: D. Goodrich
Code 36315
(Copy No. 16)

Naval Underwater Systems Center
Attn: R. J. Kittredge
Code 36313
(Copy No. 17)

Naval Underwater Systems Center
Attn: R. Nadolink
Code 36315
(Copy No. 18)

Naval Underwater Systems Center
Attn: D. A. Quadrini
Code 36314
(Copy No. 19)

Naval Underwater Systems Center
Attn: E. J. Sullivan
Code 36311
(Copy No. 20)

Naval Underwater Systems Center
Attn: R. Trainor
Code 36314
(Copy No. 21)

DISTRIBUTION LIST FOR UNCLASSIFIED TM 79-131 by G. C. Lauchle, dated 10 July 1979.

Naval Underwater Systems Center
Attn: F. White
Code 36301
(Copy No. 22)

Naval Underwater Systems Center
Attn: Library
Code 54
(Copy No. 23)

Commanding Officer
Naval Ocean Systems Center
San Diego, CA 92152
Attn: J. W. Hoyt
Code 2501
(Copy No. 24)

Naval Ocean Systems Center
Attn: M. M. Reischman
Code 2542
(Copy No. 25)

Naval Ocean Systems Center
Attn: G. L. Donohue
Code 2542
(Copy No. 26)

Commanding Officer and Director
David W. Taylor Naval Ship R&D Center
Department of the Navy
Bethesda, MD 20084
Attn: J. McCarthy
Code 1552
(Copy No. 27)

David W. Taylor Naval Ship R&D Center
Attn: Y. T. Shen
Code 1524
(Copy No. 28)

David W. Taylor Naval Ship R&D Center
Attn: M. Sevik
Code 19
(Copy No. 29)

David W. Taylor Naval Ship R&D Center
Attn: W. K. Blake
Code 1942
(Copy No. 30)

David W. Taylor Naval Ship R&D Center
Attn: T. M. Farabee
Code 1942
(Copy No. 31)

Commanding Officer and Director
David W. Taylor Naval Ship R&D Center
Department of the Navy
Annapolis Laboratory
Annapolis, MD 21402
Attn: J. G. Stricker
Code 2721
(Copy No. 32)

Commander
Naval Surface Weapon Center
Silver Spring, MD 20910
Attn: G. C. Gaunaurd
Code R-31
(Copy No. 33)

Naval Surface Weapon Center
Attn: Library
(Copy No. 34)

Office of Naval Research
Department of the Navy
800 N. Quincy Street
Arlington, VA 22217
Attn: H. Fitzpatrick
Code 438
(Copy No. 35)

Office of Naval Research
Attn: R. Cooper
Code 438
(Copy No. 36)

Naval Research Laboratory
Washington, DC 20390
Attn: R. J. Hansen
(Copy No. 37)

Defense Documentation Center
5010 Duke Street
Cameron Station
Alexandria, CA 22314
(Copies No. 38 to and including 49)

Dynamics Technology, Inc.
3838 Carson Street, Suite 110
Torrance, CA 90503
Attn: W. Haigh
(Copy No. 50)

DISTRIBUTION LIST FOR UNCLASSIFIED TM 79-131, by G. C. Lauchle, dated 10 July 1979.

Bolt Beranek and Newman
50 Moulton Street
Cambridge, MA 20136
Attn: N. Brown
(Copy No. 51)

Bolt Beranek and Newman
Attn: D. Chase
(Copy No. 52)

Bolt Beranek and Newman
Attn: K. L. Chandiramani
(Copy No. 53)

A. G. Fabula
5497 Coral Reef Avenue
La Jolla, CA 92037
(Copy No. 54)

Applied Research Laboratory
The Pennsylvania State University
Post Office Box 30
State College, PA 16801
Attn: E. J. Skudrzyk
(Copy No. 55)

Applied Research Laboratory
Attn: G. H. Hoffman
(Copy No. 56)

Applied Research Laboratory
Attn: G. C. Lauchle
(Copy No. 57)

Applied Research Laboratory
Attn: GTWT Files
(Copy No. 58)