THE DIABATIC WIND AND TEMPERATURE PROFILES

by

H. Chuang and J. E. Cermak

Prepared for

U. S. Army Research Grant

DA-AMC-28-043-65-G20

FLUID MECHANICS PROGRAM
ENGINEERING RESEARCH CENTER
COLLEGE OF ENGINEERING

COLORADO STATE UNIVERSITY

FORT COLLINS, COLORADO

THE DIABATIC WIND AND TEMPERATURE PROFILES

by

H. Chuang and J. E. Cermak

Prepared for

U. S. Army Research Grant

DA-AMC-28-043-65-G20

Fluid Dynamics and Diffusion Laboratory
College of Engineering
Colorado State University
Fort Collins, Colorado

December 1969 CER69-70HC-JEC-18

DISCLAIMER

ABSTRACT

KEYPS model and Monin-Obukhov's log-linear model were examined pertaining to their adequacy of describing wind and temperature profiles in thermally stratified shear flows for diversified thermal stability. The dimensionless wind shear and lapse rate for all ranges of thermal stability studied, $-2.0 \leq Ri \leq 0.4$, were shown to be linearly dependent on the dimensionless height derived from the log-linear model. Deacon numbers behaved quite differently from what were predicted by KEYPS model.

TABLE OF CONTENTS

INTRODUCTION

Wind and temperature profiles in thermally stratified shear flows are of great interest not only to the atmospheric scientist but also to the fluid dynamicist. Monin-Obukhov's well-known similarity theory (1) leads to the log-plus-linear profiles for flows in near-neutral conditions. Chuang and Cermak (2) used the field and laboratory data to show that wind and temperature profiles obtained in the laboratory as well as in the field approximately conform to the log-plus-linear model. A limited improvement of data scatter was made by adding a quadratic term to the log-plus-linear model (3). Bernstein (4) examined the existing three wind profile hypotheses--the log-linear profile, the KEYPS profile (5), and the exponential profile (6), and concluded that presently available data measured at O'Neill, Nebraska (7) and Kerang, Australia (8) were not sufficient to verify or refute any one of the three hypotheses. Pandolfo (9) introduced a free-convection model and claimed that it described the observed wind profiles quite accurately. However, he indicated that the free-convection profile was indistinguishable from the KEYPS profile.

Since KEYPS model is for interpolating the free and forced convection profiles, it is imparative to examine if this model can be used to describe wind and temperature profiles in all ranges of thermal stability. Monin-Obukhov's log-linear model has been proven (2) to be appropriate, even though not the most accurate method, for describing wind and temperature profiles in thermally stratified shear flows of diversified stability. Therefore, these two models are examined in this paper. As to the free-convection model, which is nothing more than one of the "power law" profiles, it will be examined and presented in a separate paper.

Deacon numbers are defined and examined for the above-mentioned two models. The rate of change of eddy Prandtl number for different thermal stabilities is also studied.

BASIC EQUATIONS

The dimensionless wind shear, S, and lapse rate, R, are defined (5) as

$$S = \frac{kZ}{u_*} \frac{\partial U}{\partial Z} ,$$

and

$$R = \frac{\alpha Z}{T_*} \frac{\partial T}{\partial Z}$$

where k is von Karman's constant; u_*, the friction velocity; U, mean wind velocity; Z, height; T_*, the friction temperature; T, mean air temperature, and α, the ratio of eddy conductivity, K_h, to eddy viscosity, K_m, defined in the following form

$$\alpha = \frac{K_h}{K_m} = \frac{\overline{tw}}{\overline{uw}} \frac{\partial U}{\partial Z} \Big/ \frac{\partial T}{\partial Z} = 1/\text{eddy Prandtl number}$$

R becomes identical with S if the above equation inserted for α and if $u_*^2 = -\overline{uw}$ and $u_*T_* = -\overline{tw}$. In Reynolds analogy α is equal to unity.

When the mean wind velocity and temperature profiles are measured, the magnitudes of u_*/k and T_*/α can be estimated by means of the regression theory. Consequently, the dimensionless wind shear and lapse rate can be calculated to a moderate degree of accuracy provided that the velocity and temperature gradients in the vertical direction are accurately measured. This is not difficult to achieve in the laboratory where a continuous profile can be obtained easily on an x-y plotter but is always a problem to face in the field. However, the method of interpolation can be used to find the velocity or temperature between two measured points and a more accurate gradient can then be determined.

KEYPS equation is an interpolation equation between free and forced convection. This equation was established in order to describe the gradual transition from forced to free convection. Hence, it cannot be expected to hold true in all ranges of thermal stability. KEYPS equation can be written in terms of Richardson number, Ri, as follows:

$$S = (1 - \gamma' Ri)^{-1/4} \quad ,$$

where γ' is an arbitrary constant which can be determined by means of the least squares method when S and Ri are known. Similarly, the dimensionless lapse rate as defined previously will be identical with the above equation. This implies that the dimensionless wind shear and lapse rate are only a function of Richardson number.

Deacon numbers are defined as

$$DEU = -\frac{d(\ln \frac{\partial U}{\partial Z})}{d(\ln Z)} = 1 - \frac{d(\ln S)}{d(\ln Z)} \quad , \tag{1}$$

and

$$DET = -\frac{d(\ln|\frac{\partial T}{\partial Z}|)}{d(\ln Z)} = 1 - \frac{d(\ln R)}{d(\ln Z)} \quad . \tag{2}$$

When the dimensionless wind shear and lapse rate profiles are known the above dimensionless numbers can be easily calculated. However, both Deacon numbers depend largely on the functional form of the dimensionless wind shear and lapse rate. When KEYPS equation is used for the dimensionless wind shear and lapse rate, both Deacon numbers will assume the same form as follows:

$$DEU = DET = 1 - \frac{\gamma' Ri}{4 - 3\gamma' Ri} \quad , \tag{3}$$

where Deacon numbers are unity at $Ri = 0$ (neutral flows) and approach 4/3 as Richardson number approaches negative infinity Since γ' may be different for different velocity and temperature profiles, it is conceivable that γ' becomes a parameter in the plot of Deacon numbers versus Richardson number.

In the log-plus-linear model, the mean wind velocity and temperature are written as

$$U - Uo = A_1 \ln Z + B_1 Z + C_1,$$

and

$$T - To = A_2 \ln Z + B_2 Z + C_2,$$

where $A_1 = u_*;k$, $A_2 = T_*/\alpha$, the B's are constants divided by a length scale, L', and the C's are constants. The dimensionless wind shear and lapse rate, then, assume the following form:

$$S = 1 + \frac{B_1}{A_1} Z \quad , \tag{4}$$

and

$$R = 1 + \frac{B_2}{A_2} Z \ . \tag{5}$$

Since S and R are identical, according to the similarity hypothesis, B_1/A_1 should be equal to B_2/A_2. Assuming that

$$B_1/A_1 = B_2/A_2 = \beta'/L' \ ,$$

where β' is an arbitrary constant, and using the identity that $SRi \equiv Z/L'$ the above equations can be rewritten as

$$S = R = (1 - \beta' Ri)^{-1} \tag{6}$$

Equation (6) is similar in form to KEYPS equation except for the difference in power. Combining Eqs. (1) and (4) yields $DEU = 1/S$. Similarly $DET = 1/R$. Therefore, Deacon numbers assume the following form:

$$DEU = DET = 1 - \beta' Ri \tag{7}$$

Equation (7) is valid in both stable and unstable thermal stratification since Eqs. (4) and (5) hold true in all stability. It shows that Deacon numbers are linearly dependent on Richardson number under log-plus-linear model.

The relative rate of change of α in α, where α has been defined previously, can be shown to be a function of Deacon numbers, DEU and DET, as follows:

$$d\alpha/\alpha = (DET - DEU)\, dZ/Z$$

If Eqs. (4) and (5) are indeed identical, then the above equation implies that the relative rate of change of α in α should vanish, namely α should be constant in the whole profile under consideration. Similarity between the mean wind velocity and temperature profiles is not always exact but is an approximation. Therefore, B_1/A_1 is only approximately equal to B_2/A_2, and the above equation is rewritten as

$$\frac{d\alpha/\alpha}{dZ/Z} = \left(\frac{B_1}{A_1} - \frac{B_2}{A_2}\right) L'Ri \tag{8}$$

The relative rate of change of Richardson number can also be shown to be a function of Deacon number as follows:

$$dRi/Ri = (2DEU - DET)\ dZ/Z - dT/T$$

The above equation can be rewritten as

$$\frac{dRi/Ri}{dZ/Z} = 2\ DEU - DET - \frac{dT/T}{dZ/Z} \quad . \tag{9}$$

The length scale is defined as

$$L' = \frac{T_m}{g} \frac{u_*(\partial U/\partial Z)}{k(\partial T/\partial Z)} \approx \frac{T_m}{g} \frac{A_1^2}{A_2} ,$$

where T_m is the mean temperature, in absolute temperature scale, averaged over the whole profile and g is the gravitational acceleration.

EXPERIMENTAL RESULTS AND DISCUSSION

Mean wind velocity and temperature profiles in a wind-tunnel boundary layer were measured and reported by Chuang and Cermak (3). The flow over a horizontal flat plate was made thermally stable or unstable by cooling the plate and heating the air stream (inversion) or vice versa (lapse). For the purpose of easy handling, data were taken at closely spaced equidistant points from the continuous profiles of mean wind velocity and temperature. The range of height considered here is from 0.5 up to 8.2 cm., about one-seventh the total boundary layer thickness, with data points 0.7 cm apart. Figure 1 shows the results of log-plus-linear profile by means of regression theory and least squares method. Data of Project Prairie Grass (7) were calculated by means of interpolation between heights from 25 up to 750 cm at an equidistant interval of 50 cm, except the first increment being 25 cm, and were fitted to the profile by the least squares method. These results were also shown in the same figure where it was defined that

$$RUU = k(U_i - U_m)/u_* - \beta'(Z_i - Z_m)/L' ,$$

$$RTT = \alpha(T_i - T_m)/T_* - \beta'(Z_i - Z_m)/L',$$

and

$$RZZ = \ln Z_i - \frac{1}{N}\sum_{i=1}^{N} \ln Z_i$$

The subscript i refers to data point at i where $1 \leq i \leq N$ with total data points N, and the subscript m refers to the ensemble average over the profile of the named variables.

The dimensionless wind shear, lapse rate and Richardson number can be computed numerically when the derivatives of mean wind velocity and temperature with respect to the height are approximated by the ratios of finite increments of mean velocity and temperature about a stepwise sequence of points to that of height. The data-point interval, which is 0.7 cm for the laboratory data and 50 cm for the field data, is small and there is no abrupt change in both velocity and temperature profiles so that the approximation is fairly good. According to KEYPS equation, the dimensionless wind shear and lapse rate are a function of Ri only and in the case of dimensionless wind shear the constant γ' is equal to 18 as reported by Panofsky, et al (10). Figure 2 shows both the laboratory and field data of these two dimensionless quantities versus Richardson number. For comparison, Eqs. (4) and (5) were plotted in Fig. 3, where A's and B's were determined from the velocity and temperature profiles by the regression theory described in the last paragraph. It is evident that the diabatic wind and temperature profiles are better represented by Eqs. (4) and (5) than by KEYPS equation. The constant, γ' for both laboratory and field data is not necessarily equal to 18 but varies with height, wind and temperature profiles, and stability even though the over-all average value of it for the field data may be 18. However, the variance of γ' is quite high.

Deacon numbers were computed according to Eqs. (1) and (2) and the finite difference approximation. They were plotted against Richardson number as shown in Fig. 4. Consider only the unstable cases where $Ri < 0$. Equation (3) is hardly descriptive of either laboratory or field data. This is due not only to the fact that KEYPS equation can vary with γ' as a parameter but also that the Deacon numbers are the second order derivatives of the diabatic wind and temperature profiles with respect to height Z. As the order of derivatives of a mean profile with respect to height increases, accuracy of the derivatives will decrease accordingly. Therefore, Deacon numbers will definitely amplify the scattering of data. Figure 5 shows the relationship between Deacon numbers and $\beta' Ri$. It reveals that Deacon numbers may not be exactly linearly dependent on Richardson number as predicted by Eq. (7).

Figure 6 shows the relative rate of change of α in α. Since $d\alpha/\alpha$ was reduced from Deacon numbers its accuracy was bad. However, this may show the general picture of similarity between the mean wind velocity profile and the mean temperature profile. It is imparative to measure the eddy Prandtl number directly. Figure 7 shows the effect of relative temperature gradient on the relative rate of change of Richardson number. The relative rate of change of Richardson number was computed by using the finite difference of Richardson number in a finite increment of height from the boundary.

CONCLUSIONS

The dimensionless wind shear and lapse rate for all ranges of thermal stability do not necessarily follow the prediction made by KEYPS equation. However, they are linearly dependent on the dimensionless height. Deacon numbers behave quite differently from what can be predicted by KEYPS model.

ACKNOWLEDGMENTS

The authors wish to thank staff members and graduate assistants of the Fluid Dynamics and Diffusion Laboratory, Colorado State University, for their technical assistance. Financial support provided by the United States Army through Research Grant DA-AMC-28-043-G20 for this study is gratefully acknowledged. Additional financial support for publishing this report was provided by U. S. Army Electronics Command Contract Number DAAB07-68-C-0423.

REFERENCES

1. Monin, A. S. and A. M. Obukhov, Trudy Geophys. Inst. Akad. Nauk. SSSR. No. 24, p. 163 (1954).

2. Chuang, H. and J. E. Cermak, Similarity of thermally stratified shear flows in the laboratory and atmosphere (to be published in the Physics of Fluid).

3. Chuang, H. and J. E. Cermak, Tech. Rept. CER66-67-HC-JEC-4, Fluid Dynamics and Diffusion Lab., Colorado State University, Fort Collins, Colorado (1966).

4. Bernstein, A. B., J. Appl. Meteor. 5, 217 (1966).

5. Lumley, J. L. and H. A. Panofsky, The Structure of Atmospheric Turbulence, pp. 239, Intersci. Publishers, N. Y. (1964)

6. Swinbank, W. C., Nature 186, 463 (1960).

7. Barad, M. L., Geophys. Research Papers No. 59, Air Force Cambridge Research Center, Bedford, Mass. (1958).

8. Swinbank, W. C., Quart. J. Roy. Meteor. Soc. 90, 119, (1964).

9. Pandolfo, J. P., J. Atmosph. Sci. 23, 495 (1966).

10. Panofsky, H. A., A. K. Blackadar, and G. E. McVehil, Quart. J. Roy. Meteor. Soc. 86, 390 (1960).

LIST OF SYMBOLS

Symbol	Definition
A	$A_1 = u_*/k$, cm/sec; $A_2 = T_*/\alpha$, $^{\circ}C$
B	Arbitrary constants
c_p	Specific heat of air at constant pressure, calories/ $^{\circ}C$/gm.
C	Arbitrary constants
g	Gravitational acceleration, cm/sec^2
H	Heat flux in the vertical direction, calories/ cm^2/sec
k	von Karman constant
k_h	Eddy thermal conductivity, cm^2/sec
k_m	Eddy viscosity, cm^2/sec
L	Monin-Obukhov length scale, $L' = \alpha L$, cm
N	Total number of data collected in a profile
R	Dimensionless lapse rate
Ri	Richardson number, $g \frac{\partial T}{\partial Z} / [T(\frac{\partial U}{\partial Z})^2]$
S	Dimensionless wind shear
T	Mean absolute temperature, $^{\circ}K$
T_*	$-H/(c_p \rho k u_*)$, friction temperature, $^{\circ}C$
u_*	Friction velocity, cm/sec
U	Local mean velocity, cm/sec
Z	Height, cm
α	K_h/K_m
β'	Arbitrary constant
γ'	Arbitrary constant
ρ	Density of air, gm/cm^3

LIST OF SYMBOLS (Continued)

Symbol	Definition
$(\ )_i$	The variable at height Z_i
$(\ )_m$	Mean value averaged over the profile
$(\ )_o$	The variable at height Z_o, an equivalent roughness height

LIST OF FIGURES

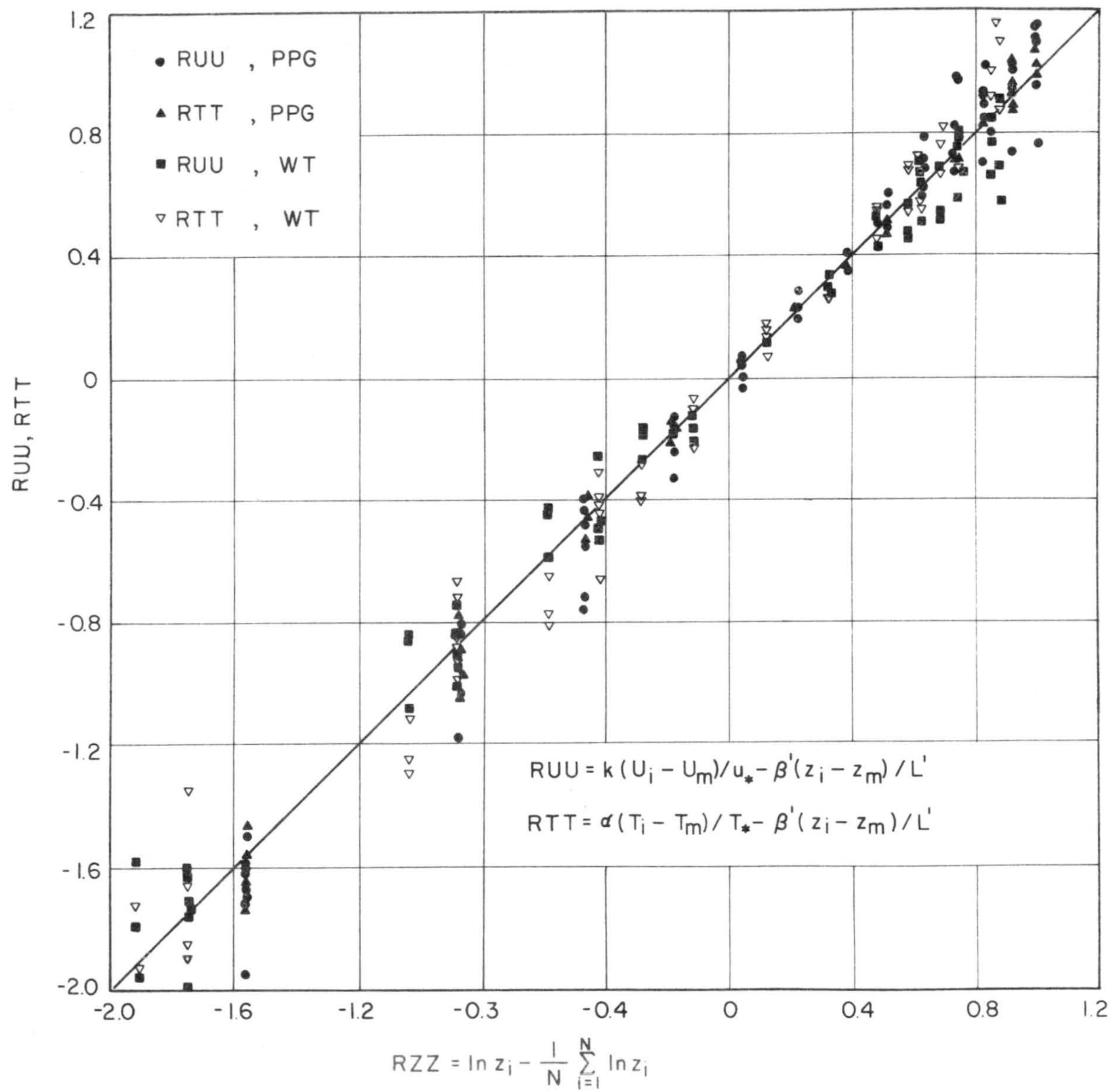

Fig. 1. Similarity law profile of mean velocity and temperature for heights from 0.5 to 8.2 cm (WT) or from 25 to 750 cm (PPG).

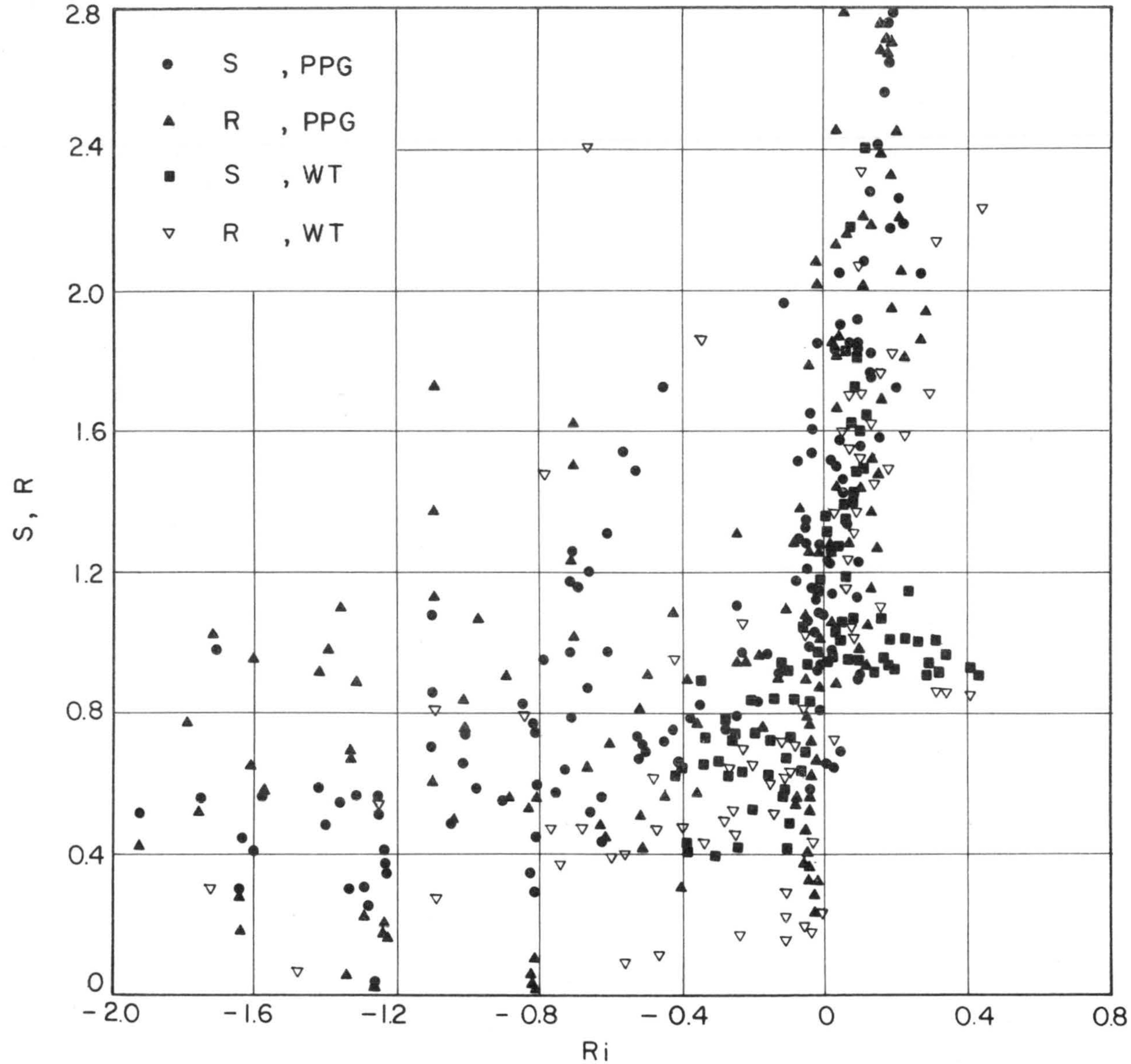

Fig. 2. Dimensionless wind shear and lapse rate versus Richardson number.

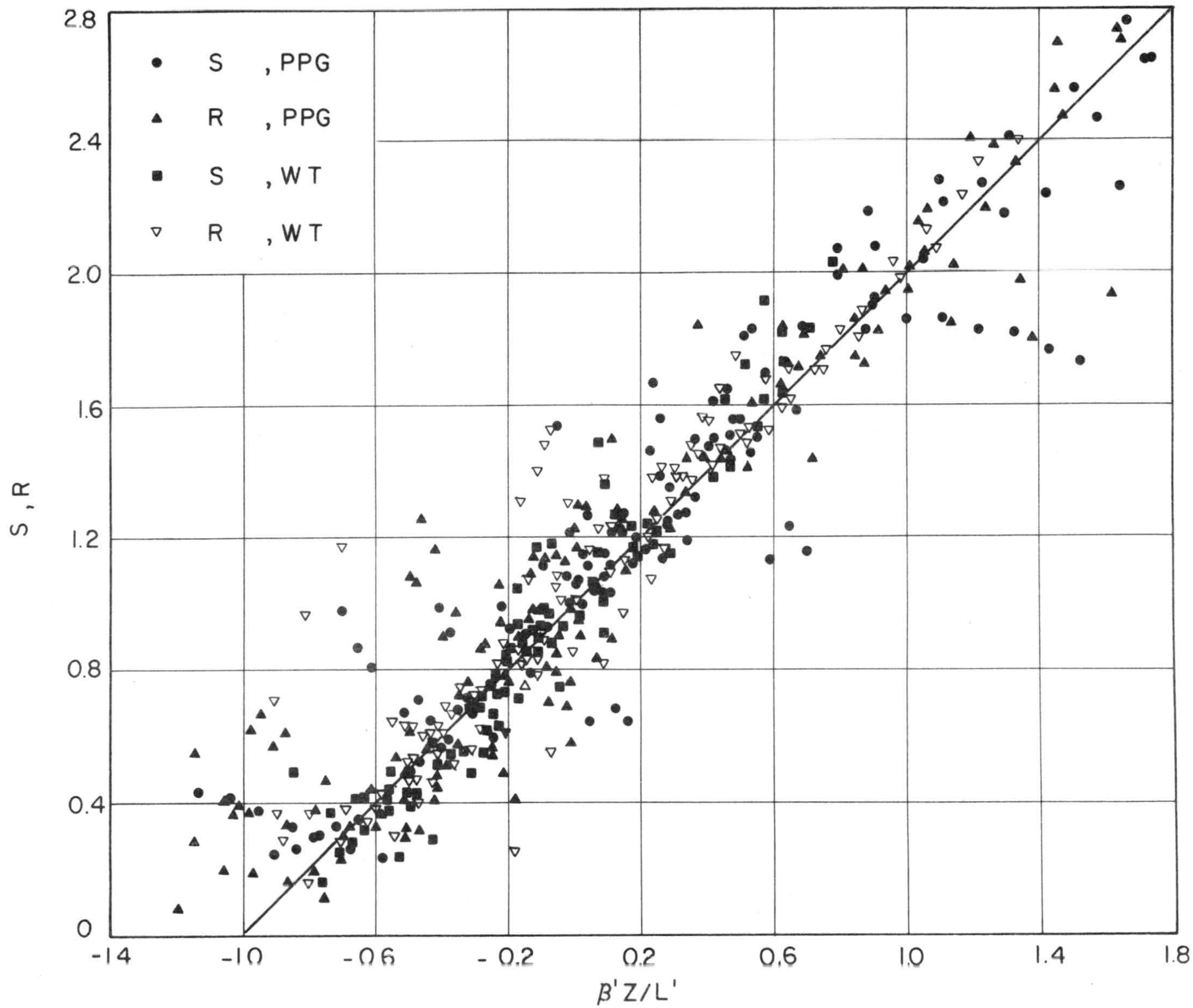

Fig. 3. Dimensionless wind shear and lapse rate versus dimensionless height $\beta'Z/L'$. The solid line represents Eqs. 4 and 5.

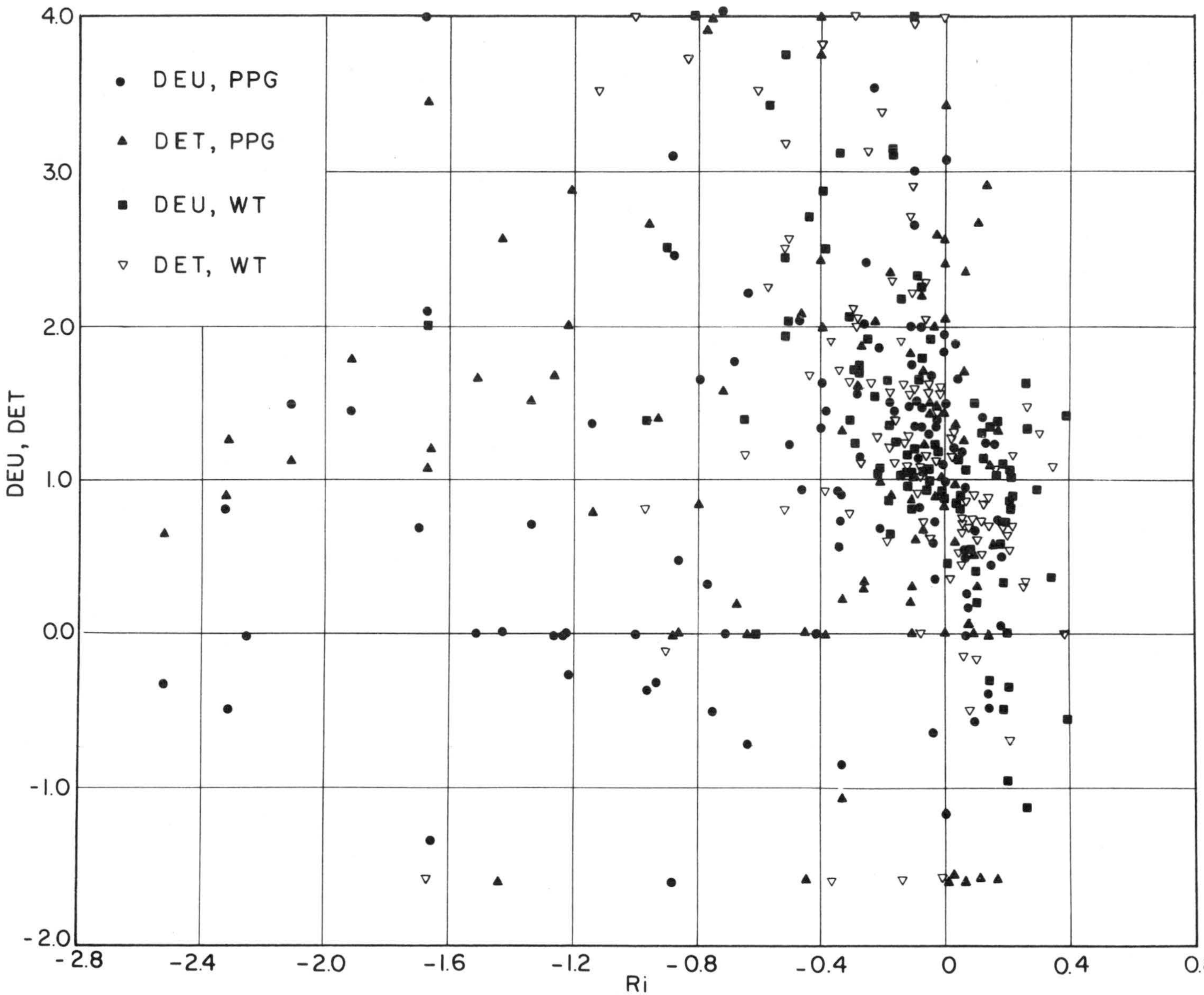

Fig. 4. Deacon numbers versus Richardson number.

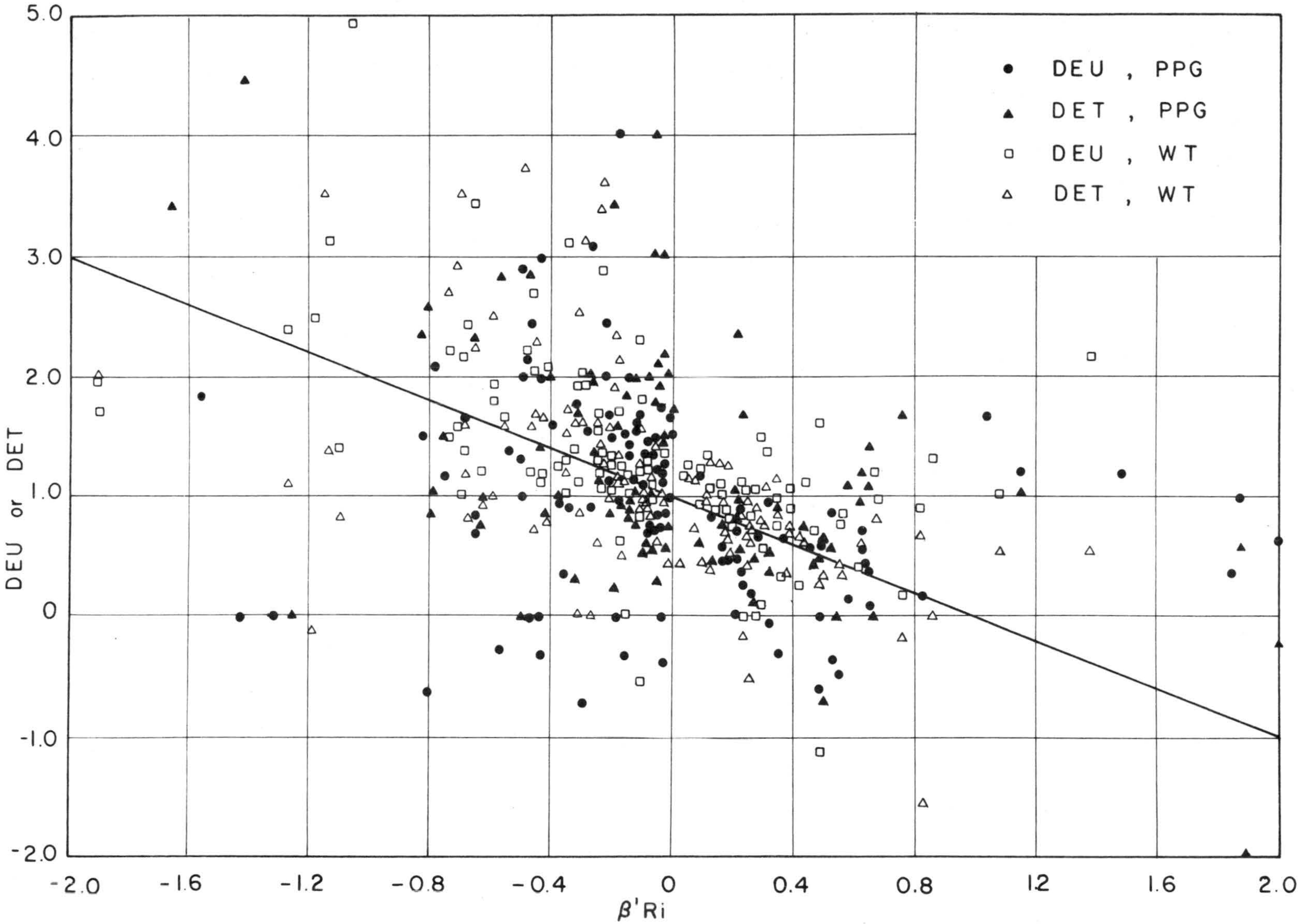

Fig. 5. Deacon numbers in terms of a linear function of Richardson number. The solid line represents Eq. 7.

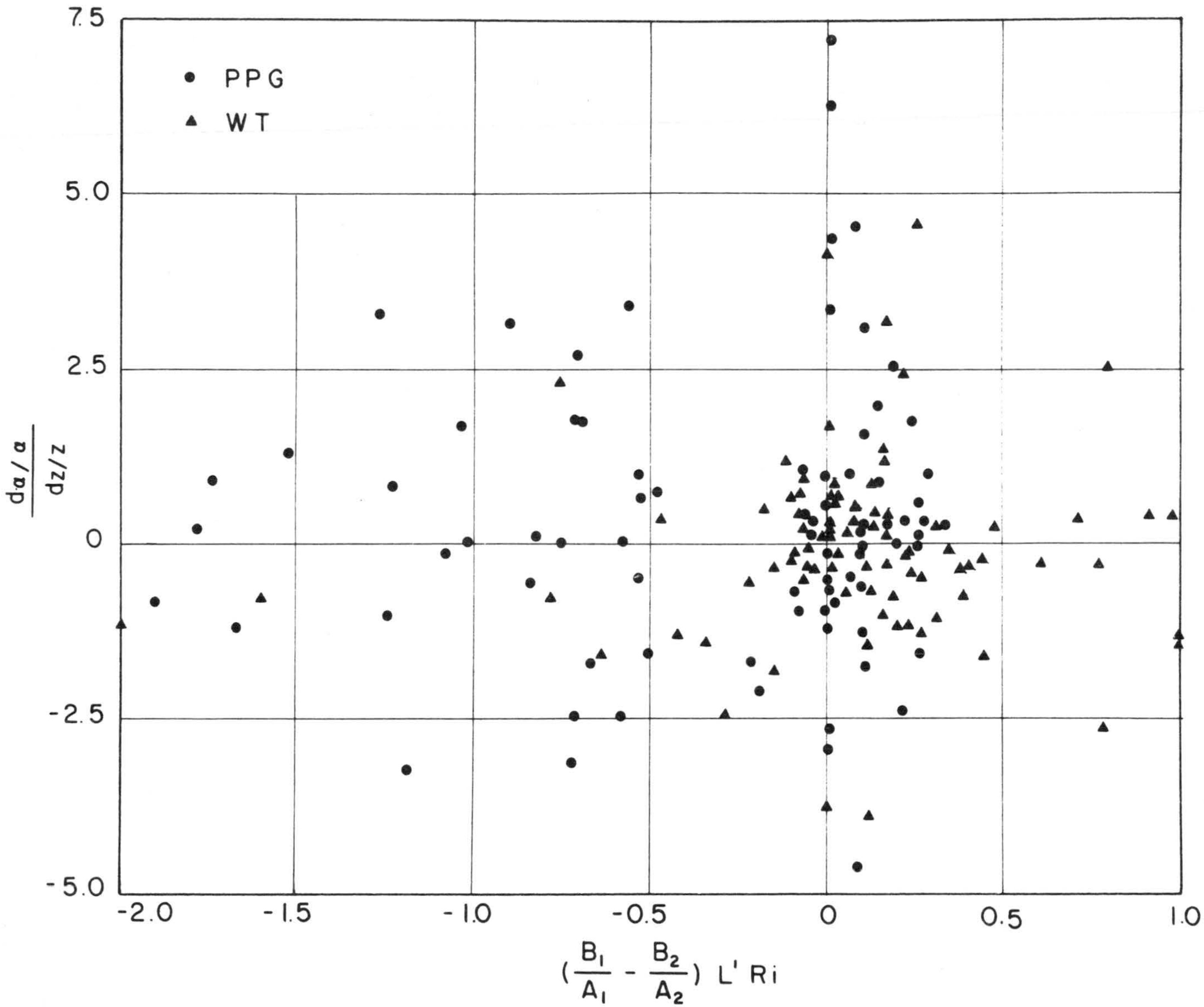

Fig. 6. Relative rate of change of α in terms of dimensionless parameters.

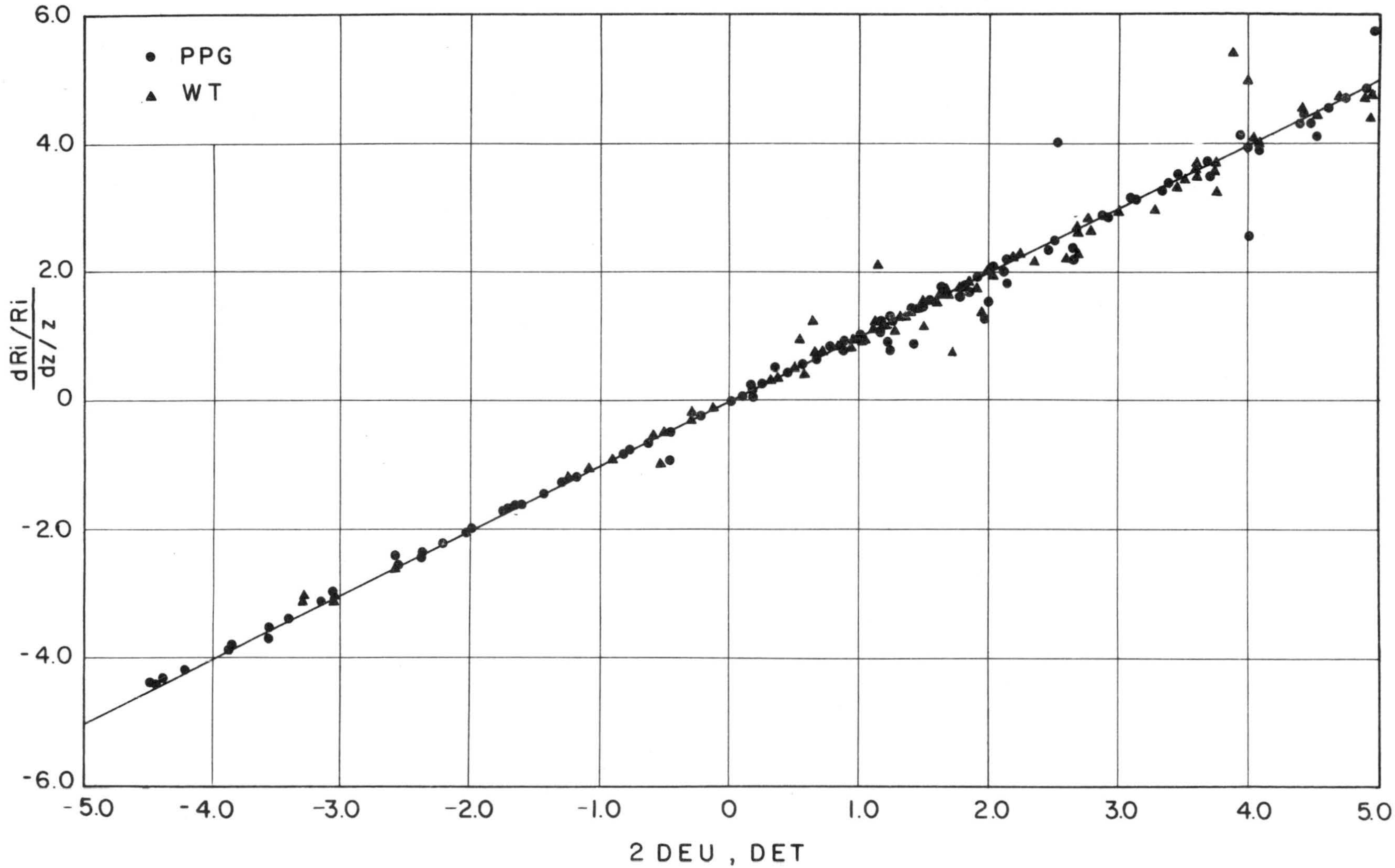

Fig. 7. Relative rate of change of Richardson number in terms of Deacon numbers.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Fluid Mechanics Program, College of Engineering Colorado State University, Fort Collins, Colo.	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

THE DIABATIC WIND AND TEMPERATURE PROFILES

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical Report

5. AUTHOR(S) *(Last name, first name, initial)*

Chuang, H. and J. E. Cermak

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1969	24	10

8a. CONTRACT OR GRANT NO. DA-AmC-28-043-65-G20	9a. ORIGINATOR'S REPORT NUMBER(S) CER69-70HC-JEC-18
b. PROJECT NO. 2246	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U. S. Army Materiel Command

13. ABSTRACT

KEYPS model and Monin-Obukhov's log-linear model were examined pertaining to their adequacy of describing wind and temperature profiles in thermally stratified shear flows for diversified thermal stability. The dimensionless wind shear and lapse rate for all ranges of thermal stability studied, $-2.0 \leq Ri \leq 0.4$, were shown to be linearly dependent on the dimensionless height derived from the log-linear model. Deacon numbers behaved quite differently from what were predicted by KEYPS model.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Wind and temperature profiles Thermal boundary layer KEYPS model						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

101 Defense Documentation Center
Attn: DDC-TCA
Cameron Station (Bldg 5)
*20 Alexandria, Virginia 22314

102 Dir. of Defense Research & Engineering
Attn: Technical Library
Rm 3E-1039, The Pentagon
1 Washington, D. C. 20301

103 Joint Chiefs of Staff
Attn: Spec. Asst. Environmental Svcs.
1 Washington, D. C. 20301

106 Defense Intelligence Agency
Attn: DIAAP-10A2
1 Washington, D. C. 20301

108 Director, Defense Atomic Support Agency
Attn: Technical Library
1 Washington, D. C. 20305

DEPARTMENT OF THE NAVY

201 Naval Ships Systems Command
Attn: Code 20526 (Technical Library)
Main Navy Bldg. Rm. 1528
1 Washington, D. C. 20325

205 Director
U. S. Naval Research Laboratory
Attn: Code 2027
2 Washington, D. C. 20390

206 Commanding Officer and Director
U. S. Navy Electronics Laboratory
Attn: Library
1 San Diego, California 92152

207 Commander
U. S. Naval Ordinance Laboratory
Attn: Technical Library
1 White Oak, Silver Spring, Maryland 20910

208 Officer in Charge
Navy Weather Research Facility
Bldg. R-48, Naval Air Station
1 Norfolk, Virginia 23511

210 Commandant, Marine Corps
HQ. U. S. Marine Corps
Attn: Code A04C
1 Washington, D. C. 20380

211 Commandant, Marine Corps
HQ. U. S. Marine Corps
Attn: Code A02F
1 Washington, D. C. 20380

212 Marine Corps Development & Educ. Comd.
Development Cen. Attn: C-E Div.
1 Quantico, Virginia 22134

213 Commander
U. S. Naval Weapons Laboratory
Attn: KXR
1 Dahlgren, Virginia 22448

214 Commander, Naval Air Systems Command
Meteorological Division (Air-540)
1 Washington, D. C. 20360

216 Commander
Naval Weather Service Command
Washington Navy Yard (Bldg. 200)
1 Washington, D. C. 20390

*Increase to 50 copies if releasable to CFSTI. See para 6e(1)(b), ECOMR 70-31, for types of reports not to be sent to DDC.

DEPARTMENT OF THE AIR FORCE

302 Air Force Cambridge Rsch. Labs.
Attn: CREU
L. G. Hanscom Field
1 Bedford, Massachusetts 01730

303 Air Force Cambridge Rsch. Labs.
Attn: CREW
L. G. Hanscom Field
1 Bedford, Massachusetts 01730

304 Air Force Cambridge Rsch. Labs.
Attn: CRH
L. G. Hanscom Field
1 Bedford, Massachusetts 01730

305 Air Force Cambridge Rsch. Labs.
Attn: CRER
L. G. Hanscom Field
1 Bedford, Massachusetts 01730

306 Electronic Systems Div. (ESSIE)
L. G. Hanscom Field
1 Bedford, Massachusetts 01730

307 Electronic Systems Division (ESTI)
L. G. Hanscom Field
2 Bedford, Massachusetts 01730

310 RFCON Central/AVRS.
AF Avionics Laboratory
1 Wright-Patterson AFB, Ohio 45433

311 HQ. AIR Weather Service
Attn: AWVAS/TF (R. G. Stone)
1 Scott Air Force Base, Illinois 62225

312 U. S. Air Force Security Service
Attn: TSG
1 San Antonio, Texas 78241

313 Armament Development & Test Center
Attn: ADBPS-12
1 Eglin Air Force Base, Fla. 32542

314 HQ. Air Force Systems Command
Attn: SCTSE
1 Andrews AFB, Maryland 20331

319 Air Force Weapons Laboratory
Attn: WLIL
1 Kirtland AFB, New Mexico 87117

DEPARTMENT OF THE ARMY

401 OFC of Asst. CH. of Staff for DS-SSS
Department of the Army
Rm. 3C466, The Pentagon
1 Washington, D. C. 20315

402 Asst. Ch. of Staff for Force Development
CBR Nuclear Operations Directorate
Department of the Army
1 Washington, D. C. 20310

405 Ofc. Asst. Sec. of the Army (R&D)
Attn: Asst. for Research
Room 3-E-373, The Pentagon
1 Washington, D. C. 20310

406 Chief of Research and Development
Department of the Army
2 Washington, D. C. 20315

407 Chief of Research and Development
Department of the Army
Attn: CRD/M
1 Washington, D. C. 20310

409 Commanding General
U. S. Army Materiel Command
Attn: AMCMA-EE
1 Washington, D.C. 20315

414 Commanding General
U. S. Army Materiel Command
Attn: AMCRD-TV
1 Washington D. C. 20315

416 Commanding General
U. S. Army Materiel Command
Attn: AMCRD-TV
1 Washington, D. C. 20315

418 Commanding General
U. S. Army Missle Command
Attn: AMSMI-RRA, Bldg. 5429
1 Redstone Arsenal, Alabama 35809

421 CG. U. S. Army Missle Command
Redstone Scientific Info. Center
Attn: Chief, Document Section
3 Redstone Arsenal, Alabama 35809

427 Commanding General
U. S. Army Combat Developments CMD
Combat Support Group
2 Fort Belvoir, Virginia 22060

428 Commanding General
U. S. Army Combat Developments Command
Attn: CDCMR-E
1 Fort Belvoir, Virginia 22060

430 Commanding Officer
USACDC CBR Agency
Attn: Mr. N. W. Bush
1 Fort McClellan, Alabama 36201

432 Commanding Officer
USACDC Artillery Agency
1 Fort Sill, Oklahoma 73503

435 Commanding General
U. S. Army Test & Eval. Command
Attn: AMSTE-EL, -FA, -NBC
3 Aberdeen Proving Ground, Md 21005

436 Commanding General
U. S. Army Test & Eval. Command
Attn: NBC Directorate
1 Aberdeen Proving Ground, Md 21005

437 Commanding General
U. S. Army Munitions Command
Attn: AMSMU-RE-R
1 Dover, New Jersey 07801

438 Commanding General
U. S. Army Munitions Command
Operations Research Group
1 Edgewood Aresenal, MD 21010

439 Commanding General
U. S. Army Munitions Command
Attn: AMSMU-RE-P
1 Dover, New Jersey 07801

442 Commanding Officer
Harry Diamond Laboratories
Attn: Library
1 Washington, D. C. 20438

445 Commanding General
U. S. Army Natick Laboratories
Attn: AMXRF-EG
1 Natick, Mass. 01760

448 Commanding Officer
Picatinny Arsenal
Attn: SMUPA-TV1
1 Dover, New Jersey 07801

449 Commanding Officer
Picatinny Arsenal
Attn: SMUPA-V46, Bldg. 59
2 Dover, New Jersey 07801

453 Commanding Officer
Fort Detrick
Attn: SMUFD-AS-S
1 Frederick, Maryland 21701

(CONTD)

454 Commanding Officer
Fort Detrick
Attn: Tech Library SMUFD-AE-T
1 Frederick, Maryland 21701

459 Commanding Officer
Edgewood Arsenal
Attn: SMUFA-TSTI-TL
1 Edgewood Arsenal, Maryland 21010

460 Commanding Officer
U. S. Army Nuclear Defense Lab.
Attn: Library
2 Edgewood Arsenal, Maryland 21010

463 President
U. S. Army Artillery Board
1 Fort Still, Oklahoma 73503

464 Commanding Officer
Aberdeen Proving Ground
Attn: Technical Library, Bldg. 313
2 Aberdeen Proving Ground, Md. 21005

469 Commanding Officer
U. S. Army Ballistics Rsch. Labs.
Attn: Tech. Info. Div.
1 Aberdeen Proving Ground, Md. 21005

470 Commanding Officer
U. S. Army Ballistic Research Labs.
Attn: AMXBR-B & AMXBR-1A
2 Aberdeen Proving Ground, Md. 21005

472 Commanding Officer
U. S. Army Limited Warfare Lab.
Attn: CRDLWL-7C
1 Aberdeen Proving Ground, Md. 21005

475 Commanding Officer
USA Garrison
Attn: Technical Reference Div.
1 Fort Huachuca, Arizona 85613

483 Commander
U. S. Army Research Office (Durham)
Box CM-Duke Station
1 Durham, North Carolina 27706

488 USA Security Agcy. Combat Dev. Actv.
Attn: IACDA-P(T) and IACDA-P(L)
Arlington Hall Station, Bldg. 420
2 Arlington, Virginia 22212

489 U. S. Army Security Agcy. Proc. Ctr.
Attn: TAVAPC-R&D
Vint Hill Farms Station
1 Warrenton, Virginia 22186

490 Technical Support Directorate
Attn: Technical Library
Bldg. 3330
1 Edgewood Arsenal, Maryland 26010

491 Commandant
U.S. Army Chemical Center & School
Micrometeorological Section (Chem. Br.)
1 Fort McClellan, Alabama 36201

492 Commandant
U.S. Army Air Defense School
Attn: C&S Dept. MSL Sci. Div.
1 Fort Bliss, Texas 79916

493 Director
U.S.A. Engr. Waterways Exper. Station
Attn: Research Center Library
2 Vicksburg, Mississippi 39180

495 CG, Deseret Test Center
Attn: STEDO-TT-ME(S) MET Div.
Bldg. 103, Soldiers Circle
1 Fort Douglas, Utah 84113

496 Commanding General
USA CDC Combat Arms Group
1 Ft. Leavenworth, Kansas 66027

497 Commanding Officer
USA Aviation Materiel Lab.
Attn: Technical Director
1 Fort Eustis, Virginia 23604

503 Director
U. S. Army Advanced Matl. Conc. Agcy.
Attn: AMXAM
1 Washington, D.C. 20315

596 Commanding Officer
U. S. Army Combat Dev. Command
Communications-Electronics Agency
1 Fort Monmouth, New Jersey 07703

597 Commandant
U.S. Army Signal School
Attn: Meteorological Department
1 Fort Monmouth, New Jersey 07703

U.S. ARMY ELECTRONICS COMMAND

*604 U. S. Army Liaison Office
MTT. Bldg. 26, Rm. 131
77 Massachusetts Avenue
1 Cambridge, Mass. 02139

605 U. S. Army Liaison Office
MTT-Lincoln Laboratory, Rm. A-210
P. O. Box 73
1 Lexington, Mass. 02173

606 Headquarters
U.S. Army Combat Dev. Command
Attn: CDCLN-EL
1 Fort Belvoir, Virginia 22060

607 Commanding General
U.S. Army Tank-Automotive Command
Attn: AMSTA-Z, Mr. R. McGregor
1 Warren, Michigan 48090

608 USAECOM Liaison Ofc., Stanford Univ.
Solid State Electronics Lab. McCul. Bldg.
1 Stanford, California 94305

613 Chief, Atmos. Sciences Res. Div.
ASL, USAECOM, Attn: AMSEL-BL-RD
1 Fort Huachuca, Arizona 85613

680 Commanding General
U.S. Army Electronics Command
Fort Monmouth, N. J. 07703

1 AMSEL-EW
1 AMSEL-ME-NMP-PS
2 AMSEL-TD-TI
1 AMSEL-RD-MT
1 AMSEL-XL-D
1 AMSEL-NL-D
1 AMSEL-VL-D

*Unclassified, unlimited reports only.
**Or number specified in contract. Add COTR's mail symbol

(5) Commanding Officer
Atmospheric Sciences Lab.
US Army Electronics Command
White Sands Missile Range, N.M. 88002

OTHER RECIPIENTS

504 Commanding General
U. S. Army Materiel Command
Attn: AMCRD-R (H. Cohen)
1 Washington, D.C. 20315

702 Institute of Science and Tech.
The University of Michigan
P. O. Box 618, (Iria Library)
1 Ann Arbor, Michigan 48107

703 NASA Scientific & Tech. Info. Fac.
Attn: Acquisitions Branch (S-AK/DL)
P. O. Box 33
2 College Park, Maryland 20740

707 Target Signature Analysis Cen.
Willow Run Labs-Inst. of Sci & Tech.
Univ. of Michigan, P. O. Box 618
1 Ann Arbor, Michigan 48107

709 Battelle-Defender Info. Center
Battelle Memorial Institute
505 King Avenue
1 Columbus, Ohio 43201

714 Infrared Information & Analysis Center
University of Michigan
Inst. of Science and Tech.
Box 618,
1 Ann Arbor, Michigan 48107

721 Vela Seismic Info. Center
University of Michigan
Box 618
3 Ann Arbor, Michigan 48107

Note: Distribute only unclassified reports to the following addresses. Consider intent of distribution statement.

901 Head, Atmospheric Sciences Sect.
National Science Foundation
1800 G. Street, N.W.
1 Washington, D.C. 20550

902 Director, Systems R&D Service
Federal Aviation Administration
800 Independence Ave., S.W.
1 Washington, D.C. 20590

903 Atmospheric Sciences Library
Environmental Science svcs Admin.
1 Silver Spring, Maryland 20910

904 Div. of Meteorology & National
c/o Air Pollution Control Admin.
3820 Merton Drive
1 Raleigh, N.C. 27609

905 U. S. Department of Agriculture
Attn: William A. Main
University of Minnesota
1 St. Paul, Minnesota 55101

907 Chief, Fallout Studies Branch
Div. of Biology and Medicine
Atomic Energy Commission
1 Washington D.C. 20545

908 NASA Headquarters
Meteorology & Sounding Br. (Code SAM)
Space Applications Programs
1 Washington, D. C. 20546

910 Director
Atmospheric Physics & Chem. Lab R31
ESSA-Department of Commerce
1 Boulder, Colorado 80302

911 Natl. Center for Atmospheric Res.
NCAR Library, Acquisitions-Reports
1 Boulder, Colorado 80302

912 OCE, Bureau of Reclamation
Attn: D755, Bldg. 67
1 Denver, Colorado 80225

913 National Oceanographic Data Cen.
Code 2220
Bldg. 160, WNY
1 Washington, D. C. 20390