



**USAARL Report No. 86-3**

**A COMPARISON OF SPEECH INTELLIGIBILITY  
CHARACTERISTICS FOR EARCUPS INTENDED  
FOR USE IN THE SPH-4 HELMET**

**By  
William R. Nelson  
Ben T. Mozo**

**SENSORY RESEARCH DIVISION**

**March 1986**

**Approved for public release, distribution unlimited.**

**USAARL**

Notice

Qualified requestors

Qualified requestors may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Human volunteer use

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to Army Regulation 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

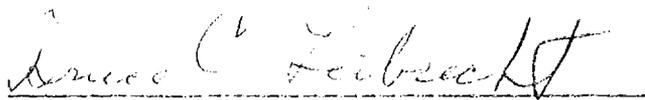
Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

Disclaimer

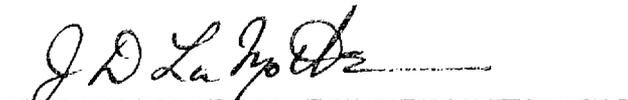
The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:



BRUCE C. LEIBRECHT  
LTC, MS  
Director, Sensory Research  
Division

Released for publication:



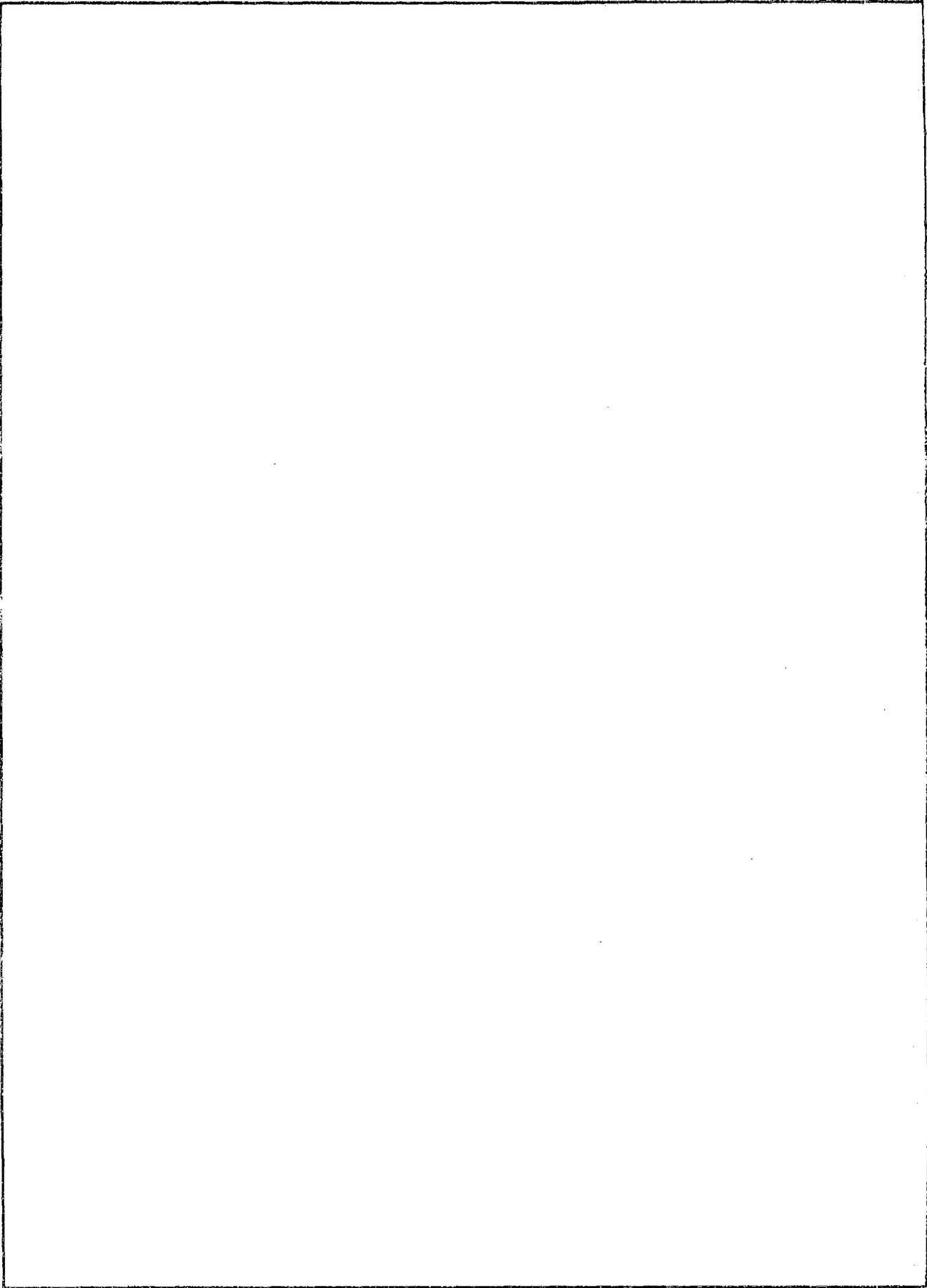
J. D. LAMOTHE, Ph.D.  
COL, MS  
Chairman, Scientific  
Review Committee



DUDLEY R. PRICE  
Colonel, MC  
Commanding

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAARL Report No. 86-3	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Comparison of Speech Intelligibility Characteristics for Earcups Intended for Use in the SPH-4 Helmet	5. TYPE OF REPORT & PERIOD COVERED	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) William R. Nelson and Ben T. Mozo	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Sensory Research Division US Army Aeromedical Research Laboratory Fort Rucker, AL 36362-5000	10. PROGRAM ELEMENT PROJECT, TASK AREA & WORK UNIT NUMBERS 62777A 3E162777A878 AC 135	
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research and Development Command Fort Detrick Frederick, MD 21701-5012	12. REPORT DATE March 1986	
	13. NUMBER OF PAGES 16	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Crushable earcups, Speech intelligibility, Noise, SPH-4, Aviator helmet, Voice communication, MK-1564, Earphones		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Studies at USAARL have demonstrated significant problems with impact protection in the area of the earcup of the SPH-4 aviator helmet. Efforts to develop a crushable earcup that will attenuate impact have resulted in development of two candidate earcups. This study compares the speech intelligibility characteristics of the two prototypes to those of the standard SPH-4 earcup and a proposed replacement earcup identified as the MK-1564. The results indicate that both crushable cups will provide speech intelligibility equal to or better than the standard cup.		

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)



SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

## TABLE OF CONTENTS

	PAGE NO.
List of tables.....	2
List of figures.....	2
Introduction.....	3
Methods and materials.....	3
Results and discussion.....	7
Conclusion and recommendation.....	8
References.....	9
Appendixes	
A. List of equipment manufacturers.....	10

LIST OF FIGURES

TABLE NO.		PAGE NO.
1	Conditions used in the evaluation of speech intelligibility.....	4
2	Octave-band sound pressure level of the simulated UH-60A noise environment.....	5
3	Percent correct responses for experimental listener's conditions, talker using the SPH-4 microphone.....	7
4	Tukey's (HSD) multiple comparison of listener's intelligibility using Alpha = .05.....	8

LIST OF TABLES

FIGURE NO.		PAGE NO.
1	Speech intelligibility test setup.....	6

## INTRODUCTION

The development of the SPH-4 aviator helmet has been recognized as a significant improvement in providing hearing protection and impact absorption for aviation personnel. However, it has been determined that impact protection is compromised significantly in the region of the earcup (Haley et al., 1983). In 1977, USAARL contracted with Simula Incorporated to develop an earcup capable of providing improved impact energy absorption while maintaining sound attenuation equal to or better than that required by the specification for the SPH-4. Sound attenuation results for that effort are reported in USAARL Report No. 84-2. Efforts to identify better and more economical "crushable" earcups have continued. Currently, there are two candidates, one made of aluminum and one made of Cycloc plastic.

Development also has been proceeding on an "improved" conventional earcup for the aviation community, the MK-1564 project. MK-1564 earcups are constructed from hard plastic as are the standard SPH-4 cups, but with different physical dimensions. These earcups were included in this evaluation.

This study focuses on the issue of speech intelligibility (the ability of the aviator to understand oral communication) with the experimental earcups. Recent studies (Mozo and Peters, 1984; and Nelson and Mozo, 1985) have demonstrated the impact of individual components on the overall performance of communications systems in difficult listening situations. The possibility was raised that changing the earcup could degrade the speech communications capability of the SPH-4 helmet. The effects on communications of the three experimental earcups when installed in the SPH-4 aviator helmet were compared to the current SPH-4 earcup.

## METHODS AND MATERIALS

Twelve warrant officers with normal hearing were selected as listeners. They were required to have hearing thresholds for each ear no greater than 20 dB at the seven pure tone test frequencies. Listeners were evaluated for acceptability on a standard clinical audiometer (ANSI S3.6-1969). All listeners were used for each of the test conditions of the intelligibility evaluation.

The parameter of speech intelligibility of interest was the ability of the listener to understand speech while in a noise environment. The listeners wore the SPH-4 helmet fitted with the various earcups as described in Table 1. Speech intelligibility of each test condition was measured using lists of 50 phonetically balanced (PB) words. The lists of words used in this experiment are described in ANSI S3.2-1960 (R1971). A different PB word list was used for each of the four experimental conditions. All speaker conditions used words recorded by the same narrator who was seated in a simulated UH-60A helicopter noise environment. An octave band analysis of the noise spectrum is shown in Table 2. The listeners were required to listen to and transcribe the PB words while subjected to the same simulated background noise.

TABLE 1

CONDITIONS USED IN THE EVALUATION OF SPEECH INTELLIGIBILITY

=====

Test condition	Listener condition	Speaker condition
1	Standard SPH-4 cup	SPH-4 microphone
2	Aluminum crushable	SPH-4 microphone
3	Cyclac crushable	SPH-4 microphone
4	MK-1564 prototype	SPH-4 microphone

=====

TABLE 2

OCTAVE-BAND SOUND PRESSURE LEVEL OF THE  
SIMULATED UH-60A NOISE ENVIRONMENT

=====

Octave-band center frequencies in Hertz

---

63	125	250	500	1K	2K	4K	8K	16K
97	97	98	95	89	88	82	83	80

---

The speech samples used in the experiment were recorded on a Nagra Model IV-SJ\* magnetic tape recorder. Each sample list was reproduced and the output recorded on a Bruel and Kjaer (BK) Type 2307\* graphic level recorder. From the level recordings, the signal intensity was determined and a 1000 Hertz (Hz) calibration tone was placed at the beginning of each list. Each subject was seated in the simulated noise environment during the test. The speech reception threshold (SRT) for each listening condition was determined to be the signal intensity at which a 50 percent correct response to spondee words was obtained under that test condition. All SRT presentations were made using commercially recorded speech samples. The SRT procedure was used to establish a consistent level of speech signal at the listener's ear for all test subjects. The PB word lists were presented through the test earphones at a level 10 dB above his SRT. This allowed an estimate of speech intelligibility for each condition relative to every other condition at equalized listener levels. The order of presentation of the test conditions was fully crossed.

It must be understood that the intelligibility estimates obtained may not represent scores achievable under conditions different from those tested. Since the test environment was a simulated condition, important variables which influence intelligibility could not be included such as stress, heat, competing tasks, vibration, and others.

The instrumentation used to present the PB words is shown in Figure 1. The Hewlett-Packard (HP) Model 239A\* oscillator was used to generate a calibration tone at 1000

-----  
\*See Appendix A

# SPEECH INTELLIGIBILITY TEST SET-UP

9

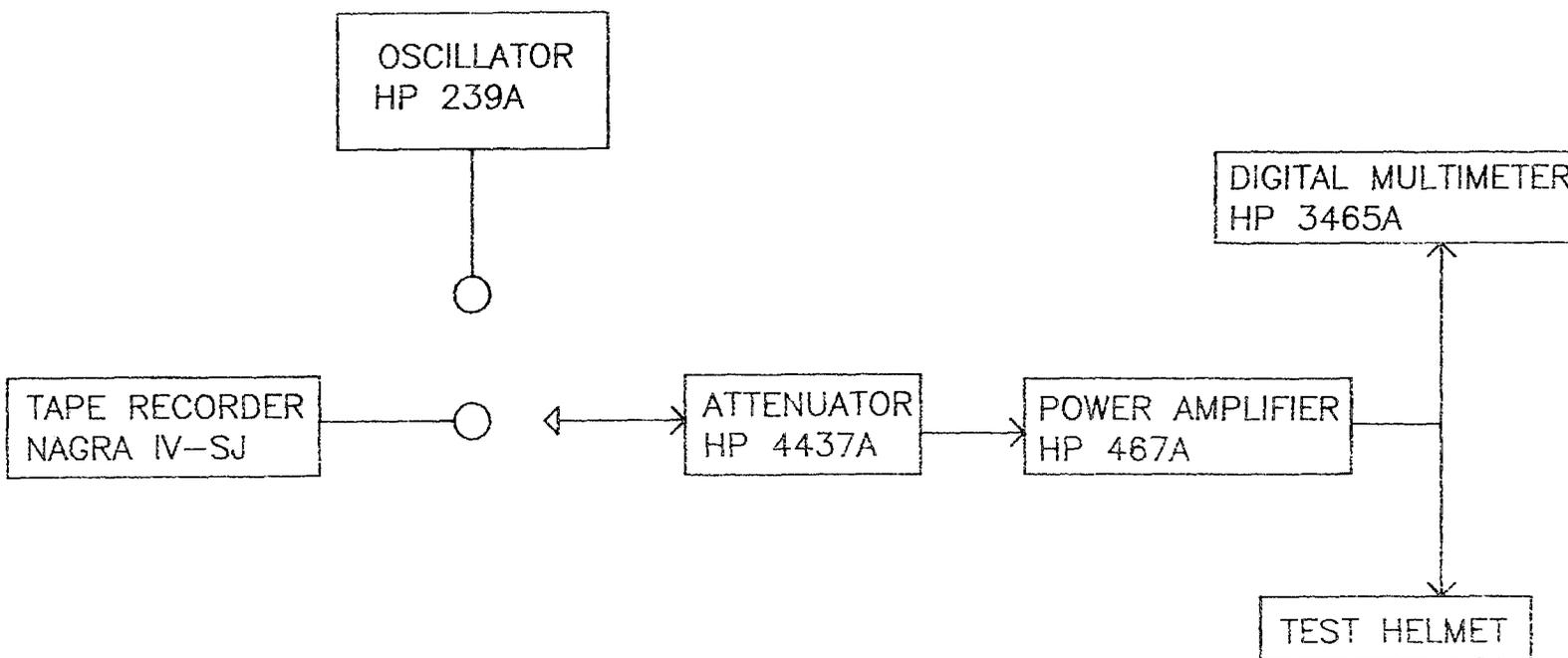


FIGURE 1. Speech intelligibility test setup.

Hertz. The HP Digital Multimeter, Model 3465A\*, was used to set and monitor intensity. The word lists were reproduced using the same Nagra tape recorder specified. The intensity of the signal presented to the listeners was controlled by an HP Attenuator, Model 4437A\*, and an HP Power Amplifier, Model 467A.

## RESULTS AND DISCUSSION

The results of the evaluations are shown in Table 3.

TABLE 3

PERCENT CORRECT RESPONSES FOR EXPERIMENTAL LISTENER'S  
CONDITIONS, TALKER USING THE SPH-4 MICROPHONE

Earcup Test condition	Mean	Standard deviation
Standard SPH-4	55.2	11.10
Aluminum crushable	63.0	6.52
Cycolac crushable	55.7	11.59
MK-1564	47.7	12.03

Table 3 shows a comparison of the average percent correct responses of the listeners for each test condition while the speaker condition was held constant. A repeated measures one-way analysis of variance (ANOVA) as described by Winer (1962) was completed on the listener results. An a priori Type I error rate ( $\alpha$ ) of .05 was selected. The result of this analysis indicates a significant difference exists between the listener conditions ( $F(3,44)=4.23$ ,  $p<.010$ ).

A multiple comparison analysis was run using the Honestly Significant Difference (HSD) method described by Tukey (1949). An ( $\alpha$ ) of .05 was used with 44 degrees of freedom. The result was a Studentized range equal to 3.79 and an HSD value of 11.54. Table 4 contains a comparison of levels of significant differences between the experimental

earcups. The letters represent factor levels which statistically are different from one another. The lowest level or mean is represented by the letter "A," with subsequent letters representing higher levels or means with statistically significant differences. As shown in Table 4, the standard SPH-4 and the Cicolac earcups are grouped together, but overlap both the aluminum and MK-1564, while the aluminum is significantly better than the MK-1564.

TABLE 4

TUKEY'S (HSD) MULTIPLE COMPARISON OF  
LISTENER'S INTELLIGIBILITY USING ALPHA = .05

=====				
TEST CONDITION				
	Standard SPH-4	Aluminum crushable	Cicolac crushable	MK-1564
Level of separation	AB	B	AB	A

CONCLUSION AND RECOMMENDATION

It may be concluded from this study that both the aluminum and cicolac crushable earcups provide as good or better speech communication capability as the standard SPH-4 earcup. Further, the MK-1564 provides significantly less communication capability than the aluminum earcup.

It is recommended that a cost analysis and selection process proceed immediately and that a crushable earcup be made standard for all aviator helmets used by DA personnel.

## REFERENCES

- American National Standards Institute. (R 1971).  
USA standard method for measurement of  
monosyllabic word intelligibility. S3.2-1960.
- American National Standards Institute. (R 1973).  
American national standard specifications  
for audiometers. S3.6-1969.
- Haley Jr., Joseph L., Shanahan, Dennis F., Reading,  
Thomas E., and Knapp, Stanley C. 1983. Head  
impact hazards in helicopter operations and  
their mitigation through improved helmet  
design. Impact injury of the head and spine,  
18:549-577.
- Mozo, B.T. and Peters, Leslie J. 1984. Effects of  
chemical protective and oxygen masks on attenuation  
and intelligibility when worn with the SPH-4 helmet.  
Fort Rucker, AL: US Army Aeromedical Research  
Laboratory. USAARL Report No. 84-5.
- Nelson, William R. and Mozo, Ben T. 1985. Effects of  
XM-40 chemical protective mask on real-ear attenuation  
and speech intelligibility characteristics of the SPH-4  
aviator helmet. Fort Rucker, AL: US Army Aeromedical  
Research Laboratory. USAARL Report No. 85-2.
- Tukey, J.W. 1949. Comparing individual means in the  
analysis of variance. Biometrics. 5:99-114.
- Winer, B.J. 1962. Statistical principles in experimental  
design. New York: McGraw-Hill.

APPENDIX A

LIST OF EQUIPMENT MANUFACTURERS

Bruel and Kjaer Instruments, Inc.  
9047-A Gaither Road  
Gaithersburg, MD 20760

Borg-Warner Corporation  
200 S. Michigan  
Chicago, IL 60604

Hewlett-Packard  
P.O. Box 28234  
450 Interstate North  
Atlanta, GA 30328