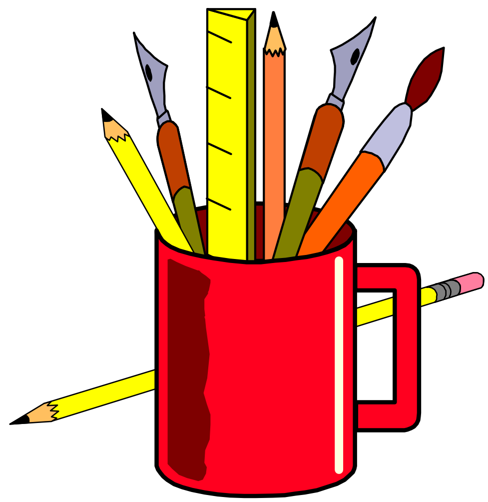
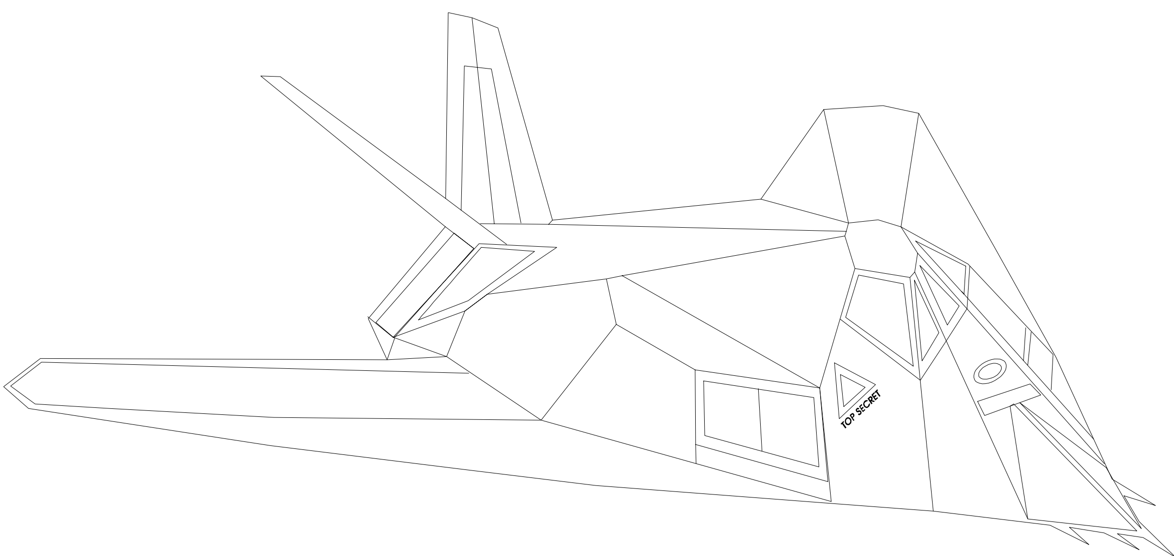
TECHNICAL COMMUNICATION GUIDE FOR ENGINEERING DIVISION COURSES





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INTRODUCTION

Good technical writing skills are critical to success in the Air Force. Nearly all of the writing done in an official capacity is technical. Unlike the literate and rhetorical writing taught in core courses, technical writing is highly specific. Its purpose is to convey factual information as clearly and unequivocally as possible. There is little room for "interesting" prose in technical writing. The writer must get to point as quickly as possible, developing only pertinent information that contributes to the reader's understanding of the material at hand.

Technical writing requires a no-nonsense, direct and to-the-point approach. This necessitates a fundamental set of rules and practices for technical writing that are nearly inviolable. While individual academic departments stipulate differences in format and grading emphasis, there are sets of technical writing rules that remain constant across all technical disciplines. Neglecting format differences, expect to apply the concepts outlined here to writing and presentation assignments in every engineering and basic science course.

This manual outlines those common rules and offers context for their use with examples from a range of scientific and engineering areas. General principles of technical writing are covered, followed by a systematic approach for completing a technical project and reporting on it. Common technical writing issues are presented, with typical problems and solutions discussed. A "Levels of Performance" section outlines the factors that comprise excellent, satisfactory and deficient technical writing. Requirements for formal reports, technical presentations and laboratory reports are each treated in detail, with examples and suggestions for each. Separate format requirements from some engineering departments complete the document.

GENERAL PRINCIPLES

Technical writing follows the same rules of grammar and sentence structure as prose writing and must effectively communicate your results to the reader. Technical writing always:

1. Conveys information accurately and concisely.

2. Is factual and specific--not open to interpretation.

3. Presents conclusions/recommendations based on the facts presented.

4. Employs concrete and concise language.

5. Uses a specialized vocabulary that demands precision (e.g. force and pressure are not the same to an engineer).

6. Uses active voice where possible.

7. Addresses a specific audience.

8. Tells the reader the exact purpose of the report in the Introduction.

9. Presents the information accurately and clearly.

10. Follows the standard format.

Professional Appearance

Format, appearance, spelling, grammar, topic transitions, and topic continuity are all essential in developing a professional report and reflect directly upon the author and the organization representing the work. Keep within the standard margins of one inch all around. Always bind the report with at least a staple unless otherwise instructed. Always spell check the report.

Writing Style

Never use personal pronouns. Write as actively as possible. Active writing takes up less space and is more interesting to read. Keep the audience in mind when writing a technical report, and avoid jargon and clichés. For example, for a report submitted to an Engineering Division instructor, assume general technical proficiency but not familiarity with the project. In other words, write the report in technical terms, but be sure to explain ideas/concepts specific to the project or subdiscipline.

A SYSTEMATIC APPROACH

Many excellent texts exist on technical writing (see section T11 x.xx on the sixth floor of the USAF Academy Library) and they all come to the same conclusion--a systematic approach is required to produce good technical writing. One successful approach is to divide the writing process into five major steps: 1) preparation, 2) research, 3) organization, 4) writing the draft, and 5) revision. Each of the steps is discussed below.

Preparation

Preparation consists of establishing the objective, identifying the reader, and determining the scope of coverage. In general, each instructor will establish the objective. Make sure to understand it completely. Determine the scope by keeping the objective and the reader in mind. Assume the reader is familiar with the subject but may have forgotten many of the details. Clearly defining the scope reduces time wasted gathering and reporting useless information.

Research

Research is the most time intensive step in technical writing. Data gathering and analysis are the real challenges in preparing technical reports. This phase is usually the most enjoyable and rewarding, but it is only a part of the job. Possible research sources are course material, experiments, computational, analytical and design studies, the library, interviews, and individual knowledge. Consider them all and use those that fit both the writer's needs and time constraints. For some reports, research may only consist of reviewing concepts in course texts and class notes and then applying them to a new situation. A more typical report will involve many types of sources. The Internet is a possible source, but always remember information on the web is not reviewed, and may not be correct or authoritative. Think about how to organize the research as it is gathered.

Organization

Organization is vital to presenting any type of information. A method must be chosen in order to organize effectively. Some different methods used in technical writing are chronological, sequential, spatial, increasing order of importance, comparison, analysis, general to specific, and cause and effect. Reference 9 has examples of these different methods of development. Choose the method that best fits the subject, objective, and reader. Some subjects obviously fit a particular method of development. To describe the procedures to perform a tensile test, for example, the sequential method is the best choice. Outlining a plan of development before starting the draft will make the report easier to write and understand.

Writing the Draft

Writing the draft is surprisingly easy if the first three steps have been done. Concentrate on ideas! In other words, don't polish or revise, or worry about grammar and spelling, but instead get ideas on the paper. Once this is done, then revise.

Revision

Revising the report makes it clearer and more professional. Evaluate the report from the point of view of the reader. Be anxious to find and correct faults. Allow time to do the revision. ***Proofread! Spellcheck!*** However, don't proofread immediately after writing the report. Writing that looks acceptable at midnight may not look as good the next day. Some items to check for include:[9]

1. Accuracy and completeness.

2. Unity--all sentences of a paragraph contribute to the paragraph's central idea.

3. Coherence--all sentences and paragraphs flow smoothly from one to the next.

4. Clarity--avoid ambiguity and jargon, but do use proper scientific terminology.

5. Conciseness--eliminate useless words and phrases.

6. Awkward sentences and tone--try reading the draft aloud, awkward sentences will sound forced or clumsy.

7. Grammar, spelling, punctuation, format--proper use will greatly contribute to a professional report.

COMMON TECHNICAL WRITING ISSUES, PROBLEMS, AND CORRECTIONS

There are numerous problems that occur in technical writing. Keeping the following in mind during the composition process will reduce these errors. Always:

1. Employ a gender-neutral style - write without using "he" or "she".

2. Always begin with an outline. Include some of this outline in the report headings and sub-headings.

3. Establish report milestones - specific dates when report sections will be complete.

4. Define and write to specific audience(s).

5. Write easy report parts first.

6. Write in an active, direct manner.

8. Cite **ALL** sources (personal contacts, web sources, written sources, etc.).

Items to Avoid:

1. Long, rambling, involved sentences;

2. Weak sentence beginnings (pronouns such as it, etc.);

3. Long, complicated paragraphs, especially ones dealing with multiple topics;

4. Short sketchy paragraphs;

5. Unnecessary repetition of words, sentence structure, ideas;

6. Omission of words such as because, since, but, although;

7. Use of the word 'that';

8. Use of vernacular, technical shorthand, and general terms;

9. Mixing verb tenses unnecessarily.

<u>Active Vs Passive Voice</u>

The difference between active and passive voice is simple. The voice of a verb tells the reader if the subject performs an action, in active voice, or receives an action, in passive voice. Applying this in technical writing can be challenging. The combination of technical writing and active voice will make the report easier to read and more understandable. It is almost impossible to compose an entire technical report in active voice. This is particularly difficult if first person is not allowed, as some departments stipulate. The best practice is to use active voice where possible to create simpler, more concise sentences.

Common passive voice statements found in technical writing (note the presence of the verb *to be*):

1. The experiments were performed in the Low Speed Wind Tunnel at the USAF Academy Aeronautics Laboratory.
2. Pressure measurements were obtained for all angle of attack values.
3. Satellite power fluctuations were measured each second during the mission.

Common active voice statements found in technical writing (note the lack of the verb *to be*):

1. The resistor controlled the feedback circuit.
2. The beam fractured under ten pounds maximum load.
3. The unmanned combat air vehicle (UCAV) performed best at subsonic speeds.

Examples of conversion from passive to active voice:

1. Passive: The airflow over the delta wing was controlled using piezoelectric actuators.
   Active: Piezoelectric actuators controlled the airflow over the delta wing.
2. Passive: The hybrid automobile was powered by a diesel engine and an electric motor.
   Active: A diesel engine and electric motor powered the hybrid automobile.

First Person Vs Third Person

It is generally more accepted in technical writing to use third person. For example, instead of writing "I fractured the beam under ten pounds of pressure." write "The beam fractured under ten pounds of pressure." NEVER use the second person, *you*, in technical writing. Each department or instructor will specify whether first or third person is to be used. The default should be third person.

Verb Tense

The correct verb tense selection can at times be confusing. The formal report section of this guide gives a suggested tense for each section. A common error in technical writing is to switch tenses in the same section, sometimes in the same paragraph. First and foremost, apply the same tense throughout the entire section of the report.

NUMBERS, EQUATIONS, TABLES, AND FIGURES

Numbers, equations, tables, and figures are crucial to most technical writing and appear extensively. Properly presented, they can significantly increase the report's effectiveness.

Numbers

1. Numbers are the language of the technical writer. Use commonly accepted conventions for a quantity.[1]

2. Numbers ten and under and rounded-off large numbers are written as words; e.g., *six bolts* or *about a thousand cadets*. One exception is when using numbers with technical units of measurement, e.g., *5 ksi* or *2000 rpm*. Another is page, figure, or table numbers.

3. For a series of quantities the larger number determines whether words or figures are used; e.g., *there are 3 months and 16 days until graduation*, **not** *there are three months and 16 days until graduation.*

4. A sentence should not begin with a number unless it is spelled out; e.g., *Seven rivets connect the stringer to the aircraft skin*. If the number is "cumbersome", rearrange the sentence; e.g., *There are 213 rivets connecting the stringers to the skin*.

5. In compound number adjectives, spell out the first number to avoid confusion; e.g., *thirty 18-inch longerons*.

6. Don't spell out numbers as words for dates, times, or exact sums of money.

7. Decimal numbers less than one should be represented with a leading zero, for example, as *0.2* instead of *.2*.

8. The number of digits presented in a number should reflect its accuracy; e.g., *The compressive yield stress of 2024-T42 aluminum sheet is 38 ksi* instead of *38.0453 ksi.*[2] Use several digits only if the accuracy of the measurement warrants it.

9. Always include units where applicable.

Equations

Equations can be a concise and effective way to present a concept. Number and center equations with sufficient space on the top and bottom for easy reading. Refer to the equation by number in the text. For example, see Eqn (1). Define symbols immediately following the equation unless they are already defined in the Lists of Symbols/Abbreviations.

$$F = \frac{\pi^2 E_c}{\left(L'/\rho\right)^2}\eta \tag{1}$$

Tables

Tables are an excellent method to present repetitive and quantitative results. Table 1 comes from Hallauer's article.[3] Could this much information be conveyed as clearly with just a paragraph of text? Carefully consider whether a graph or a table best presents the data. Tables should be introduced and discussed in the text. In addition, they must be titled and numbered, as shown in Table 1. Include units in the column (or row) headings. Remember, tables are titled ***above*** the information presented, while figures are titled ***below*** the information.

TABLE 1. Plane Grid Natural Frequencies.[3]

Structure Mode	Experimental Natural Frequency (Hz)	Theoretical Natural Frequency (Hz)	Percent Difference from Theory
1	0.60	0.60	0.00
2	0.95	0.96	1.05
3	1.44	1.43	-0.70
4	3.42	3.40	-0.59
5	3.65	3.72	1.88

Figures

Figures include photographs, drawings, and graphs. A photograph or drawing of the lab equipment used in an experiment is easier to understand than a verbal description ***alone***. Figures must be introduced and discussed in the text in sufficient detail to indicate figure importance and lessons learned. Many types of drawings are possible and drawings from other sources can even be used, with proper documentation. Figure 1 presents a great deal of information concisely.[4] Additionally, an exploded view of a figure could be an effective way to describe a small yet important detailed area.

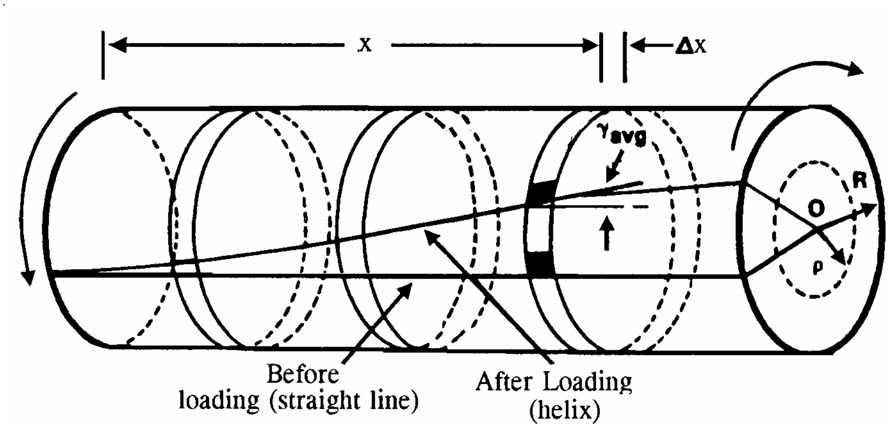


FIGURE 1. Deformation of a Solid Shaft by Twisting.[4]

X-Y graphs are another common method to convey technical information concisely, as shown in Figure 2.[5] Graphs must be computer generated. Other types of graphs can be used, (e.g., pie charts, bar graphs, etc.) You should follow this checklist when preparing a graph:

1. The graph should stand alone and be neat.

2. Title the graph as shown in Figure 2.

3. Label the axes with name or symbol, and units of the parameter being plotted. Clearly mark and label the increments. Ensure all labels and data points are large enough to be easily read.

4. Plot data points and use different symbols for different parameters or trials. Indicate uncertainty in the data, if quantifiable.

5. Use a computer to generate the graph. Ensure the curve fit is not misleading to the reader.

6. Reference any source used for the figures and tables.

7. Make sure the data presented is in the intended format and has the correct units.

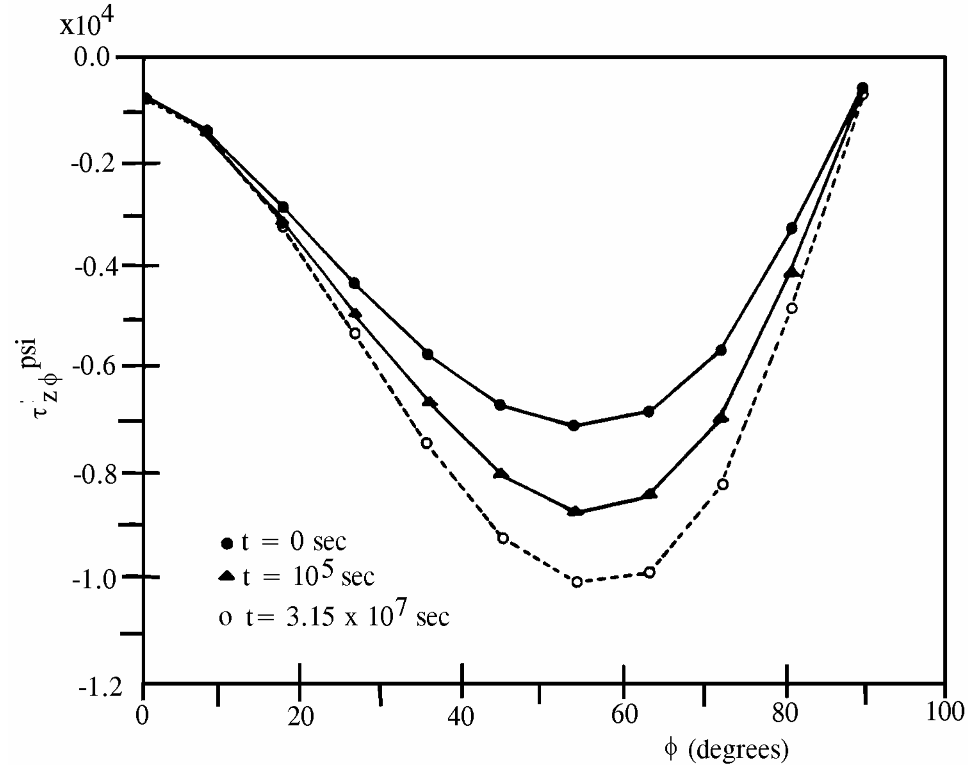


FIGURE 2. Interlaminar Shear Stress $\tau_{z\phi}$ at the Ply Interface in a (0/90) Laminate.[4]

CONCLUSIONS

This technical writing guide provides:

1. Several general principles of technical writing.

2. Report and presentation format requirements for all Engineering courses, and appendices describing the elements of technical reports and presentations.

3. A description of the proper use of numbers, equations, tables, and figures.

4. Suggestions to improve your technical writing.

5. Specific format guidance from aeronautical, mechanical, and electrical engineering.

Use this guide for all Engineering courses. Listen to each instructor and read the course policy letter for exceptions and additional guidance. Make an effort to improve technical writing skills on each assignment. Remember this takes more then one draft! The writing skills developed at the USAF Academy will be important in each Air Force career.

LEVELS OF PERFORMANCE FOR USAFA TECHNICAL WRITING

(Based on USAFA Effective Writing Standards and Levels of Performance)

I. CONTENT

Excellent:

- Meets the assignment. Is consistently clear and concise.
- Reasoning is consistently logical.
- Background and objectives cover all necessary points.
- Results are clearly compared with those in the literature and theory. No gaps in argument or evidence, and the reliability of results is accurately addressed. Makes a substantial argument.
- Conclusion follows directly from the evidence.

Satisfactory:

- Generally follows the assignment requirements. Some parts are unclear. Leaves the impression the writer does not understand some portions of the theory, experimentation, computational development, etc.
- Background is incomplete, but the reasoning is understandable. Results are not adequately compared with previous results. Facts or other supporting evidence are accurate, but there are gaps in argument or evidence.
- Reliability of results is not assessed adequately, but the argument is satisfactory. Conclusion is loosely connected to the evidence.

Deficient:

- Does not meet the assignment. Is generally unclear.
- Does not meet the stated objectives. Little apparent reasoning.
- Ignores opposing or alternative views.
- Facts or statements are inaccurate.
- Validity of data or results is not addressed. Serious gaps in argument or evidence. Makes a weak or pointless argument.
- Conclusion is unrelated or poorly related to the evidence.

II. ORGANIZATION

Excellent:

- Main ideas are clear. Thesis is presented early in the paper.
- Paragraphs are unified around a central idea. Entire paper is well integrated and unified. The reader can follow the paper.
- Connections (transitions) between paragraphs are consistently clear. Figures and tables are clearly integrated into the text.
- Supplementary information is in the appendices.

Satisfactory:

- Main ideas are generally clear. Thesis is presented before the discussion.
- Some paragraphs are unified around a central idea. Paper generally does not digress.
- Transitions between paragraphs are usually clear. The significance of figures and tables is not always clear.

Deficient:

- Unsure of main ideas. Thesis is vague or missing. Paragraphs are randomly organized.
- Paper is seriously disconnected. No transitions are apparent. Figures and tables are inappropriate. Material belonging in the report is in the appendices.
- Supportive material is missing.

III. STYLE & MECHANICS

Excellent:

- Uses words correctly. Is in the standard English idiomatic pattern.
- Is free of clichés. Wording is concise. Language is exact and appropriate. No first person is used. Includes jargon, but it is fully explained in context.
- Document has been spell-checked. Active voice is used where appropriate.
- All figures and tables are in the proper format.

Satisfactory:

- Misuses some words. Some lapses from standard English. Occasional use of clichés.
- Wording rambles in places. Occasional lapses in language use.
- Occasional use of first person. Uses a limited amount of unexplained jargon.
- A few spelling errors. Passive voice is sometimes used where active voice could be.
- Some figures and tables are in the proper format.

Deficient:

- Misuses many words. Is not in standard English. Is riddled with clichés.
- Needless repetition. Language is inexact, vague, ambiguous, illogical, inappropriate, or has unintended meaning. Is filled with unexplained jargon.
- First person is prevalent. Numerous misspelled words. Passive voice is prevalent.
- Figures and tables are incorrectly formatted.

IV. SENTENCE STRUCTURE

Excellent:

- No unintentional sentence fragments. Parallel sentence parts. No needless sentence splits.
- No shifts in subject, tense, voice, or person from clause to clause or sentence to sentence.
- Clear pronoun references. Voice appropriate to argument. Use of connectives (so, as, then, therefore) is correct and logical.
- Important ideas are in independent clauses. Coherence within and between sentences. No comma splices or run-on sentences. Sentence patterns vary appropriately.
- No needless use of the verb "to be."

Satisfactory:

- Few unintentional sentence fragments. Most sentences are parallel. Few needless sentence splits (such as dangling modifiers).
- Few shifts in subject, tense, voice, or person from clause to clause or sentence to sentence. Few pronoun references are unclear.
- Some needless use of the passive voice. Use of connectives (so, as, then, therefore) is generally correct and logical. Most important ideas are in independent clauses.
- Occasional lack of coherence within or between sentences. Few comma splices or run-on sentences.
- Little variety among sentence patterns. Some needless use of the verb "to be."

Deficient:

- Several unintentional sentence fragments. Faulty parallelism throughout the paper. Several needless sentence splits (such as dangling modifiers).
- Many shifts in subject, tense, voice, or person from clause to clause or sentence to sentence. Many pronoun references are unclear. Frequent needless use of the passive voice.
- Use of connectives (so, as, then, therefore) is incorrect or illogical. Many important ideas are in subordinate clauses. Frequent lack of coherence within or between sentences.
- Several comma splices or run-on sentences. Sentence patterns are obviously repetitive. Frequent needless use of the verb "to be."

V. DOCUMENTATION AND FORMAT

Excellent:

- All borrowings cited in text. Borrowed material presented in proper format.
- Borrowed material framed for credibility. Clear transitions between borrowed and original ideas. Other types of assistance acknowledged appropriately.
- Paper layout according to appropriate stylesheet.

Satisfactory:

- All borrowings cited in text. Few errors with format of borrowed material.
- Frames of borrowed material are mechanical or fail to add credibility. Transitions between borrowed and original ideas are awkward.
- Other types of assistance acknowledged appropriately.
- Paper layout generally follows appropriate stylesheet.

Deficient:

- Borrowings not cited in text. Frequent errors with format of borrowed material.
- Borrowed material not framed.
- No clear transitions between borrowed and original ideas. Other types of assistance not acknowledged.
- Paper layout random.

THE FORMAL REPORT

REPORT REQUIREMENTS

Formal reports include:

1. **Title Page** - include report title, course, instructor, cadet name(s), section, and date.
2. **Abstract**
3. **Table of Contents**
4. **List of Tables and Figures**
5. **Nomenclature List**
6. **Introduction**
7. **Experimental Methods**
8. **Results and Discussion**
9. **Conclusions**
10. **Recommendations**
11. **References**
12. **Appendices**

Use a computer to complete all formal reports. Prepare all equations and figures using a computer. Space the body of the report as directed by the instructor. Use double space as the default. Note the examples in this report are single spaced to save paper. Margins are one inch on all sides unless otherwise directed. Use 12-point, Times New Roman fonts unless otherwise instructed. Bind the report with at least a staple.

ELEMENTS OF THE REPORT

Each part of the formal report serves a specific purpose and must cover particular items. The following information acts as a guideline for both the necessary content and the accepted format for each section. An example of each section is provided as a reference. The examples are not complete, but give an idea of the writing style and content expected in the section. Material for the examples comes from a report by Fritzinger and Keeton.[1] The reader must consider that certain aspects of the report will be slightly different depending on the subject material covered.

Abstract:

Purpose: The abstract is a condensed version of the entire report. The abstract succinctly tells the nature of the problem, how it is investigated, and what the significant results and conclusions are. The abstract should contain only essential material and should always be limited to one double spaced page, about 100 to 250 words. The abstract must stand alone, since it is frequently the determinant for whether the reader continues with the rest of the report. It is the first item of the report, placed on a separate page following the title page so it is easy for the reader to find. Include three key words or short phrases below the abstract which index the most important report topics.

Tense: Present tense.

Example:

The vortex flow above the wing and body of the F-15 aircraft is investigated, with particular emphasis on the vortex-tail interactions. Vortex impingement on the vertical tail is a topic of current interest due to the extended time the tails interact with the vortical flows during high angle of attack maneuvers. Subsequent vortex impingement on the tails causes buffeting and fatigue, reducing total flight time of the tails by 60% and limiting controllability. Laser-light sheet flow visualization in a water tunnel is compared with hot-film velocity and turbulence intensity information obtained in a wind tunnel. A 1/48 th scale F-15 model is used in both experiments. Extensive analyses of vortex development, trajectories, and breakdown are provided. Results show the longitudinal vortices developing at the forebody-engine inlet junction. The vortices burst and become turbulent at moderate to high angles of attack, between 15° - 25°. This significantly expands the region of influence from the vortices. Highly turbulent flow, up to 75% at 25° angle of attack, interacts with the vertical tails.

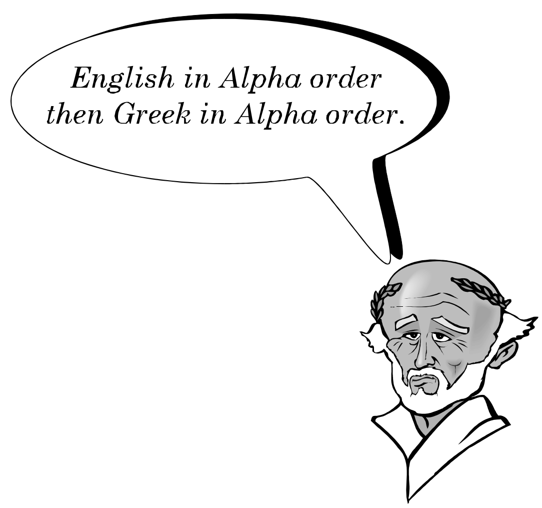
Key Words: F-15, Vortex Impingement, Buffet

<u>Nomenclature List:</u>

Purpose: The nomenclature list defines ALL symbols and abbreviations. The list is given in alphabetical order, with Greek symbols last. Define any equations (see C_L and ρ below). Include every variable used in the report, even if it should be obvious to the reader. Also include the units where applicable. It is not necessary to repeat definitions in the report body if a nomenclature list is provided.

Example:

b	Wing span, ft
C_L	Lift Coefficient, $\frac{L}{1/2 \rho V^2 S}$
D	Drag, lbf
L	Lift, lbf
P_∞	Atmospheric Pressure, psi
R	Ideal Gas Constant
S	Surface Area, ft^2
T_i	Turbulence Intensity (See equation 1)
T_∞	Atmospheric Temperature, °R
u_i	Instantaneous velocity value
V_∞	Freestream Velocity, ft/sec
y	Distance along span
z	Vertical distance
ρ	Atmospheric Density, $P_\infty/R\,T_\infty$



Introduction

Purpose: The Introduction must present the report's subject, objective, scope, and organization succinctly. The nature of the problem details the who, how, what, why, and when of the investigation. Support the new, current work with relevant historical background and theoretical references leading to motivation for the present study. This could include theoretical, computational, or experimental work. The last paragraph or two of the introduction covers the objective and basic overview of the current work. The examples given in this guide are for an experimental investigation.

Theoretical Background

Theoretical Background discusses physical and mathematical concepts, not experiments.

Purpose: Support the report with any applicable theoretical material. Endorse report relevance with theoretical explanations, such as vortex theory, thermodynamics, electromagnetics, etc. Leave the specific theoretical concepts used to explain results for the Results and Discussion section. All other background theory designed to lay the groundwork for the reader must be included here. Summarize previous work. Do not use quotations; rather summarize the information succinctly. Reference all work appropriately.

Tense: Present tense.

Example:

Note: Only use a separate theoretical background section if there is specific theory to discuss. Most reports will not have this section.

Combat aircraft at high angles of attack experience unsteady vortex flows, causing problems in tail buffeting and lateral instability. Anderson defines vortex flow as a flow where all the streamlines are concentric circles about a given point.[2] The velocity along the circular streamlines is constant, yet varies from one streamline to another inversely with distance from the common center. Vortex flow makes a positive contribution to lift by increasing the induced lift for a delta wing by energizing the upper surface of the upper surface boundary layer. The vortex flow is created when the boundary layer on the lower wing surface flows outward and separates as it travels over the leading edge, forming a separated shear layer. The shear layer curves upward and inboard, rolling into a core of high vorticity. There is an appreciable axial component of motion and the fluid spirals around and along the axis. The size and strength of the coiled vortex sheets increase with increasing incidence angle until they eventually become dominant features of the flow. This vortex development is responsible for the unsteady aerodynamic characteristics that exist over the practical angle of attack range.[3]

On the F-15 aircraft, the leading edge glove attached to the inlet of the aircraft acts as a flat plate. The flow separates immediately at this inboard location, forming a vortex flow as a result. As this vortical flow moves downstream, it encounters an area of low pressure. This region develops as a result of the separation of the streamlines of the vortical flow. Further downstream, the vortex flow loses energy and the vortices burst when the stable vortex breaks down. The angular velocity of the vortex decreases, allowing the vortical flow to spatially expand. Once the angle of attack becomes sufficiently large the point of vortex breakdown progresses ahead of the wing trailing edge and the vortex flow effects become adverse. When breakdown and expansion occur upstream of the aircraft's vertical tail, the tail is immersed in a vortical flow of large radius. This phenomenon results in the buffeting and fatigue in the twin tails of the F-15.

Experimental Background

Experimental Background supports the current work with past research. Work may also be computational.

Purpose: The Experimental Background portion of the Introduction succinctly summarizes all previous relevant research supporting the current work. All pertinent supporting literature associated with the work being presented is discussed and referenced appropriately. The technical writer supports the importance of the current work by showing progression through past research up to the current objectives. A completely new project is rare, and the writer should be able to find related topics in the literature.

Tense: Discuss supporting literature in past tense.
Introduce current research in present tense in a separate paragraph.

Include the motivation for the work. Why is this research important?

Example:

Recently combat aircraft maneuvers have evolved to where the time spent at high angles of attack have become a substantial fraction of the total flying hours. Consequently, vibration-free control and long fatigue life under such conditions have become crucial issues, and the emphasis on twin-tail buffeting has increased. Twin tailed fighter aircraft such as the F-15 and F/A-18 have exhibited susceptibility to buffeting and lateral instability at high angles of attack. The source of this buffeting has been previously determined to be the unsteady vortical flow impinging on the vertical tails.[4] Considerable research has been done into the longitudinal vortex-vertical tail interaction. Komerath, et al,[5] conducted a quantitative study concerning the low-speed flow characteristics of scale models of twin-tailed fighter aircraft at moderate to high angles of attack. Similar to the analysis discussed in this paper, laser-light sheet flow visualization was employed to determine the source and evolution of these vortex flows. A concentrated vortex was not present at the tails. On the contrary, the vertical tails were immersed in a large radius vortical flow. Triplett[6] coupled the buffeting pressures to this detached vortical flow from the wing-body. These buffeting pressures were encountered during high angle of attack maneuvers and caused high-frequency tail oscillations. An experimental parametric study of vertical tail location and its effect on the vortex trajectory was explored by Washburn, Jenkins, and Ferman.[7] The location of the tail did not affect the trajectory of the longitudinal vortex, but it did affect the location of the vortex breakdown and the fin buffeting levels.

The last paragraph of the introduction should be a brief summary of the current work, in present tense.

This study uses hot-film anemometry to evaluate the vortex - vertical tail interaction on the F-15E. Special emphasis is placed on determining vortex initiation and development characteristics, and the aerodynamic parameters governing tail buffet intensities.

Note: The theoretical and experimental background can be combined if it makes sense for a partcular report.

Experimental Methods

Purpose: The equipment and procedures used to obtain the data or run the computer code discussed in the report must be detailed thoroughly. Include all information regarding test configuration, equipment models where appropriate, test conditions, data acquisition hardware and software, sample rates and sizes, computational codes applied, calibration information, and uncertainty analysis procedures and results. Clearly state and support any assumptions and approximations. The detail must be sufficient enough such that the reader can recreate the experiment.

Tense: Past tense.

Include uncertainty values as appropriate

Example:

All velocity data were obtained in the low-speed wind tunnel located in the Aeronautics Laboratory at the U.S. Air Force Academy. The tunnel freestream turbulence intensity level was 0.5%. All tests were run at a tunnel velocity of 50 ft/sec ± 0.5%, corresponding to a chord Reynolds number of 3.5×10^4. The model, a 1/48th scale F-15E, was mounted on a rigid sting as indicated in Figure 1. Three angles of attack, 15°, 20°, and 25°, were used for the experiments discussed.

Automated hot-film anemometry measurements gave both mean and fluctuating components of the velocities at various locations along the model. Data was collected using the IFA-100 Intelligent Flow Analyzer in conjunction with a Keithley 500 data acquisition system. A data file containing a 4” x 4” grid at 0.2” ± 0.1% increments was input into the Keithley, which both controlled the automatic traverse and obtained the velocity measurements. This yielded 256 point measurements at each of two measurement locations, 52% and 76% span. The hot-film sensor was calibrated using the known wind tunnel velocities across the velocity magnitudes of interest. Both the mean and fluctuating components of the velocity were taken at each point. A sample calibration graph can be found in Appendix A. Contour plots of both velocity magnitude and turbulence intensity were created using Surfer Grid Software.

Put supplementary information in an appendix

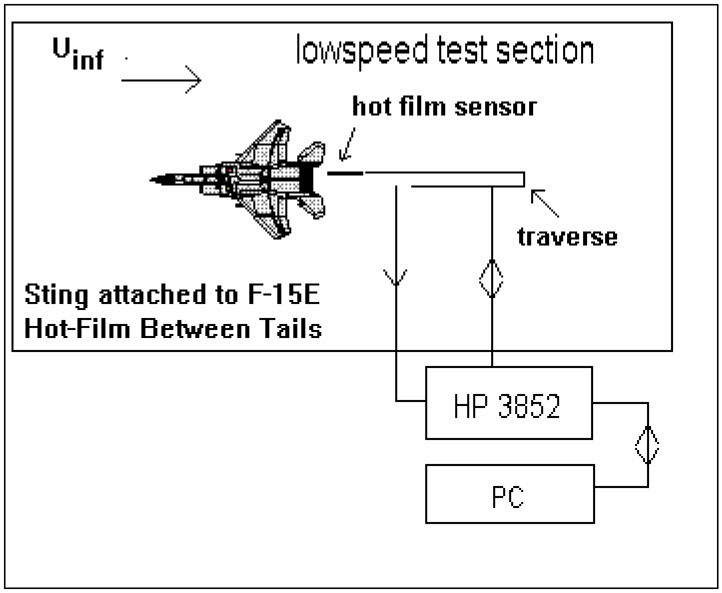


Figure label is in bold and centered below the figure.

Figure 1. Wind Tunnel Experimental Setup.

<u>Results and Discussion</u>

Purpose: This section comprises the bulk of the report. Present results in a detailed and succinct manner, including additional explanations as necessary. Compare results to theory or other available data to discuss significant findings or differences, breaking the section into sub-headings as necessary for clarity. Interpret key figures and tables for the reader, pointing out key results leading to conclusions. Include these key figures and tables within the Results and Discussion section. Place additional information, figures, and calculations not discussed in the final report in the appendices. Be specific when referring to data in the appendices, including the appendix distinction and the page number so the reader can easily find the reference. This example is used by permission from the authors (Guy, Morrow, and McLaughlin).[8]

Tense: Present tense.

Include a brief overview of the topics discussed at the beginning of the Results/Discussion section.

Example:

Experiments examine the effects of the frequency and of the oscillatory momentum coefficient on the flow over the delta wing. The possible optimum operating point of the flow actuator is also determined.

Clearly introduce each Figure. **TALK ABOUT THE RESULTS OF EACH FIGURE IN THE TEXT.**

The effect of the frequency on the local velocity is presented in Figure 3, where the ratio of the local velocities with and without periodic blowing and suction is plotted against the nondimensional frequency F^+, for constant values of the oscillatory momentum coefficient C_μ. An optimum range of the nondimensional frequency is evident, $1.2<F^+<1.4$, where the effect of the periodic blowing and suction is maximized. This nondimensional frequency corresponds to $0.71<TU_\infty/C<0.83$. In other words, the optimum period of the periodic blowing and suction corresponds to just less than one convective time scale. A maximum fourfold velocity increase was obtained at this point, at maximum C_μ.

The effect of the momentum coefficient is presented in Figure 4. The ratio of the local velocities with and without periodic blowing and suction is plotted against the momentum coefficient for constant values of the nondimensional frequency. A monotonic increase of the local velocity is observed as the momentum coefficient increases. The effect of the periodic excitation reaches its maximum value at $C_\mu=0.0045$.

Explain/describe the key results in each figure. Do not expect the figure to "speak for itself."

It is of interest to compare these results with the results of Gu et al[9], where the effect of periodic blowing and suction tangential to the blunt leading edge of a delta wing was investigated. They found that $F^+=1.3$ and $C_\mu=0.0036$ are the most effective in delaying vortex breakdown.

Compare current results with past results if applicable.

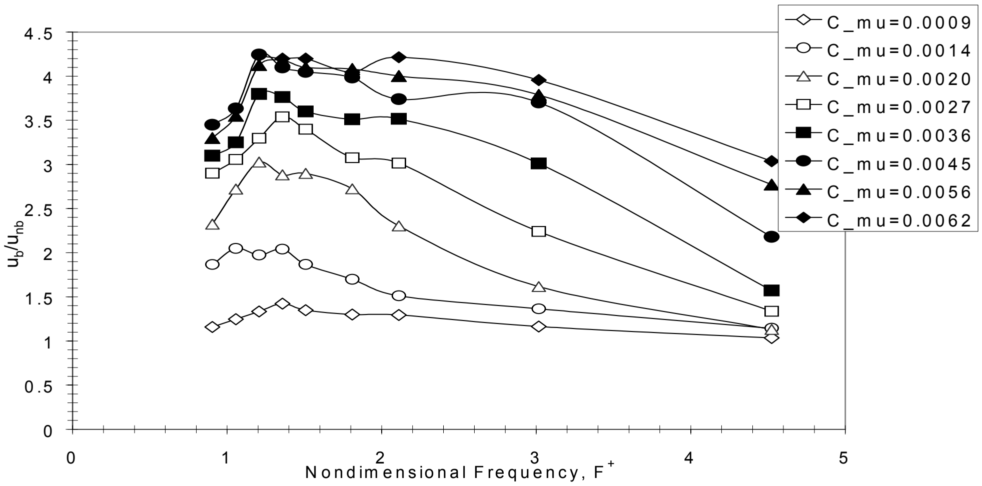


Figure 2: The effect of frequency on local velocity enhancement at X/C=0.1, Y/S=0.5, α=40^o

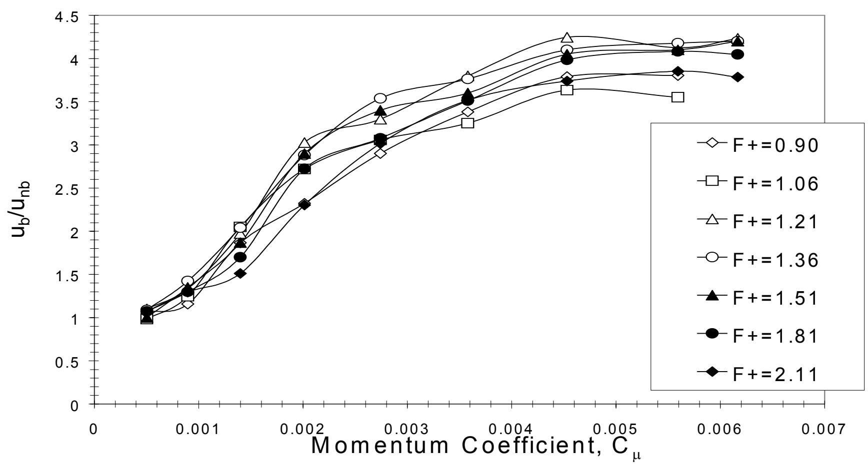


Figure 3: The effect of momentum coefficient on local velocity enhancement at X/C=0.1, Y/S=0.5, α=40^o

Note: The length of the Results and Discussion section depends on the subject. Tell a complete story.

Conclusions

Purpose: The Conclusion section tells the reader the key findings in the report and their significance from the technical viewpoint. The conclusion only summarizes what was presented previously in the report. **Address all key issues or questions noted in the Introduction**. **Do not introduce new material**. Each conclusion is presented in a concise, clear manner. If the reader requires more details, the Results and Discussion section is available. Remember this is frequently the only section other than the abstract read by a time-conscious reader, so it is important. If results are not what as expected, state it here and detail suggestions in the Recommendations section.

Tense: Present tense.

Briefly summarize the work done.

Example:

Periodic blowing and suction applied at the leading edge of a 70^o-sweep delta wing and its efficacy in delaying vortex breakdown is experimentally demonstrated. An optimum working point of the periodic flow actuator is established in a parametric study conducted at an angle of attack of 40^o. Results show the effect of the flow excitation is maximized at a nondimensional frequency of 1.2-1.4 and at an oscillatory momentum coefficient of 0.0045. These conditions result in a fourfold increase in local velocities.

Restate KEY points.

Velocity surveys close to the wing and across the vortex show that the periodic flow excitation greatly affects the flowfield over the wing and increases local velocities after the onset of vortex breakdown. These findings, combined with the results of flow visualization, indicate that periodic blowing and suction at the leading edge of a delta wing can delay vortex breakdown by as much as 0.2 chordlength.

Explain the significance of the work

Recommendations

Purpose: Every investigation opens additional questions the researcher is unable to answer. These questions serve as recommendations for future research. As the researcher, you have the most insight on the issues and problems with your work. Do not be afraid to be self-critical when making your recommendations.

Tense: Present tense.

Example:

This study identifies the turbulent flow upstream and surrounding the vertical tails on an F-15E. Due to experimental constraints, only three positions along the fuselage are evaluated. Further study is necessary to completely understand the physical mechanisms governing turbulence development. Additional examination of the relationships between turbulent characteristics and vertical tail buffet would enhance development of a solution to the buffet fatigue problem plaguing the aircraft.

Acknowledgements

Purpose: No engineering project is completed without help. It is vital to acknowledge the people or organizations contributing significantly to the success of your project.

Tense: Present tense.

Example:

The authors would like to thank Mr. Jim Philp, Low Speed Wind Tunnel Director, for his invaluable help during this investigation. Mr. Philp was instrumental in assisting with experimental setup, data acquisition, and numerous model-related issues. Appreciation is also due to the project sponsor, Capt Scott LeMay, USAFA Department of Aeronautics.

References

Purpose: Very few technical reports are written using only your ideas. To document an idea or any material that is not yours, follow the following format at the direction of your instructor. Be sure to give credit where it is due, citing the intellectual work of others.

1. AIAA Format

Indicate a reference by placing a superscript number at the end of the sentence or grouping of words you are referencing. References are placed at the end of the report in the order they appear in the text and should be numbered accordingly.

Type of Reference	Example
Book	Anderson, John D. Jr., *Modern Compressible Flow*, McGraw-Hill Book Company, New York, NY, 1982, pp. 26-35.
Article	Maestrello, L., “Control of Panel Response to Turbulent Boundary-Layer and Acoustic Excitations,” *AIAA Journal*, Vol. 24, No. 2, Feb 1996, pp. 259-264.
Personal Communication	Smith, K. L., Private Communication, University of Michigan, Ann Arbor, MI, 1996
Class Handout	Lovato, J., “AE 471 Test Plan Oral Presentation Guidance,” Department of Aeronautics, USAF Academy, CO, 1996.
Internet	Motorola, “Power PC”, http://www.mot.com/SPS/PowerPC, 6 Mar 1996.

The AIAA format references for the example used in this appendix would look like:

1. Fritzinger, M. and Keeton, S., “Wind Tunnel Investigation of F-15 Vortex Tail Impingement,” *Aero Lab Reports*, Vol. II, Fall 1993.

2. Anderson, J. D., *Fundamentals of Aerodynamics*, McGraw-Hill, New York, 1991.

3. Bertin, J. J. and Smith, M. L., *Aerodynamics for Engineers*, 2nd Ed., Simon & Schuster, New Jersey, 1989.

4. Rockwell, D., “] Flow Structure on Delta Wings at High Angle-of-Attack: Experimental Concepts and Issues,” AIAA Paper No. 93-0550.

5. Komerath, N. M., et al., “Flow Over a Twin-Tailed Aircraft at Angle of Attack, Part I: Spatial Characteristics,” *Journal of Aircraft*, Vol. 30, No. 3, May-June 1993, pp. 413-420.

6. Triplett, W. E., “Pressure Measurements on Twin Vertical Tails in Buffeting Flow,” *Journal of Aircraft*, Vol. 20, No. 11, Nov 1983, pp. 920-925.

7. Washburn, A. E., Jenkins, L., Ferman, M., “Experimental Investigation of Vortex-Fin Interaction,” AIAA Paper No. 93-0050.

8. Guy, Y., Morrow, J., McLaughlin, T., and Wygnanski, I., "Control of Vortex Breakdown on a Delta Wing by Periodic Blowing and Suction," AIAA Paper No. 99-0132.

9. Gu, W., Robinson, O. and Rockwell, D., "Control of Vortices on a Delta Wing by Leading-Edge Injection", *AIAA Journal*, Vol. 3, No. 7 July 1993, pp. 620-626.

2. ASME Format

Indicate a reference by giving the last name of the author(s) and the year of publication of the reference . For example: [this has previously been determined (Anderson, 1982), or, Anderson (1982) states ...] . References should appear at the end of the report in alphabetical order.

Type of Reference	**Example**
Book	Anderson, John D. Jr., 1982, *Modern Compressible Flow*, McGraw-Hill Book Company, New York, NY, pp. 26-35.
Article	Maestrello, L., February 1996, “Control of Panel Response to Turbulent Boundary-Layer and Acoustic Excitations,” *AIAA Journal*, Vol. 24, No. 2, pp. 259-264.
Personal Communication	Smith, K. L., 1996, Private Communication, Univ. of Michigan, Ann Arbor, MI.
Class Handout	Lovato, J., 1996, “AE 471 Test Plan Oral Presentation Guidance,” Department of Aeronautics, USAF Academy, CO.
Internet	Motorola, “Power PC”, http://www.mot.com/SPS/PowerPC, 6 Mar 1996.

Appendices

Purpose: Appendices supplement the main body of the report. Title each appendix and indicate its order by a letter prefix, for example: Appendix A - Hot-Film Calibration Information. Include additional calculations, derivations, computer programs and listings as necessary, supplemental drawings and experimental details not necessary in the report main body. It is better to graphically represent data, even in the appendices. Lists of numbers are difficult to read.

TECHNICAL PRESENTATIONS

PRESENTATION REQUIREMENTS

The following section contains the requirements for technical presentations and example slides.

Technical presentations include:

1. **Title**
2. **Overview**
3. **Objective of Study**
4. **Relevant Background**
5. **Relevant Theory**
6. **Instrumentation**
7. **Experimental Procedure (Including a drawing)**
8. **Key Results**
9. **Conclusions**
10. **Recommendations (Only if pertinent to presentation)**

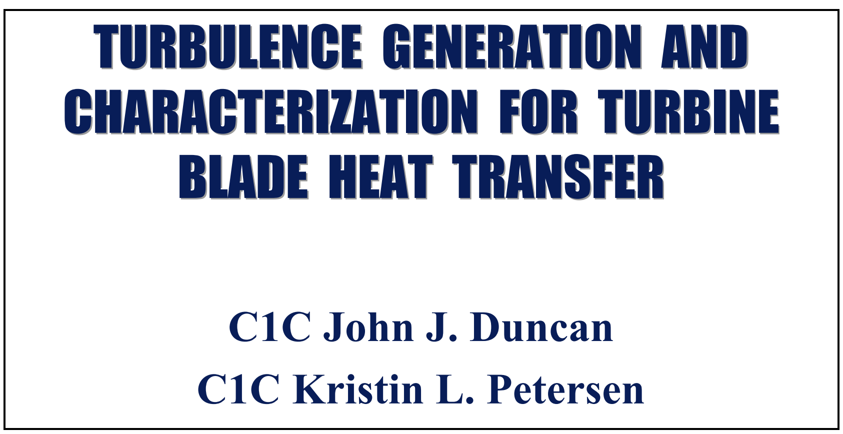
Technical presentations are a concise way to convey research results to the appropriate audience. The research relevance, objectives, methods, results, and conclusions are woven together to tell a story. The following slides are examples of the various types of slides commonly used in presentations. They are part of a presentation given in AeroEngr 471, Aeronautics Laboratory, reprinted with the authors' permission. Included with each slide are key points and guidelines designed to help prepare a complete, exemplary technical presentation.

General Suggestions:

- Use color whenever possible. Colors, font sizes, and graphics should be visible from where the audience sits. Avoid light colors such as yellow on light backgrounds.
- Use advanced features of presentation software (such as animation) if appropriate, but don't rely on it to cover inadequacies in effort or methods.
- Practice the presentation. Nothing says "lower the grade" louder than a presentation that seems poorly rehearsed or inadequately organized. Know what the next slide is and practice the transition from one slide to another. "Um" is not the proper transition.
- Resist the urge to include everything done in the project. Both the presentation and its delivery must tell a complete, organized story. It must leave no "loose ends" and must satisfy the listener that the work is defensible and complete.
- <u>Never</u> read the presentation. The information on the slides is a memory jogger for the presenter and a means for the listeners to process and organize your information. Too much detail confuses. Too little detail ensures the audience can not follow your development.
- Outline the presentation. Know the audience and the amount of time available.
- Plan the slides. Do not attempt to put all thoughts on the slides. Include main points and talk to them during the presentation.

- Practice. Know the slides inside and out. - Hardcopies. Ensure there are a sufficient number of hardcopies of the briefing. It is permissible to print the slides "two on a page" from PowerPoint, but six may be too small for the audience to read.
- Be prepared. If possible, load and view the slides in the briefing room – do it well in advance of the briefing. Locate remote controls, pointers, and podium lighting well ahead of time. Load and view the slides early enough to correct problems, get another disk, or make that last little “tweaking." This loading and reviewing needs to take place before the *first* briefing commences.
- Anticipate Problems. Bring an extra disk in case the previously loaded briefing vaporizes or there is a virus. Double check the slides, notes, the room, the clicker, and all backups.
- Read the audience. During the briefing watch the audience and adapt. If there are numerous head nods at the beginning of a slide, try to speed up.
- Look sharp. This should go unsaid, but better safe than sorry.

What makes a good slide?
- Visibility: everything on the slide is easy to see from every point in the room. Binoculars are not required to discern details.
- Clear" Visuals appropriately titled and understandable without help from the speaker. Would the presentation be understandable without you there to explain it?
- Simple: Uncluttered, with only one main idea per slide.
- Logical: Remember, you are telling a story. Every slide must support the flow and completion of the story. No unnecessary information or clutter.



⇒ Use large bold letters for title. Keep title as concise as possible while communicating the nature of the project
⇒ Include all authors on title slide, including faculty sponsor, if appropriate.
⇒ You may be asked to use particular logos or slide formats depending on the organization. This will be left up to your instructor and department.

OVERVIEW

- Objective
- Background
- Expected Results/Theory
- Equipment and Instrumentation
- Setup
- Calibration
- Experimental Procedure
- Results
- Uncertainty Analysis
- Conclusions

⇒ Include all sections. Use large print and bold letters.
⇒ Cover briefly, one or two words.
⇒ As with any slide, explain what the presentation will cover, without reading the words to the audience.

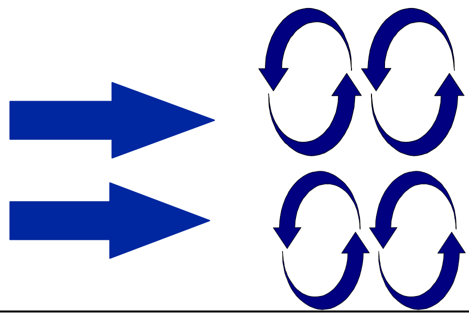
OBJECTIVES

- **Experimentally characterize turbulent flow production in Aero-Thermal Cascade Facility**
  - **Planar velocity and turbulence intensity mapping**
  - **Streamwise turbulence intensity, decay rate, and length scale variations**
- **Describe trends and turbulence prediction methods for use in turbine blade heat transfer experiments**

⇒ Include only key objectives. Be succinct. Explain objectives to audience, rather than having them read.
⇒ Ensure each objective is addressed in results and conclusions slides.
⇒ Word objectives carefully. A common grading criterion is “how well you met your objectives”

THEORY/EXPECTED RESULTS

- **Macroscopic length scale from local velocity-time analysis**
  - **7500 Hz hot-wire sampling rate**
  - **Statistical analysis for correlation factor**



⇒ Use enough detail to orient the audience to your problem and establish a common level of understanding.

⇒ Remember the technical level of the audience!

⇒ Derivations and long explanations are rarely appropriate, even in presentations to a learned society. Refer an interested listener to the technical report that accompanies the presentation for those details.

THEORY/EXPECTED RESULTS

- **Hot-wire velocity (4th order calibration)**

$$V = C_0 + C_1 (e_o - e) + C_2 (e_o - e)^2 + C_3 (e_o - e)^3 + C_4 (e_o - e)^4$$

- **Temperature thermocouple for steady state verification and T_{surr} measurement**

⇒ Summarize key equations and concepts.

⇒ Define variables only if they are not obvious to the audience.

EQUIPMENT

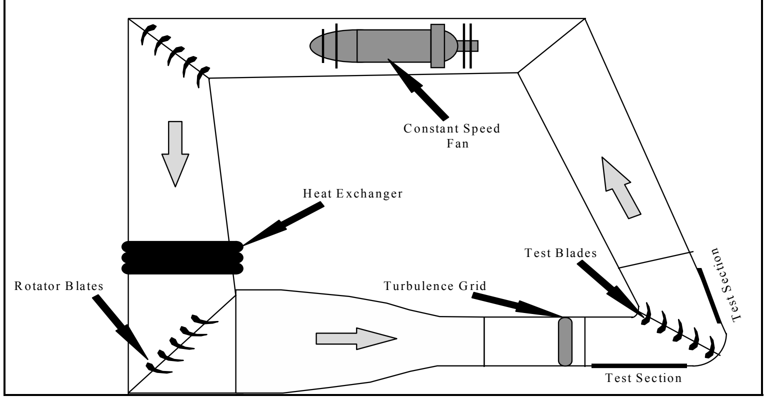
- **USAFA cascade facility with 24”x12” capable traverse**
- **2” pipe turbulence grid with 60 psi air jets**
- **Single-axis hot-wire and IFA 100**
- **HP system with TV3 and statistical software**
- **Digital pressure transducer**
- **Room barometer**
- **Pitot-static probe**
- **Thermocouple**

⇒ List all used equipment, even if minor.
⇒ Include model numbers and relevant specifications of major instrumentation.
⇒ Succinctly state the purpose of each item.

SETUP

Cascade Facility Description

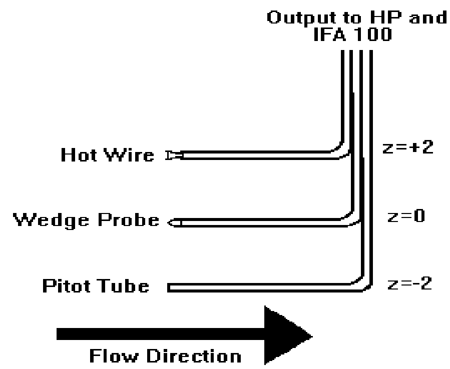
105° turning angle / 43.3 cascade angle



⇒ Use sufficient detail so the audience can visualize the experimental or computational arrangement, as well as how the experiment was conducted.
⇒ Ensure all items are readable.
⇒ Use a drawing or diagram if at all possible. Clarity is more important than complexity. Explain pertinent parts of drawing.

SETUP

- In-Flow Traverse Instrumentation
  - Flow mapping in 2” steps
  - 22.5” from blade array



⇒ Use detail slides as necessary, and as time allows. Always have them available to aid in answering questions (back-up slides), even if they are not part of the planned presentation.

⇒ Cover key points.

CALIBRATION

- Prior calibration by PMEL
  - Digital Pressure Transducer
  - Atmospheric Pressure Barometer
  - Thermocouple
- Hot-wire calibration
  - Prior dynamic calibration from curve fit experimentation
  - Spreadsheet static (bias) calibration

⇒ Summarize key calibrations of all pertinent instrumentation.

⇒ Include any limitations or concerns that can significantly impact the quality/accuracy of your results.

EXPERIMENTAL PROCEDURE

a. **Determine grid inputs**
   - **Roach's correlation for constant Tu increments and greatest Tu range**

b. Affix instrumentation

c. Calibration and test runs

d. HP traverse programming and data collection

e. Move grid

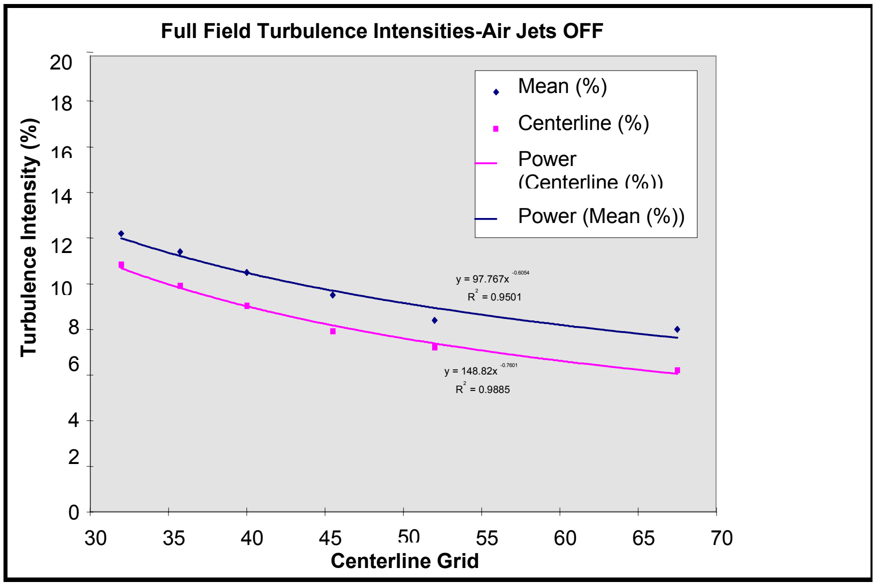
⇒ Include all steps, but summarize. Use bullets as a guide to the presentation.
⇒ Use sub-headings as a reminder to discuss issues and pertinent issues.

RESULTS

Grid Distance versus Turbulence Intensity

- **Magnitudes and Decay Rates**
- **Air On and Air Off**
- **Centerline and Mean**
- **Full Field and Central Region**
- **Micro and Macro**

⇒ Results are presented either with bullets (above) or with plots (below).
⇒ The author must decide the most appropriate presentation method.
⇒ Ensure plots are clear, readable, and tell the appropriate story. Remember error bars!
⇒ Never show all the data you have collected. Present only the data relevant to the points you are trying to make.



⇒ Though a picture is worth a thousand words, it isn't worth a million. Every plot or data result needs explanation and context. Explain what you are plotting, the axes and data legends, and the most important features of the data.

⇒ Ask yourself "What one thing do I want the audience to understand from this plot?"

UNCERTAINTY/ERROR ANALYSIS

Two main sources of error

- **Hot-wire velocity bias**
- **Tu spreadsheet mapping method**

$$Tu = \frac{dV}{d(\Delta e)_{Vm}}\left(\frac{e}{V}\right)100$$

- **0.5% turbulence intensity bias - Air Jets OFF**
- **1.5% turbulence intensity bias - Air Jets ON**

⇒ Summarize uncertainty analysis results.

⇒ Include all pertinent uncertainties. List if necessary. Do not go into details about the mathematical formulations, but be prepared to defend your answers.

CONCLUSIONS

1. **High turbulence levels (15-20%) from air jets on must be reproduced with revised grid**

2. **Roach's correlation valid for decay rate with air jets off**
   - **Air on is grid-specific: USAFA facility correlation**

     $$Tu = C\,(x/d)^{-0.5}$$

- ⇒ Succinctly summarize key conclusions.
- ⇒ Include equations only if significant.
- ⇒ Never present new information in the conclusions. Everything here should have been introduced previously in the presentation.
- ⇒ Don't overreach! Limit your conclusions to what your work has clearly shown.

LABORATORY REPORTS

What did you have for breakfast on 18 July 1981? What color socks did you wear that day? Chances are you don't have a clue because you failed to keep a detailed record of that day's events and circumstances. Granted, that may not be a big deal. It probably isn't unless you need to reconstruct the events of that day for some reason. In that case, you have a problem; history has failed to record the required information. Time has swept those events away like the wind would sweep away the sand from a broken hourglass. Some information about that day is forever lost and unknowable.

Now, what if on that day you had invented the Flux Capacitor, making time travel a reality? You finally got the device up and working in the lab then stepped across the street to have dinner and celebrate. On the way back across the street ***BLAM-O*** you were hit by a Mac truck and met an untimely death in front of your lab. Because you didn't keep a good lab book, the world will never know the process you went through to invent your device. They may never fully understand what the Flux Capacitor is and how to use it because you didn't write anything down as you were developing your design. Your invention can not be patented because there is no legal evidence to document its development. By not keeping a notebook, those long hours spent in the lab were wasted. You might as well have been watching re-runs instead.

Nothing quite that dramatic is likely to happen in your lab experience here at the Academy but it's still important to practice keeping a good record of your lab activities. Because of the transitory nature of the AF, it's likely that you will either step into a lab project that has been going on for awhile or that you will "hand off" your work to someone else. Think how great it would be to receive a good lab notebook from the last person to work on the project. It would bring you up to speed on the project quickly and save you countless hours of frustration. If you didn't keep a good lab book while working on the project, the next person to work on the project will not have the benefit of your experience. Your contributions to the project will be lost because you didn't write down what you did. Keeping a good lab notebook is a professional discipline that will go a long way toward making you a good engineer.

Notebooks record the process of scientific discovery, the evolution of a project, and the steps in engineering analysis. The notebook is a repository of all procedures followed, in-lab computations, and raw data collected. In it you will record any ideas or observations you have as they occur, no matter how outlandish. The ***lab report***, on the other hand, summarizes the work accomplished in the lab. The lab report allows you to introduce readers to the observations and discoveries documented in your notebook. The notebook contents are thus used to document and substantiate the lab report.

A. Notebook Format:

1. Use only bound, sequentially numbered laboratory notebooks.

2. Pages must be filled and numbered sequentially. There shall be no back-filling of pages. Unused pages or page space shall be X'd or Z'd through to ensure that material is not later added.

3. Entries must be made in either black or dark blue pen.

4. Entries must be signed, dated, and witnessed. Dates should be unambiguous. Your instructor cosigns your notebook pages as a witness when he or she inspects your notebook.

5. All alterations and attached material must be signed and dated. You may glue in extra material, such as computer printouts of figures, but do not use tape or staples. The idea is to create a document that shows no signs of data tampering. Do not fall into the habit of making notes, computations, or sketches on other paper and transcribing the information into your notebook. *It is essential that you learn to think in the notebook.*

6. Errors are a history of your thought process. Do not white-out, erase, paste over, or otherwise obliterate your errors. Rather, cross them out with a single line.

B. Notebook Contents: The easy answer here is "include *everything*." Realistically, you should include the information necessary to document what you did during the experiment. This includes equipment settings, displays, simulations, successes, and failures. Here are some items you should include in your notebook. Note that these have been adapted from the newspaper reporter's list of *5 W's and a How* to fit the format and needs of a lab notebook.

1. Who
    a. List all experimenters and make their contributions clear.

2. What
    a. Possible solutions
    b. Experimental design
    c. Results: material samples or their locations, raw data
    d. Analysis of data
    e. Conclusions drawn from the data
    f. Difficulties encountered (and their solutions if possible)
    g. False starts, bad assumptions, wrong turns, blind alleys, etc.

3. When
    a. Chronological record of work

4. Where
    a. Note where you accomplished your work (in lab, in your room etc.)

5. Why
    a. Statement of problem
    b. Rational for decisions, assumptions, and design

6. How
    a. Equipment used including model numbers
    b. Schematics or diagrams
    c. Procedure followed
    d. Flow charts

C. Notebook Evaluation: Your notebook may be evaluated each lab period, giving the instructor the chance to provide immediate feedback and ensure that you are keeping up. The emphasis is on proper use of the notebook, not having the "right" answer for the experiment. The following criteria apply:

1. Is every page signed and dated?

2. Are alterations or errors crossed out and blank areas X'd out?

3. Is your writing legible?

4. Is your table of contents up to date?

5. Is the work described completely so no additional explanation is required for complete understanding? *Note*: You may assume the reader of your notebook is someone similar to yourself. What would you need to know to repeat the experiment?

6. Are you thinking in the notebook? Are ideas and observations entered immediately and directly into the book? Are important experimental parameters, such as circuit diagrams and equipment connections, included?

D. Lab Reports: For lab reports, assume the audience is an engineer who understands the technical jargon, but has no prior knowledge of the experiment, i.e., has not read the assignment. Lab reports typically have the following sections of the formal report: Abstract, Introduction, Theory, Methodology, Results and Analysis, Conclusions, Recommendations, References, Appendices

Documenting work is one of the most important aspects of the experimental process. A good write-up clearly tells the reader what was done in the experiment. The following elements should be included in all experiment write-ups.

General. All write-ups must be done on a computer. Sketches, data tables, and calculations may be done neatly by hand, but must be **IN PEN.** Remember the reader should be able to repeat the experiment completely from your report, and all your conclusions must be supported with data and calculations, where applicable.

Abstract. Include a brief explanation of the objective and nature of the experiment. Include significant results.

Sketch. A schematic of the test apparatus. The purpose of the sketch is to aid you or another researcher who is trying to reproduce the experiment. Include enough detail to allow the reader to determine how things were connected together and what the apparatus generally looked like. Include model numbers and serial numbers of all test equipment, as well as other pertinent information.

Procedure. Clearly explains what was done. A well-written procedure will allow someone with a basic knowledge of the equipment and theory to replicate the experiment completely.

Data. This is the "meat" of the report. All numerical values should include units. A clearly-labeled table (called a "data matrix" -- set up before the lab) greatly enhances the readability of the report. Always include relevant environmental conditions such as ambient temperature and pressure.

Calculations. This is where the data is converted into the quantities of interest. Include all units. If a spreadsheet is used to reduce the data, include a sample calculation for each type of quantity that was solved. The calculation should relate a specific measured value to a specific number on the spreadsheet.

Question/Answers. Laboratory assignments will include a few questions to answer. Write down not only the answer, but also enough of the question to indicate what is being asked. Some questions do not necessarily have a "right" answer, but are designed to encourage thought about important laboratory concepts. Support all answers with necessary data and calculations.

Conclusion: A summary of the important results, lessons learned, problems encountered, and recommendations.

Acknowledgments. All work must give credit to those who helped. This includes references to written materials, written and oral communications, and people with whom data was collected.

REFERENCES

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2. Department of Defense, "Metallic Materials and Elements for Aerospace Vehicle Structures." Military Standardization Handbook. MIL-HDK-5E, Washington, 1 June 1987.

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AERONAUTICAL and MECHANICAL ENGINEERING INFORMATION

Department of Aeronautics
United States Air Force Academy

Report Writing Guidelines

DFAN has adopted the American Institute of Aeronautics and Astronautics (AIAA) report writing format. This format is explained here along with some minor modifications to fit our academic purposes. Follow the examples in the main guide for format.

Your report will be:

1. ***SINGLE COLUMN-DOUBLE SPACED*** **-** (this will ease the preparation process, give more room for graphs, charts, pictures, etc., and will allow room for evaluation comments.)
2. One inch (1") margins all around.
3. 12 point Times New Roman font.
4. Page numbers must be used. Page numbers will first appear on page 1.
5. Use superscripts, subscripts, and proper Greek symbols.
6. All paragraphs will be justified.
7. Section headings will be centered, have one blank lines before, and one blank line after.
8. Figure titles will be single spaced, boldface, and centered below the figure.
9. Table titles will be single spaced, boldface, and centered above the table.
10. Equations, figures, and tables will all have one blank line *above* and *below* each. Table and figure titles are considered part of the table or figure, therefore place titles so they appear to be part of the table or figure.
11. All documentation is considered a reference, put it in the reference section.
12. References within the document will be numbered (using superscripts, AIAA format) according to the order in which the reference is used.
13. Reference entries will be singly spaced within the entry and double spaced between entries.
14. The paper must be stapled.

ELECTRICAL ENGINEERING INFORMATION

Department of Electrical Engineering
United States Air Force Academy

Report Writing Guidelines

DFEE has adopted the Institute of Electrical and Electronics Engineers (IEEE) report writing format. This format is explained here along with some minor modifications to fit our academic purposes. The following pages give many examples of the various sections of a formal report.

Article extracts in the following section are examples:

1. Examples ***only*** of IEEE format papers; articles are not complete; just examples of good form and documentation.
2. Papers submitted for initial publication would typically be in single column format.
3. Published papers would be in double column-single spaced format.

Your report will be:

1. ***SINGLE COLUMN-DOUBLE SPACED*** - (this will ease the preparation process, give more room for graphs, charts, pictures, etc., and will allow room for evaluation comments.)
2. One inch (1") margins all around. Examples provided have a right margin that is larger than 1"; this is just to allow room for the bullet comments.
3. 12 pt Times Roman Type Face.
4. Page numbers must be used. Page numbers will first appear on page 2. Page 1 will **NOT** have a number.
5. Italics are used when appropriate, **NOT** underlining.
6. Use superscripts, subscripts, and proper Greek symbols.
7. All paragraphs will be justified.
8. Section headings will be centered, have two (2) blank lines before, and one (1) blank line after.
9. Figure titles will be single spaced and centered below the figure.
10. Table titles will be single spaced, centered above the table.
11. Equations, figures, and tables will all have two (2) blank lines *above* and *below* each. Table and figure titles are considered part of the table or figure, therefore place titles so they appear to be part of the table or figure.
12. The **ONLY** thing allowed in a report is text, equations, figures, and tables. (no plots, diagrams, etc.; they are all figures)
13. All documentation is considered a reference, put it in the reference section.
14. References within the document will be numbered (in square brackets) according to the order in which the reference is used (i.e., first used reference [1], second is [2], etc.)
15. References used many times may contain a page number following the reference number to indicated exactly where the information was found (i.e., first reference page 27 -[1:27]).
16. References in the reference section will begin with a square bracketed reference number, author, title of work, title of source (book, journal, World Wide Web, instructor, etc.), publisher of work, location within the source, and date.
17. Reference entries will be singly spaced within the entry and double spaced between entries.
18. The paper must be stapled.

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 33, NO. 1, JANUARY 1995

Dielectric Constants of Rubber and Oil Palm Leaf Samples at X-Band

H. T. Chuan, K. Y. Lee, and T. W. Lau

Abstract describes entire report, stands alone, conclusions given.

Abstract: **This paper reports on the measured dielectric constants of leaves of two tropical crops, namely rubber and oil palm, as a function of moisture content at N-band. Using a microcomputer-based automated system consisting of a Wiltron scalar network analyzer and a slotted waveguide, the measurements are done based on the waveguide thin sheet technique. Theoretical values from the dual-dispersion model by Ulaby and El-Rayes [13] and from the simple dielectric theory of Fung and Fung [2] are compared with the experimental data. The model from Ulaby and El-Rayes is found to be able to give good estimates of the dielectric constants for the two types of leaf samples at N-band.**

Note: two blank lines before section heading.

Section Headings Centered with single blank line after.

I. INTRODUCTION

Dielectric properties of vegetation samples are important parameters to be investigated for they describe the lineage between electromagnetic properties of the samples. The dielectric constants are required in theoretical models that calculate propagation constants and radar backscatter coefficients from a vegetation medium such as a forest stand [3]-[5].

Page numbers--But NOT on page 1.

Numerous reports are available in the literature on measurements of various types of vegetative samples of temperature climate. We mention for examples the dielectric properties of grains such as winter wheat studied in [6]: grass, corn, leaves, and needles of taxus cuspidatus in [7]: corn leaves and stalks in [8]: balsam fir and poplar tree trunks in [9]: and foliage in [10]. Reports of measurements of tropical vegetation are, however, scarce [1], [11]. In addition, comparison of dielectric constants of various dielectric models are usually made with vegetation components of temperate climate. Thus there is room for extensive studies of the dielectric properties of tropical vegetation materials. Measurements need to be conducted and compared with theoretical calculations to test applicability of these theories.

This paper reports on the measurements of dielectric properties of leaves of two types of tropical trees, namely the rubber (Hevea brasiliensis) and the oil palm (Elaeis guineensis), at X-band. The waveguide thin sheet method [12] if employed to obtain the dielectric properties of the vegetative specimen. It consists of a Wiltron scalar network analyzer to provide amplitude information and a slotted line to provide phase information. The measurement is automated with a microcomputer as described briefly in Section KK. The

Proper format for references.

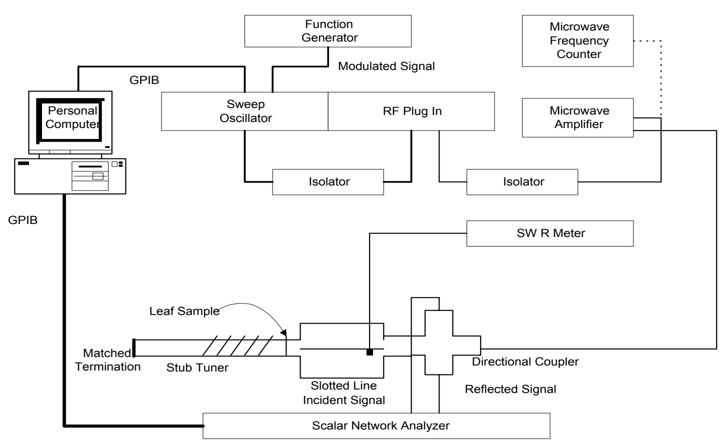
Page numbers beginning with page 2.

experimental results are given in Section III. A comparison is also made between the measured data and predictions from two dielectric mixing models in [2], [13].

II. METHOD AND MATERIALS

Figure 1 shows the experimental set-up. The major components are a HP Model 8620 sweep oscillator as the microwave source, a HP Model 495A microwave amplifier, a Wiltron Model 560A scalar network analyzer, a HP Model 415E SWR meter, a IBM-XT microcomputer as the control and processing unit of the systems, and the slotted waveguide and the associated couplers.

Note: two blank lines before and after Figures!



Diagrams of test setups are very helpful in conveying what you did.

Figure 1 Schematic of microwave measurement system.

Figure captions - single spaced, directly under figure and centered and two blank lines after.

The measurements technique used is thin sheet techniques as reported in [12]. A piece of leaf sample is sandwiched between two waveguide sections. A modulated microwave is amplified and fed into the directional coupler. The magnitude of the reflection coefficient is measured by the scalar network analyzer and its phase is obtained using the standard standing wave method [1].

The complex reflection coefficient Γ is then used to calculate the dielectric constant of the leaf specimen as given in [12]:

Note: two blank lines before and after equations.

$$\varepsilon = \frac{[1 - \tfrac{1}{}(\tfrac{\lambda}{4}) \; - jtk_\iota(\tfrac{\lambda}{2a}) \; - 2j\,\tfrac{k\iota}{tk}]\Gamma}{1 + (1 + jtk_\iota)\Gamma}$$

Equation format is centered in column.

(1)

Equation numbering is sequential, in parentheses, with numbers against right hand column margin

where $$k_\iota = \sqrt{(k \; - (\tfrac{\pi}{}) \;)} = \frac{\pi}{\lambda a}\sqrt{(4a \; - \lambda \;)}$$

λ the wavelength, a broad dimension of the rectangular waveguide, and the thickness of the specimen.

The experiment was carried out at room temperature of about 25°C. About 200 measurements were made with each type of leaves at three different frequencies (8, 13, 9, 12, and 10.0 GHz) in X-band. In each measurement, the initial weight of a leaf specimen to be tested was measured using an electronic balance. The sample was then inserted between the flanges of two waveguide sections. Both magnitude and phase of the reflected coefficient were obtained as explained previously. Measurements were made with different sides of the leaf specimen facing the microwave source. The acquired data are automatically logged on to the microcomputer system through the General Purpose Interface Bus (GPIB). The weight of the leaf specimen after the experiment was taken to check that there was no significant change. Finally the leaf sample was dried slowly in an oven at 50° to 60°C to obtain the gravimetric moisture content based on the wet weight basis.

Most of the difficulties encountered in the experiment are associated with the nature and size of the specimens. The water content of the newly plucked leaves drops quickly. Thus results for moisture content of the newly plucked leaves drops quickly. Thus results for moisture content above 0.6 are difficult to obtain. The sensitivity of the electronic balance limits the accuracy of the experimental data with moisture content below 0.2. The overall accuracy of our measurements is estimated to be within 8 to 10%. Test measurements with a thin specimen of perspex agree with his accuracy estimate.

Quantitative Results!

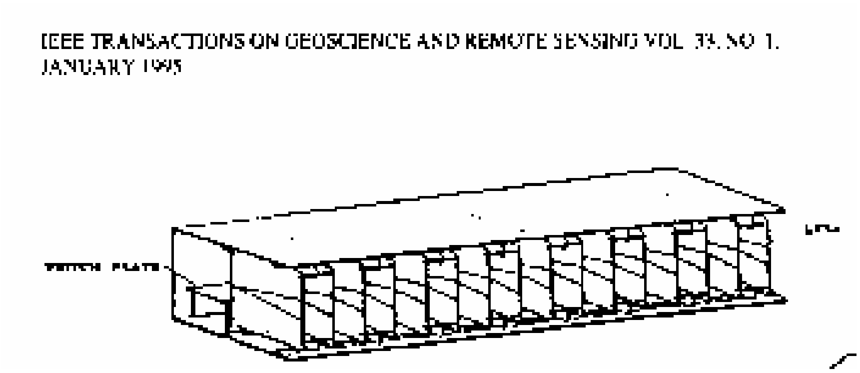
III. EXPERIMENTAL RESULTS AND COMPARISONS WITH THEORIES

Sections titles - centered and two blank lines above.

Our measurement results show that there is no noticeable difference in the dielectric properties of a leaf

Indicates beginning of a different example.

sample with different sides facing the source. Figs. 2 and 3 show the measured dielectric constant.



Pictures very effective

Figure 3. FOPAIR array module cutout showing 16 LTSA elements

Two blank lines before table.

TABLE 1
FOPAIR SYSTEM PARAMETERS

Table Format, Table number, title single spaced.

Transmit Antenna	Type Polarization Azimuth/Elevation Beamwidth	Pyramidal Horn Vertical 17°
Receive Array	Element Type Polarization Azimuth Beamwidth Elevation Beamwidth Number of Elements Element Spacing Array Length Array Azimuth Beamwidth Visible Space	Linear tapered Slot Vertical 24° 18° 128 5.4 cm (1.8λ) 6.8m 0.25° ±16°
Radar Transceiver	Peak Power Frequency Video Bandwidth Effective Pulse Bandwidth Chirp Mode Compression Gain	200 W 10 GHz 100 MHz 10 ns 21.5 dB
Data Acquisition and Storage	Number of Channels Sampling Rate Quantization Imaging Capacity Throughput Disk Capacity	2 (I and Q) 100 MHz 12 bits 8192 samples/image 160 images/sec 2.1 GB

TABLE II
N_{min}, N_{as}, and I_a

Different, but effective table formats.

Scene	ρ_1	ρ_2	N_{min}	D	N_{rq}	I_a	N_{as}
Brazil-1	0.08	0.03	316	3	20	368	23
Columbia	0.10	0.05	337	3	20	400	25
Brazil-2	0.06	0.03	306	3	20	368	23
Illinois-1	0.17	0.09	394	10	20	4112	257
Illinois-2	0.18	0.07	389	10	20	4064	254
Brazil-3	0.13	0.07	363	3	20	416	26
Canada	0.10	0.05	337	5	20	928	58
Sumatra	0.06	0.02	301	3	20	352	22

*N_{min} are pixels. Effective look number N_L is 3.5.

Two blank lines following table.

Dividing (9) by $(P_{CSN})^2$ and considering (7) and (11) provides the error criterion for the selection of the area A and the number of the uncorrected image data values, N, in reflection of antenna pattern measurement requirement.

Note: Equation Number references in parentheses.

$$\frac{\sigma_E^2}{(P_{CSN})^2} + \frac{1+2\rho_1+2\rho_2}{N_L N} \le \left(\frac{2\Delta G}{\bar{G}}\right)^2, (0.2dB), \ (0.2dB) \qquad (12)$$

In Figure 5, we show a plot of the backscatter coefficient, for L-Band HH data obtained over the rain forest in Belize, Central America. The data were extracted from a calibrated NASA/JPL DC-8 airborne SAR data set obtained over a site in northwestern Belize during 1990. The scene was calibrated using information derived from tri-hedral corner reflectors deployed within the imaged area. It is noted that is, indeed less variable over a wide range of incidence angles. If variations of * are examined for incidence angles varying between 30% and 40% is confirmed constant with standard.

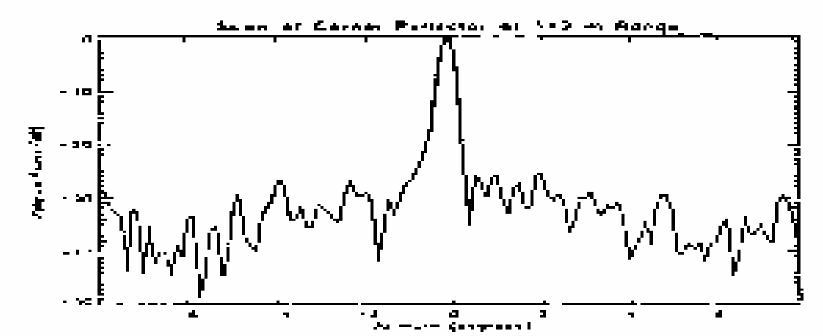


Figure 4. Azimuth scan of a corner reflector in a grass field at 142-m range. The unfocused signal-to-clutter ration is approximately 13 dB.

"A picture is worth a thousand words." Include P-Spice plots, 0-Scope pictures.

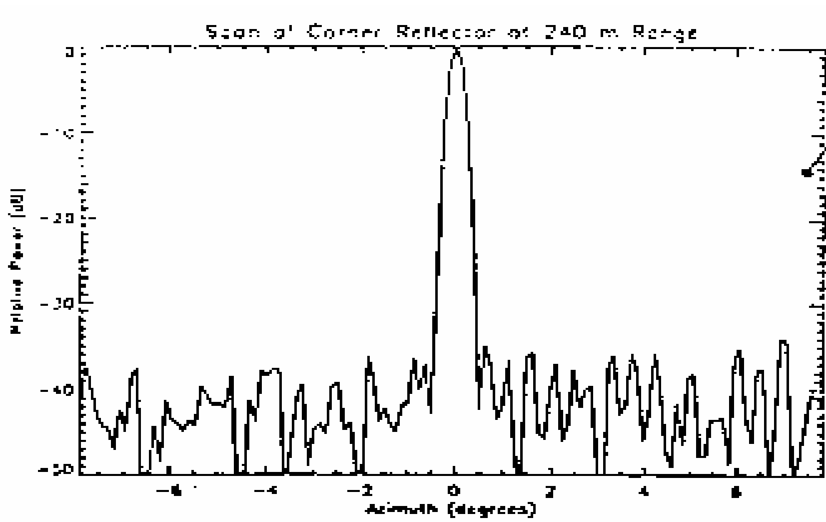


Figure 5. Azimuth scan of a corner reflector deployed on a boat in calm water at 240-m range. Clutter is negligible, but the unfocused signal-to-noise ration is approximately 25 dB.

Plot data when appropriate. Plotted data is frequently easier to interpret.

III. SCREENING PROCESS FOR THE DISTRIBUTED TARGETS

Give the reader adequate background on your subject.

To obtain the antenna pattern from SIR-B images of distributed targets, it is desired that the distributed targets behave uniformly in their backscattering characteristics, i.e., the scattering coefficient is independent of incidence angle or varies in a known fashion. Here, we use the word "uniformly" with the meaning that every datum in some specific area has the same specific distribution function. The Amazon rain forest is held generally to satisfy this requirement, because the rain forest scatters the radar wave by the mechanism of volume scattering [1].

The "personal" touch and yet remains technical and professional.

-

Approximation of (9) leads to a CDR$\approx$2LDR; similarly, from (7) and (8) we obtain $D\rho^{\lim} \approx 1-2LDR$, which is also equal to ρ_{HV}, and DP$^{cir} \approx 1-4LDR$.

Note that using (7) the Mueller matrix in (4) can be written as:

$$\mathrm{M} \cong \frac{\mathrm{A}}{1+LDR}\begin{bmatrix} 1+LDR & 0 & 0 & 0 \\ 0 & 1-LDR & 0 & 0 \\ 0 & 0 & 1-LDR & 0 \\ 0 & 0 & 0 & 1-3LDR \end{bmatrix}$$

(10)

This is identical to the Mueller matrix described for orientation-independent media in connection with backscatter from trees, grass and snow cover [19], [20].

At vertical incidence for hexagonal plates and stellar crystals the Mueller matrices are diagonal with nearly identical elements (resulting from negligible depolarization), except for stellar crystals with d >1000 μm in which case the Mueller matrices are still diagonal but the elements are not all equal.

Finally, the Mueller matrices of all three type ice crystals with uniform random orientation in three dimensions have the form show in (4). The only difference in this case is that the elements M_{11}, M_{23}, M_{32}, and M_{41} are smaller than the diagonal elements by a factor of about 10^{-2}, rather than 10^{-4} or less as for the other off-diagonal elements. This difference has a negligible effect on all the scattering parameters discussed above. As a result, (5)-(10) are also valid for this model.

Again, references to equation numbers.

V. CONCLUSION

Conclusions should include tangible results, proven and disproved. Nothing new.

Polarimetric backscattering (σ_B) and extinction (σ_E) cross sections of hexagonal columns, hexagonal plates, and stellar crystals were determined at 94 and 220 GHz frequencies using the FDTD method. Model ice crystals were randomly oriented on the horizontal plane with their largest dimensions parallel to the plane. Side and vertical incidence cases were considered for crystal sizes in the range 100 to 2000 μm. A model with ice crystals having uniform random orientation in three dimensions was also considered. The columns and plates (including stellar crystals) show significantly different scattering characteristics for both orientation models. These differences are expected to be observable even with a distribution of crystal sizes.

The dual frequency ration (DFR) σ_B (220)/σ_B (94) decreased monothonically from about 15 dB down to 10 dB for columns over the entire size range considered here for the case of horizontal polarization at side incidence and horizontal alignment mode. For the horizontal alignment model the plates and stellar crystals had DFR's steadily decreasing from 15 dB at 100 μm down to negative values as low as -13 dB in the size range 800 μm to 1200 μm. The 3-D random orientation model produced similar results, but with a narrower range of DFR. These characteristics of DFR may be useful in gauging ice crystal size, however, this will require further studies involving size distributions together with 3-dimensional canting models. Furthermore, DFR for columns was always above 10 dB, whereas for plates and stellar crystals it dropped significantly below 10 dB. This aspect of DFR may be useful in differentiating columns for planar crystal types.

For the horizontal alignment model and at vertical incidence, the columns had LDR increasing from -18 dB at 100

μm to about -11dB at 2000 μm. On the other hand, for the same model LDR was negligibly small for plates (< -50 dB) and stellar crystals (< -35 dB). These aspects of LDR may be useful in discriminating columns from plates and stellar crystals.

The Mueller matrices of columns for the horizontal alignment model and vertical incidence, and of all three crystal types for the 3-D random orientation model showed interesting characteristics. All these Mueller matrices were approximately diagonal and the normalized matrix elements were functions of only LDR. As a result, one can obtain the correlation coefficient, the degree of polarization, and circular depolarization ratio from LDR alone.

APPENDIX

A. *Analytical Derivation of (4)*

Use of Appendix - Nice information to have access to, but ***not vital*** *to report*!

Consider a column (or some other scatter with rotational symmetry) lying parallel to the *xy*-plane with its symmetry axis along the *y*-axis as in Figure 12. Let an incident wave be propagating in the +*z* direction. Let the vertically polarized E field make and angle α with the *y*-axis. Note that both the V and H polarization's are parallel to the *xy*-plane. When α = 0 we have the following form of the scattering matrix:

$$\begin{bmatrix} S_{11} & 0 \\ 0 & S_{22} \end{bmatrix} \tag{A1}$$

which is a good representation of the hexagonal columns we have considered in this paper. For an arbitrary angleα, similar to [21] we obtain

$$\begin{bmatrix} S_{W} & S_{VH} \\ S_{W} & S_{HH} \end{bmatrix} \tag{A2}$$

Where

$$S_{VV} = S_{11}\cos^2\alpha + S_{22}\sin^2\alpha \tag{A3a}$$

$$S_{HV} = S_{11}\sin^2 + S_{22}\cos^2\alpha \tag{A3b}$$

$$S_{HV} = S_{VH} = \left(S_{11} - S_{22}\right)\sin\alpha\cos\alpha \tag{A3c}$$

From this scattering matrix we can construct the Mueller matrix (for the BSA convention defined in [17], see (A4)).

REFERENCES

[1] A. Rosenfield and L. S. Davis, “Iterative histogram modifications.” *IEEE Trans. Syst. Man Cybernet.*, vol SMC-8, pp. 300-302, Apr 1978

[2] L. R. Rabiner and R. W. Schafer, *Digital Processing of Speech Signals*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1978

[3] J. L. Yen, “On Nonuniform sampling of bandwidth-limited signals,” *IRE Transactions on Circuit Theory*, pp. 251-257, Dec 1956

[4] Maj Rasmussen, Discussion of problem(s) for homework set #3 or computer exercise #2, 25 Sep 1995

Reference number must correspond with callouts within report.

References: Each reference is internally single spaced, double spaced between references. Each begins with square bracketed number, author, title of work, location (book, journal, World Wide Web, etc.), publisher, location within source, and date.

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Abstract: This project examines the use of a bipolar junction transistor to implement an amplifier circuit with a gain of 100 and minimal distortion. The BJT is a non-linear circuit element which must be designed to work at a specified Q point. The design of the amplifier circuit must account for the correct operation of the transistor and output the desired signal. A common-emitter amplifier was designed for a 10 kHz input signal and to output a 5 V undistorted signal with a gain of at least 100. PSpice was used to simulate the circuit on a computer and to further refine the design of the circuit. The initial design achieved the desired gain, but had considerable distortion in the output signal. Once a good circuit design was

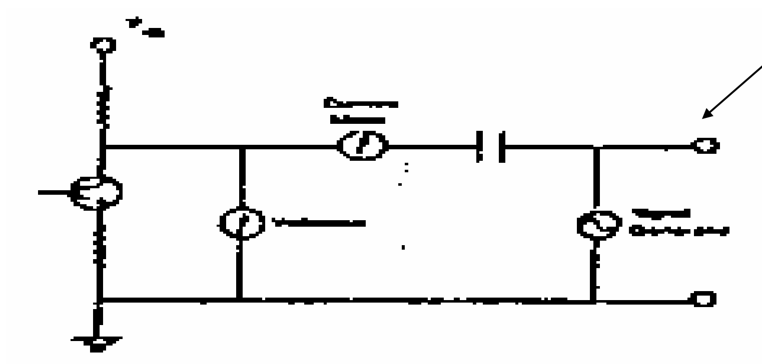
Another example of a good abstract.

obtained, the circuit was constructed and tested in the lab. Some minor modifications were needed to implement the circuit with the available components. The circuit was first implemented with an NPN transistor, then a PNP transistor was also placed in the circuit. Both circuits worked to give an undistorted signal and a 5V output with a gain of 100.

Another abstract example

Abstract: This lab implemented a common emitter amplifier with a gain of 100 and a 5 V_{PP} output signal. Both a 2N2222A npn and N2N2907A pnp transistor were implemented with a classical biasing scheme using one voltage source of 18 V. The amplifier provided a nearly linear output signal with a 10 Ohm unbypassed resistor in the emitter. The design of the amplifier was based on the curve trace of the BJT amplifiers and theoretical equations governing the operation of the circuit. Incremental changes were made to the design throughout the lab. In sum, the performance of the amplifier in the lab followed the predicted operation very closely.

Characterizing the physical circuit was relatively easy at this point with the exception of calculation R_o. A_i could be calculated by measuring the current into the base and across R_{load} using the multimeter. R_{in} was also calculated by taking multimeter readings for v_b and i_b. The procedure for finding R_o, however, was more involved. A test signal was input from the collector to emitter. The current and voltage looking gin from the test signal were then used to calculate R_o. The diagram below describes the procedure for measuring R_o.



A good example of using words and schematic describing a test setup.

Figure 5. Open circuit base with input test voltage across collector to emitter. This circuit was used to calculate R_o.

The final step in characterizing the circuits was to find their bandwidth of operation. This was found by increasing/decreasing the input frequency until the gain on V_o fell off past the 3 dB point.

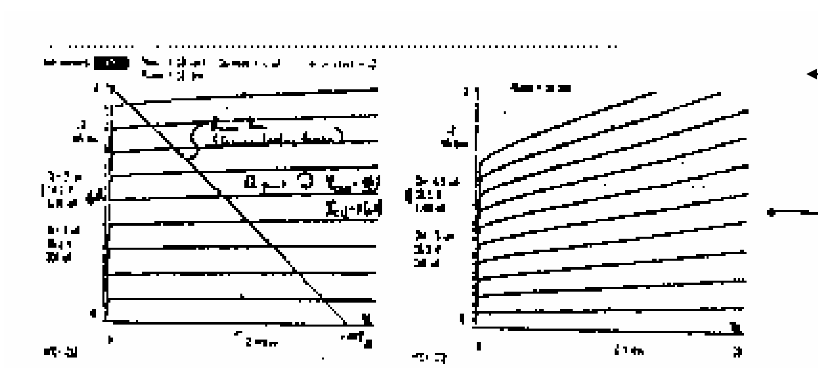
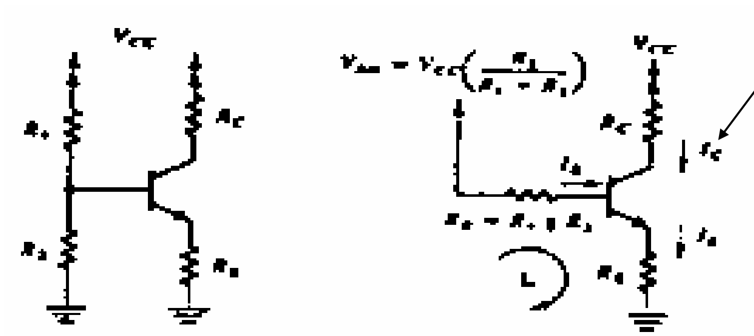


Figure clearly supports discussion in text.

Figure 1. I_C vs. V_{CE} characteristic curves created using the 571 curve tracer. Notice the Q-point and load line approximations drawn on the graphs along with the β calculations.

Biasing the BJT involves choosing the proper resistance in each branch in order to establish a constant current in the emitter thus acting in a linear region of the curves from Figure 1. When using a single power supply as in this lab, we use the biasing configuration shown in Figure 2.



Circuit diagram supports equation development and data gathering.

Figure 2. Single power supply biasing configuration for a BJT common-emitter configuration.

In general we would like to divide V_{cc} such that the voltage at the base is about 1/3 V_{cc} and the voltage from collector to base is also 1/3 V_{cc}. Additionally, the current and resistance in the emitter branch should be designed such that I_cR_c is about 1/3 V_{cc}. The reasoning behind this will be given shortly.

The relationship between V_{cc}, the biasing resistors, and the current in the emitter can be described by the following equations:

The voltage and resistance at the base:

$$V_{\mathrm{BB}} = \frac{R_2}{R_1 + R_2} V_{CC} \tag{2}$$

$$R_{\mathrm{B}} = \frac{R_1 R_2}{R_1 + R_2} \tag{3}$$

The current in the emitter:

$$I_{\mathrm{E}} = \frac{V_{\mathrm{BB}} - V_{\mathrm{BE}}}{\frac{(R_{\mathrm{E}} + R_{\mathrm{B}})}{(\beta + 1)}} \tag{4}$$

We desire the voltage drop between collector and base to be large in order to provide for a large signal swing before we get into the saturation region from Figure 1. We also want a high collector resistance so that the swing is large before cutoff. This presents a problem when we consider that V_{pp} must be high in order to insure that we get a stable I_c in the face of temperature and β variations. There is tradeoff involved in the construction of the circuit for these cases. This is the reasoning behind the choice of component and voltage drop values mentioned earlier.

Figure referred to in text. Makes discussion much clearer.

TABLE 1

AMPLIFIER DATA SUMMARY

Excellent table showing results of design, simulation, and measurements.

	Design	NPN			PNP		
		Sim	Meas	%Chg	Sim	Meas	%Chg
R_c (Ω)	7.2k	7.2k	7.23k	0.4	7.2k	7.23k	0.4
R_e (Ω)	1.8k	1.5k	1.52k	1.3	1.5k	1.52k	1.3

R_1 (Ω)	140k	140k	101.8k	-27.3	140k	101.8k	-27.3
R_2 (Ω)	22.5k	2.5k	22.4k	-0.4	22.5k	22.4k	-0.4
C_2 (F)	15.9u	16u	10.97u	-31.4	16u	10.97u	-31.4
C_s (F)	15.9u	16u	10.97u	-31.4	16u	10.97u	-31.4
C_b (F)	15.9u	16u	10.97u	-31.4	16u	10.97u	-31.4
V_{ceq} (V)	-9.0	8.17	4.38	-46.4	-8.38	-4.35	-48.1
I_{eq} (A)	-1.0m	1.365m	1.556m	14.0	-1.105m	-1.557m	40.9
V_c (V)	-10.8	9.88	6.75	-31.7	-10.04	-6.74	-32.9
V_e (V)	-1.8	1.71	2.37	38.6	-1.66	-2.39	44.0
V_b (V)	-2.5	2.36	3.01	27.5	-2.4	-3.03	26.3
I_b (V)		6.83u	32.5u	376	-7.36u	-31.43	327
I_v (V)		1.372m	1.589m	15.8	-1.113m	-1.589m	-42.8
βeta		199.9	47.8	-76.1	150.1	49.5	-66.9
A_V (V/V)	-100	-126.3	-180.9	43.2	-129.2	-161.0	24.6
A_i (A/A)		-54.4	-54.0	-0.7	-67.3	-49.2	-26.9
R_{in} (Ω)		4.26k	3.53k	-17.1	5.16k	3.02k	-41.5
R_{out} (Ω)			4.70k			6.26k	

The pnp amplifier was not simulated due to the fact that the PSpice results for the simulation are the same for both amplifiers. Figure 2 is a plot of the input and output signals for the amplifier. The input signal has been magnitude scaled so that it would be visible. From this plot we can see that for a 50 mV_{pp} wave that is inverted.

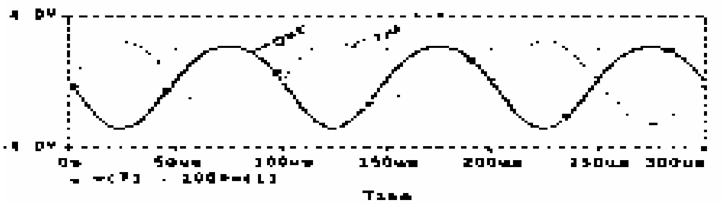
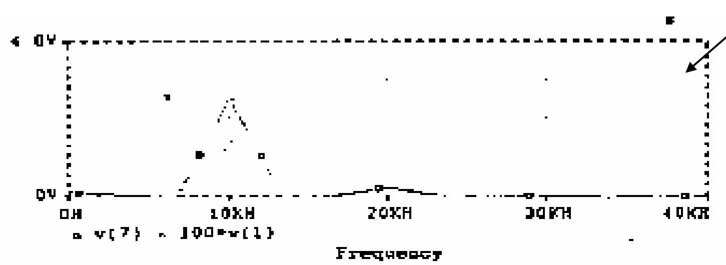


Figure 2. PSpice Circuit Simulation (npn)

In order to determine if there were any distortions in the output waveform, a Fourier analysis was run on the output signal. Figure 3 shows that besides the frequency at 10 kHz, additional frequencies were noted at 0 Hz and 20 kHz. The frequency at 0 Hz represents an added DC component to the output and the frequency at 20 kHz represents a slight distortion to the output. These frequencies have an amplitude of about one tenth the amplitude at the fundamental frequency and therefore do not distort the output to any great degree.



A good example of incorporating simulation results in the main body of report. (not appendices)

Figure 3. PSpice Fourier Analysis of amplifier output signal

(npn)

From the tables it can be seen that the values of similar components are very close. The npn and the pnp transistors are interchangeable if the voltage V_{cc} is switched from positive to negative 18 Volts. This experiment demonstrated how an amplifier is designed using only transistors and resistors and capacitors.

The input that obtains the 5 Volt peak to peak output had to be increased in the lab. The PSpice analysis allowed for a low value of this input that was difficult to use in the practical lab. The oscilloscope plots for the npn and pnp are given below (Figure 8 and Figure 9).

Incorporating oscilloscope print-outs into main body of report. (not appendices)

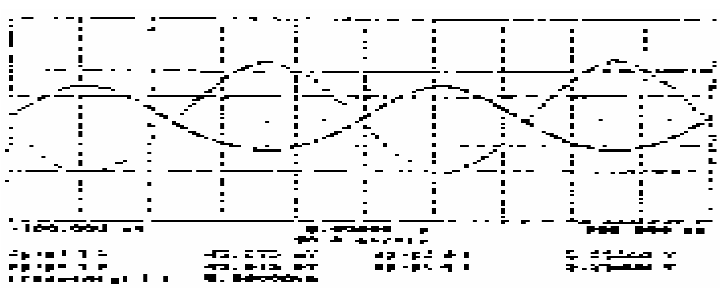
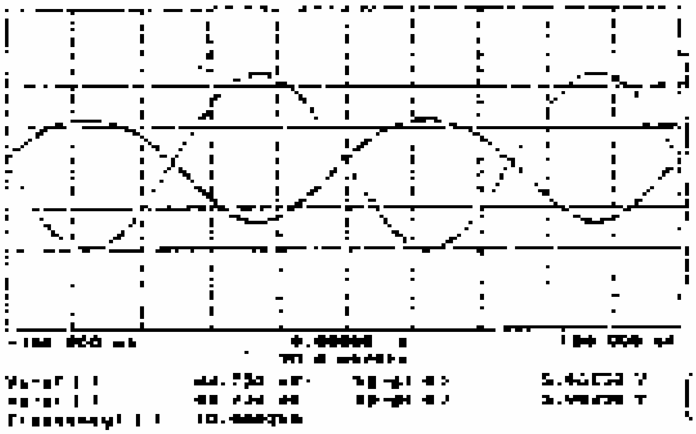


Figure 8. Input vs. output signals for npn transistor amplifier



Incorporating oscilloscope print-outs into main body of report. (not appendices)

Figure 9. Input vs. output for pnp transistor amplifier

These plots show the phase shift to be equal to 180 degrees. By taking 3 dB of the output voltage, the voltage for the pass band was 2.89 Volts. The frequency was increased and decreased using the oscilloscope to determine the high and low frequencies for this pass band. The high frequency is 5.7 MHz and the low frequency is about 2.55 kHz. This was with an input voltage of about 40 mV.

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