CLARITY IN TECHNICAL REPORTING

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CLARITY IN

TECHNICAL REPORTING

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FOREWORD

With the sharp increase in recent years of the volume of technical reports in aerospace fields, it has become even more important for report authors to present their material clearly and concisely. This booklet, which offers common-sense suggestions for improving written and oral reports, is designed not only for prospective writers within the National Aeronautics and Space Administration but also for scientists and engineers among the agency's contractors who must report the results of their research.

The history of this booklet is that of a publication that did not set out to be one, but that has been virtually forced into print by the demand of would-be readers. For a number of years prior to and since the initial printing, the author, a busy scientist at the Langley Research Center, has acted as counselor to fresh-out-of-college youngsters coming to work at the Center—guiding these inexperienced authors in the art of writing technical reports that measure up to Langley's exacting standards. In 1955, Dr. Katzoff, convinced of a widespread need for practical pointers on technical writing, put some of his thoughts on the subject on paper. Typed and duplicated in small numbers, this highly informal document was classed as a Langley internal paper.

But publications, notably the best ones, have a life of their own quite separate from the intentions of their authors. Soon "Clarity in Technical Reporting" began to earn a word-of-mouth reputation as a small classic. Several times copies became scarce, and were run off in small amounts, and became scarce once more. Meantime Langley, acting as a kind of seedbed for its rapidly expanding parent agency,

sent many of its alumni to other NASA Research Centers, and thus treasured personal copies were carried to other locations, there to repeat similar cycles of modest reproduction and scarcity.

When this curious spread of an elderly informal document was discovered, this Division concluded that so prized and useful a paper merited better treatment. In fairness to its author, now Senior Staff Scientist of the Langley Research Center, one should note that he had no intention of appearing in print as an authority on technical writing. Instead, this booklet should be read as what it is: counsel for those who may wish it from a man who has read—and written—many technical papers.

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INTRODUCTION

THE RATE OF PRODUCTION of technical reports is now so high that the typical research worker is continually frustrated in his desire to keep informed of other workers' progress while working effectively on his own problem. His predicament is made worse by the fact that many of the reports that he must read are so ineptly written that the effort required to assimilate them is several times as much as their contents should require. The monetary cost of this additional effort is certainly an appreciable fraction of the total cost of research and development, while the hindrance to our nation's scientific progress may be of crucial importance.

The basic reasons for lack of clarity are sometimes difficult to identify, and no doubt vary from one author to another. Work with inexperienced authors has indicated, however, that they generally do not have ineradicable weaknesses, and that a few discussions of basic principles of report writing frequently suffice to improve considerably the quality and lucidity of their reports.

This pamphlet contains the essence of these discussions. Most of it is contained in some form in the existing literature on report writing. This pamphlet is not intended, however, as a replacement for this literature, nor is it intended as a short summary or review course in report writing. It is presented only as a small supplement to such formal courses or formal directions for report preparation, and it discusses only a few principles that experience has indicated generally needed special attention. In particular, it discusses basic attitudes, some elements of composition, the organization

and contents of the report, and the editorial review. Stress throughout is on striving for clarity, for if this one ideal can be deeply impressed upon the report writer, the desired result will have been largely achieved.

Since technical information is transmitted not only in written reports but also in talks and lectures, as during technical meetings or formal conferences, a section has been included on the technical talk—the orally delivered technical report. Some special treatment of this subject was considered necessary because the technical worker frequently shows himself to be profoundly unaware of the difference between a written and an oral report. Here again the emphasis has been laid on principles found frequently to need attention, and no effort has been made to provide a thorough discussion of the oral report or of public speaking.

BASIC ATTITUDE

Purpose

The purpose of the report is to present information. You will hardly disagree with this statement; yet many authors seem to subordinate this purpose and quite forget the poor reader when preparing a report. For example, when a reviewer complains that a certain word seems incorrect, the author may proceed to an unabridged dictionary and triumphantly point out the rare definition that clarifies his sentence. Obviously such an author is more interested in demonstrating his erudition than in presenting information clearly to his harried reader; for if he had his reader in mind, he would try immediately to substitute a more common phraseology.

This example is only one of many that could be given. Apparently the presumed purpose to present information is frequently forgotten in the author's desire to show his own brilliance, to impress the boss, to impress the secretary, to demolish the rival, or to get a raise. Worthy as these objectives may be, the basic objective should be to make the

report clear and informative; furthermore, if this objective is attained, the secondary objectives will automatically be attained.

This basic viewpoint is fundamental. If you remember nothing else of this pamphlet, you will have retained the essence if, when writing your report, you continuously bear in mind the busy reader, who has only a limited time to devote to your report and who, in addition, may not be very familiar with your subject.

Honesty

The great scientists who established the foundations of modern science seldom had to admit an error, if for no other reason than that they generally had time to correct any inadequacies that became apparent. The high degree of thoroughness and perfection that characterized their work, however, is often unattainable in many modern laboratories. For example, a complete test program may be run through a particular experimental facility before a single result is available for examination; and the equipment may no longer be available when eventual examination of the results shows that the crucial test was not within the range of variables chosen, or that some of the tests were spoiled, or that perhaps the whole program was not very cleverly conceived. Thus, the hectic pace of modern research frequently results in studies that, although useful, have rather significant faults or weaknesses. Even purely analytical studies may suffer in this way, when the worker is forced to publish what he has and proceed to a more urgent job.

Such situations are, of course, unfortunate, and are particularly distressing to authors trained in admiration of the masters. What is more unfortunate, however, is the fact that these same authors may strive desperately to hide the faults. They may spend days trying to concoct wording that will lead the reader's attention away from the faults or that will make the faults appear less significant

or less blameworthy, or they may simply write up the re-sults without any suggestion that they are inadequate.

Actually, your reader is aware of the origin of such difficulties and is not interested in blaming anyone. He will be most grateful, and may even admire you, if you give him a frank and open statement of omissions, errors, inac-curacies, or even gross blunders; and he will definitely not appreciate being forced to wade through your incompre-hensible doubletalk in order to find out for himself that your work has grave faults.

Shadowboxing

Clear technical writing presupposes ability to think logically. Such ability as you have represents years of training, and no effort will be made in this pamphlet to add to it. Some remarks will be made, however, on the illogical or irrelevant outbreaks that occasionally arise to bewilder the reader.

Sometimes a usually rational author will produce some-where in his report an essentially incomprehensible state-ment. Questioning in such cases may bring out that the statement involves a complex of motives and is the result of an effort to overload it with special meaning. For example, it may represent a refutation of some remark by an associate (perhaps the boss) or of some statement published by another worker in the same field, and the phraseology may constitute an effort to be very polite (or perhaps impolite) in this refutation. Such a delicately cut statement with both scientific and personal undertones tends merely to confuse the reader, and its significance may be lost even on the person for whose special benefit it was composed.

Such shadowboxing is, of course, only one of the motives behind the impenetrable fogs that sometimes settle over simple technical discussions. Another common motive is the desire to build a sentence or a discussion around a particular phrase that has taken the author's fancy. It may be some

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heroic remark by Julius Caesar, or it may be some impressive technical phrase equally inapplicable in the particular sentence.

The remedy for such apparently illogical outbreaks is to avoid secondary motives and efforts at elegance and to stay close to straight scientific reporting. In general, if you find yourself struggling excessively in composing a statement, you might do well to pause and ask yourself whether the idea is necessary and, if so, whether it is actually complex or whether you are muddling it as a result of extraneous motives.

CLEAR THOUGHTS, CLEARLY EXPRESSED

Words

Only a few remarks are needed with regard to choice of words. As has already been suggested, avoid using a rare word unless it is essential. Under no circumstances use a common word in a rare usage, because it will mystify your reader without even suggesting that he consult an unabridged dictionary. Foreign words and phrases should not be used; whatever elegance or subtlety they may add to your paper is probably lost on your reader, who will merely find the paper that much more difficult to follow. These remarks, of course, do not refer to the technical words of your branch of science. Be sure, however, that your technical words are not merely the jargon of your own laboratory, because such language can be meaningless to workers at another laboratory.

This advice is possibly contrary to the style encouraged during your formal education, when your English instructor may have beamed if you used a phrase from Shakespeare or a bit of Latin in your themes. Now you must emphasize clarity and easy readability, remembering that your readers are not English instructors, and save your ornamentation for other occasions.

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Sentences

One cannot prescribe, for sentences, "do" and "don't" rules that are as simple and obvious as those just presented for words. The basic purpose, however, to present your material as clearly as possible is still your guide; and the following few suggestions, of fairly general applicability, will exemplify the approach.

The length of a sentence should generally not exceed about 35 words, unless it is broken up (as by semicolons) into two or three distinct and logically consecutive parts. Any sentence presents the reader with the task of first identifying its constituent phrases, and then bearing them all in mind while their logical interrelation crystallizes. Forcing him to bear in mind and fit together more than about 10 phrases (each of about three words) is unnecessarily cruel. Here again your English instructor's joy at your ability to compose grammatically correct 200-word sentences must be disregarded as against your present goal of simplifying your reader's job.

An equally important rule is that a sentence should generally contain some indication as to how it is related to the preceding sentence or to the development of the paragraph. This indication is usually near the beginning of the sentence. For example, in the first three sentences of this paragraph, the opening phrases ("An equally important rule," "This indication," and "For example") all serve to show relationship to what has gone before. Omitting such tie-in wording may not essentially alter the main content of the sentence, but it forces the reader to figure out for himself how the sentence fits into your train of thought. In general, then, you must remember, while composing each sentence, to indicate by appropriate wording how it is related to the preceding sentence. You must take your reader by the hand, and lead him step by step along the path by which you develop your topic.

Make every effort to eliminate ambiguous phraseology from your sentences. Unfortunately the English language offers many opportunities for ambiguity, as in the following well-known pitfall:

Time flies.　　You can't.　　They fly too fast.

where the reader is quite confounded by the third sentence until he goes back and reinterprets the first two sentences. Ask yourself as you write each word, phrase, or sentence whether its meaning would be clear or whether it has a chance of being momentarily misunderstood.

Frequently a particular fact or idea must be stated more than once in a report; for example, it may be given in the Introduction and then also in the Tests and in the Discussion. Rather than treating it every time as brand-new material, you might introduce the repeat with a phrase such as "As has already been mentioned" or "Here, again, the fact that . . ."; otherwise the reader may wonder whether his memory is playing tricks. Such introductory phrases are not always essential, but their omission can sometimes be very annoying.

Paragraphs

The main characteristic of the clear paragraph has already been mentioned; namely, that the relation of each sentence to the preceding or following one be clear, as by means of transition words or phrases. In addition, it may be desirable to indicate definitely the relationship of each paragraph to the preceding or the following one. Usually the relationship to preceding material is indicated in the opening sentence or sentences of the paragraph; and relationship to following material is indicated in the final sentence or sentences of the paragraph. In any case, make sure that your reader is not required to proceed very far into the paragraph (say, beyond the second sentence) before the general drift of the subject matter becomes apparent. Do not make him read on and on while wondering just how the paragraph fits into your report. You, as the author, are

in a much better position than is your reader to organize your material; and the responsibility both for organizing it and for showing the organization rests on you.

Do not make your paragraphs too long. Just as a sentence with too many phrases is difficult to grasp as a unit, so is the paragraph with too many sentences. A long paragraph should not, of course, be broken up into shorter ones by arbitrary subdivision. If you find your paragraph getting very long, either simplify the idea or break up the idea into smaller units, with a paragraph for each.

ORGANIZATION OF A TECHNICAL REPORT

Different writers have different methods of organizing their reports, and some seem to have no discernible method at all. Most of the better writers, however, appear to be in remarkably close agreement as to the general approach to organization. This approach consists essentially of stating the problem, describing the method of attack, developing the results, discussing the results, and summarizing the conclusions. You may feel that this type of organization is obvious, logical, and natural. Nevertheless, it is not universally accepted. For example, many writers present results and conclusions near the beginning, and describe the derivation of these results in subsequent sections. Although some obvious arguments exist for this latter type of organization, most readers and most of the better writers seem to prefer the former. The straightforward organization, then, is recommended here, not only because it seems basically more logical, but also because your reader will be more familiar with it and will therefore have to expend less effort in understanding your paper if it is so organized. Even if he is impatient for the final results and conclusions he can merely turn to the back of your report; and he will hardly demand that you destroy the logical sequence of your presentation in order to present the conclusions first.

The following sections discuss the main parts of the report in more detail. As already indicated, the detail will be far from complete, since the purpose is only to throw some light where the inexperienced author most often blunders. The experimental research report and the analytical research report will be treated separately.

The Experimental Research Report

The typical report of experimental research is organized roughly as follows:

1. Introduction   4. Results
2. Equipment   5. Discussion
3. Tests   6. Conclusions

The contents of these parts will be briefly reviewed.

Introduction—Many people have a notion that the Introduction serves to put the writer's best foot forward, to charm the reader and excite his interest, or somehow to ease the reader into the subject matter; and they accordingly struggle to produce a literary gem with which to begin the report. Actually no gems are needed or are particularly desirable. The Introduction may be written in a straightforward manner along the lines indicated in the following idealized outline:

(a) Begin by describing enough of the background to show where or how the problem arose and how important it is. For example:

> As a result of such-and-such developments, such-and-such problems have arisen. In reference 1, such-and-such phases of the matter were studied. In reference 2, certain other phases were studied. The results, however, leave the question of . . . unsettled, so that the basic problem of . . . remains, and it is not yet possible to design accurately. . . .

The main question in your composing such an opening is whether you actually know the background well enough to write it accurately, with the emphasis placed correctly. If you are not sure, reread the references or go to your super-

visor (or to whatever expert is available) and ask him to discuss the whole subject with you. In general, do whatever is necessary to give yourself sufficient background to compose an opening that will not confuse the reader with inaccurate or off-key statements.

It may happen that an adequate review of the background, with enough detail to clarify the precise contribution of your report, would be much too long to be included in the Introduction. In such a case, summarize it in this first section of the Introduction and provide a separate chapter for the detailed background (or perhaps give the background detail at appropriate points throughout the paper, depending on the nature of the material).

(b) Having indicated where the problem exists, or, in general, what the background is, now state broadly what it is that you have tried to contribute by your research and along what general lines you have worked. For example:

> In an effort to obtain further insight into . . ., an experimental study was made of . . ., with special emphasis on. . . . The material available was considered to be especially favorable for the study because. . . . Furthermore, special apparatus (to be subsequently described) developed for this purpose was capable of . . ., thereby providing information of (a previously unavailable) type. . . .

(c) Your reader is now aware of what you have tried to do and why. It is usually desirable at this point to add a final portion to the Introduction, in which you state more specifically what types of tests and analyses were made, the ranges of variables considered, and similar information that broadly defines the nature and extent of your work. The reader will thereby get an insight into the scope and thoroughness of your research and will know what to expect in the report.

These three sections thus constitute the typical Introduction. Frequently the three sections are found in three paragraphs, but such sharp separation is not essential.

One of the sections may require two or more paragraphs, or all three sections may be contained in one paragraph.

The general applicability of the preceding formula, as well as the ease with which it can be applied, is illustrated by an experience in a report-writing class of about 20 young research engineers. After receiving a brief lecture on the preceding material, every member of the class was able to write out, in less than an hour, an acceptable first draft of an Introduction for the report that he would eventually be writing on his research.

Apparatus and Tests—Normally, the final portions of your Introduction will have provided enough insight into the nature of your study so that little or no argument for your choice of equipment or technique is needed. You may then simply give a straighforward description of your equipment under Apparatus. If, however, some particular ingenuity was involved, be sure that your presentation makes the matter clear. The reason is not that you must brag wherever possible, but that you must not present something new with so little emphasis (as if it were obvious or well known) that the contribution cannot be recognized. The same rule, of course, applies to any part of your paper; a reader becomes very bewildered when he cannot make out from your discussion what is old and what is new.

Sometimes different tests may have required different pieces of equipment, or you may have developed your apparatus as you proceeded from one test to the next. In such a case, do not hesitate to make Apparatus and Tests a single heading. If the two are not so intimately related, however, a separate chapter, Tests, will generally be preferable.

Results and Discussion—Some authors prefer, wherever possible, to present all their experimental results (as in the form of charts or tables) first, under Results, and then to discuss them, others prefer to discuss their results as they are presented. Sometimes the subject matter develops in such a way that one or the other method is obviously to be

preferred. In any case, the nature of the decision is similar to that discussed for Apparatus and Tests and will not be further discussed here. Although this part of a report is normally the most important part, adequate presentation depends mainly on careful and logical analysis of the material rather than on rules of report writing. The following remarks, however, may be useful.

You will recall that in the Introduction you described the problem and what you hoped to accomplish or contribute. Bear this Introduction in mind while you present your data, and show by your discussion how these data shed light on the problem or, in general, to what extent your originally stated objectives were achieved. Some authors also find it helpful to prepare a list of the main points that were developed in the investigation (these are, essentially, the final Conclusions of the report) and then to aim the Results and Discussion to bring out these points.

Organization along some such line is essential. Avoid a rambling, disorganized presentation. Above all, avoid the ponderous revelation of unenlightening trivia, such as "It may be seen by reference to figure 8 that the lift increases with angle of attack until the stall is reached, beyond which. . . ."

Conclusions—Your Results and Discussion will already have brought out the main contributions of your work. It has become standard practice, however, to gather together these main contributions and enumerate them in a final section called Conclusions. Essentially, the Conclusions state concisely (seldom more than two sentences per conclusion) what you have concluded from your research. They are the answer to "So you have done a piece of research. Well, what did you find out?" They should be written with little or no reference to the body of the report, as a favor to those readers who like to go directly from the Introduction to the Conclusions in order to see how it turned out. An additional purpose in making them approximately self-sufficient is to minimize the possibility of a misunderstanding

if they are quoted. (For similar reasons, incidentally, it is generally desirable that figures be reasonably self-explanatory.)

Sometimes the research turns out in such a way that enumerating sharply drawn conclusions is practically impossible. In such cases a short discussion of the problem and what you learned and believe about it should be given under Conclusions. Sometimes, however, the original problem, as stated in the Introduction, remains essentially unanswered (as when the experimental technique turned out to be inappropriate, or the information obtained turned out to be less useful than originally expected). A frank discussion of the situation, together with, possibly, suggestions for future research, is preferable in such cases to drawing uninteresting or irrelevant conclusions. Such a final section is generally entitled Concluding Remarks.

Sometimes the technical report merely describes equipment or procedures, or it tabulates design data obtained by standard methods. Neither Conclusions nor Concluding Remarks is usually appropriate or desirable for such a paper. If a closing section is desired, it might be a Résumé, in which the information is briefly sketched and the charts or tables containing the data are indicated.

Chapter headings—In the preceding discussion the chapter headings were assumed to be the standard ones previously mentioned (Introduction, Apparatus and Tests, and so on). Although these headings are quite satisfactory, more specific titles are preferable whenever they can be used. Thus, instead of Apparatus, you might use Wind Tunnel and Models (or two separate chapters, one entitled Wind Tunnel, the other, Models); instead of Results and Discussion, you might use Dihedral Effect, Longitudinal Stability, and so on (again, there is no objection to having several main headings to replace Results and Discussion). The headings Introduction and Conclusions (or Concluding Remarks or Résumé) are almost never replaced by more specific titles.

Tables, charts, and figures—The inexperienced writer tends to present his numerical results in the form of tables, usually because he has studied his results so thoroughly that he can see the significant trends from the numbers themselves. The reader, however, is much less familiar with the results and may fail to see from the tables the trends that seem so obvious to the author. In general, visual presentation by means of charts or curves will put across your points much more effectively. Furthermore you should give considerable thought to the question of how to plot your results so that their message will be most easily grasped. Crowding too many curves on one figure should be avoided so that the reader can easily identify each curve as you discuss it in the text.

State clearly in the text what each figure shows and how the figure shows it. Avoid referring to a figure in so casual a manner (as by the simple parenthesis (fig. 2)) that the reader himself must determine how the figure is related to your discussion.

Summary—Among the scientific journals there are a number, such as Science Abstracts, Chemical Abstracts, and Applied Mechanics Reviews, that provide abstracts, or summaries, of practically all published papers in their fields. The actual preparation of the abstracts is performed free, or for only nominal payment, by a large number of dedicated scientists who do this essential work at considerable personal sacrifice. The Summary that you append to your paper is your contribution to this effort, and it should be prepared in such a way as to lighten the abstractor's burden. That is, it should be capable of being used directly as the abstract or of being easily summarized further if a relatively short abstract is desired.

In general, the Summary should contain only a minimum of background and should proceed as quickly as possible to describe what was learned. Considering that the report itself may not be readily accessible to the reader, put into

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the Summary what you consider to be the most valuable contributions that the report makes, including the most significant conclusions and some mention of interesting techniques or concepts. There is no room, of course, for all the detail that you would like. In any case, however, include enough so that the reader can determine whether he should exert himself to get a copy of the report itself for closer study.

Note that the Summary is not actually a part of the report itself, so that duplication of portions of the report need not be avoided. For example, you need not hesitate to include sentences lifted unchanged out of the Introduction, Conclusions, or any other part of the report.

The reader of a report will frequently begin by reading the Summary in order to get a quick review of the contents. You need not give any extra thought to such a reader, however, since the material that satisfies the primary purpose of the Summary will adequately serve this additional purpose also.

The Analytical Research Report

Theoretical or analytical papers may not fit into standard organizational patterns as readily as do the usual experimental papers. The remarks previously made with regard to the Introduction and Conclusions still apply, but the body of the paper is arranged in whatever manner seems most logical. A long theoretical development, however, frequently tends to leave the reader unable to see the woods for the trees. Accordingly, you might do well to include near the beginning of such a report an overall view of your line of development, and as you begin each chapter, indicate what will be done in that chapter and how it fits into the development. Incidental material, such as a side proof or derivation, may be put into an appendix in order to avoid interrupting the continuity of the main development.

REVIEWS AND CRITICISMS

After your paper has been completed, it will generally be reviewed by one or more separate reviewers or by a reviewing committee. Many authors seem to consider such a review to be an unwarranted impertinence, and they approach the review with various bewildering psychological defenses, ranging from "Here I am. Crucify me!" to "Do you wanna fight?" Needless to say, such attitudes are absurd. Your purpose should not be to exhibit your own brilliance as against the reviewer's wickedness and stupidity, but only to make your paper more readable and more accurate scientifically.

Consider all comments and suggestions carefully. Some of them may be incorrect or may indicate that the reviewer has not understood you. In such cases, do not scold the reviewer, but try to determine where he was misled and consider whether others might be similarly misled. If an appreciable likelihood exists, try to revise the material so that this danger will be minimized. Remember at all times that your report should be clear and that your reviewer is probably a typical reader—or is at least typical of a considerable proportion of your readers. The fact that you can explain a passage to his satisfaction does not mean that the passage is satisfactory; it must be written so that it will be clear to the reader even when you are not present to explain it.

Sometimes the reviewer will make an important technical contribution to your report, such as a clearly superior method of developing an equation. Such contributions should be accepted. Do not insist on publishing inferior material merely because you do not wish to take credit for what is not yours. Your responsibility to your reader is still paramount. It may be appropriate, however, to acknowledge the reviewer's contribution in the text, to ask him to write an appendix under his own name, or to make him a coauthor.

THE TECHNICAL TALK

You have doubtless been subjected to the lecturer who buries his face in his papers and, in an expressionless voice, reads long involved sentences while waving vaguely toward hopelessly complicated charts. One may wonder why any rational person would commit such an atrocity; yet many research workers actually seem to have no better concept of what a technical talk should be. Needless to say, the talk, like the printed report, should convey information.

Simplicity

You will be given, say, 20 minutes in which to present to visiting scientists a review of your research. Your first reaction is to insist that you need more than 20 minutes. Your arguments will be rejected, however, so you eventually proceed complainingly to your task. With great ingenuity you apply yourself to outwit your stubborn and arbitrary boss by getting an hour's material into a 20-minute talk. You concoct long and brilliantly comprehensive sentences for your discussion, you organize all of your numerical results so that you can present them in rapid-fire order, and you lay out 15 slides, each crammed with detailed information. Unfortunately, when you first read through your prepared speech, it takes nearly 30 minutes instead of 20. You are not very disturbed, however, because you are confident that, with a little practice, you will be able to increase your speaking rate until the delivery time is down to the required 20 minutes.

All that is missing from your approach is consideration for the central figure—the man in the audience. After 2 minutes of your talk he will be rapidly developing mental indigestion; after 5 minutes he will have lost the thread of your discussion; and during the remainder of your talk he will simply concentrate on hating you or on trying to sleep. If you will consider that he will probably hear about 15 talks during the day, on a variety of subjects in perhaps none of

which he is expert, and if you will ask yourself how much a person can hope to learn in one day (learn, that is, so that he will remember it for a long time), you will see the futility of trying to cram detailed information into him as if you were stuffing a goose. Actually, your mission will usually be successfully accomplished if you leave him with a fairly clear impression of the nature of your work and of your most significant results or contributions.

In preparing your talk, then, your first task does not consist of gathering together all of your data so that not a single detail is missing, but rather in thinking over your subject and deciding just what fundamental progress you have made, or what new fundamental ideas you have developed, that you wish to give your hearer to carry away with him. In fact, you will do better not to reacquaint yourself with the details at this time, because if you yourself have forgotten them they certainly do not represent the basic new ideas or contributions that you would like your hearer to remember. Details such as numerical data have their place, of course, in the technical talk; but you must make clear whether the numbers are of such fundamental importance that they should be remembered as such, whether they are presented for comparison with other numbers, as in showing trends or in showing agreement between theory and experiment, or whether they are presented merely to show the thoroughness or the scope of your work (as when the research consists of determining large quantitities of design data).

You should next consider how to organize your presentation with utmost simplicity and logic, so as to maximize the probability that your hearer will absorb your story. As to whether the allotted time is adequate, the question need not concern you. You should be able to describe your work in any specified amount of time, be it 1 minute or 1 hour, and all that is required of you is that you present as informative and understandable a story as possible within the allotted time.

Choice of Language and General Approach to Presentation

Suppose that your friend Joe should ask you to tell him about your research. Would you proceed with language of the following type?

> The momentum method of measuring profile drag, which consists of making total-pressure and static-pressure measurements across the wake and inserting these measurements into certain integral expressions developed by Betz and Jones, has been an important addition to experimental aerodynamics. Unfortunately, application to flight evaluation of the drag contributed by wing surface roughness or by various protuberances has been hampered by the experimental difficulty of making the necessary number of simultaneous pressure measurements in the wake.
>
> In the present research, an effort has been made to reduce the experimental complication in order that application to flight testing may be made more practical. . . .

Such sentences might well be the introductory sentences of a printed technical report; but as spoken material they demand a degree of concentration that most listeners cannot maintain. If, in addition, they are spoken in a rapid monotone, the listener's position is hopeless almost from the very beginning.

Actually, as a result of your years of experience in conversation, both technical and nontechnical, you have developed a speaking style that is not too demanding of either your own or your listener's mental processes, and that serves satisfactorily to convey your ideas; and this speaking style, in general, is entirely different from that of a printed technical report. Using this style, you would speak to Joe perhaps as follows:

> You're probably familiar with the momentum method of measuring profile drag (a pause, while you look at him to see whether he nods his head or merely looks blank; you decide to add a few words of

explanation), in which you measure total and static pressures at a number of points across the wake, put the readings into certain formulas, and finally integrate across the wake to get the drag (a pause)— the profile drag, that is. The method ought to be especially useful for flight measurements behind actual airplane wings, in order to determine the drag due to (a pause, a slight motion of the hand, while you think of examples) rivet heads, gun ports, or any other irregularities. Now, trying to make all those measurements in the wake would require rather complicated instrumentation—which is the reason that it hasn't been done—and what I have tried to do is to simplify the method—especially to simplify the instrumentation—down to something more practical. . . .

Such language and the indicated mannerisms (pauses, hand motions, and so on) are more characteristic of some people than of others. Your own normal manner of speaking, for example, may be entirely different. There is no objection at all to your having and expressing your own personality; and it is definitely not suggested that you try to imitate anyone else's mannerisms or style of speech. The point emphasized here is that, in general, merely reading or reciting a carefully written technical report does not constitute a technical talk. In your daily technical discussions with your coworkers, or if you were teaching a class, you would not expect your friends or students to understand you if you poured forth such formal language—especially if you spoke rapidly and with an expressionless voice; and you should not demand more of an audience at a technical conference.

The conclusion, then, is that the technical talk is not merely a technical report that is short enough to read or recite in, say, 20 minutes; rather, it is a monologue, presented in whatever conversational, or perhaps teaching, manner is natural to you, in which you try your very best to get across a few basic ideas to your audience. Since the man in your audience cannot reexamine any sentence or para-

graph that he finds confusing, you must make every thought clear enough to be understood the first time. If the thought is a difficult one, you may even find it best to repeat it. You may repeat it in the identical words, or you may use different words and a slightly different approach. For example, add "Perhaps you didn't quite follow that idea. What I mean is that if . . . ." Speak easily and not too rapidly. Even an awkward hesitation, while you grope for the right word (just as in normal conversation), may have some value in that it excites the hearer's interest while he tries sympathetically to guess the word you want. Avoid, however, affecting excessive casualness or extemporaneousness, since the effectiveness of the talk can be spoiled by the appearance of carelessness in its preparation or lack of earnestness in its presentation.

In general, the talk should not be written out during its preparation. The inexperienced speaker will usually be unable to write anything but the formal sentences of the typical printed report, so that his talk is ruined from the moment he puts pencil to paper. Compose it entirely in your mind, and, as you compose each sentence, make the hand motions, hesitations, facial expressions, and so on that will accompany it. At the same time ask yourself whether it will be clear; and if not sure, struggle with it some more. After you are satisfied with your opening sentences, your conclusions, and a few other especially critical sentences, you may write them down in order to assure having them exactly as you composed them. Do not try to improve them as you write them down, however, for you will surely spoil them.

The question as to whether your talk should be memorized will now be seen as rather irrelevant and misleading. After you have composed and rehearsed your talk so that in two successive rehearsals (alone or with a friend) you were satisfied with it, you may be sure that the final talk will be satisfactory. Some speakers will, by this time,

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have essentially memorized every word and gesture, while others will remain quite flexible as to detail. There is actually very little chance that you will forget anything important, and no more than a small card outlining your main points should be taken with you to the speaker's stand.

It is not intended here to imply that preparing and delivering a talk in this manner is a simple task for the inexperienced. The same, perhaps, applies to almost all the precepts presented in this pamphlet—they are easier to agree with than to incorporate in your style. On the other hand, the task is not nearly so formidable as many people seem to believe. The technique is merely one more of those that could not be taught in your formal schooling but that you have to learn in order to be effective in your job.

Does the danger of stage fright make you want to rely on written copy? Actually, much less reason exists for emotional reactions in technical talks than in typical college "public speaking." In the latter, emphasis is generally on demonstrating or exhibiting the speaker, with the contents of his speech of minor significance, whereas, in the technical talk, the contents are of paramount importance, while the speaker is merely the medium through which they are presented. If you should ever listen to the comments of an audience after a technical conference has adjourned, you would find that oddities of presentation, such as strange accents, speech defects, nervousness, or even grotesque eccentricities of manner seem to go virtually unnoticed so long as they do not interfere with intelligibility, while bitter criticism is applied to speakers who read incomprehensible papers. Bear in mind, then, that you are not required to give a polished performance, but only a clear one. Your listeners are not interested in judging you. They want only to understand what you are telling them.

Visual Aids

In the preceding discussion the point has been emphasized repeatedly that your technical talk should resemble as closely as possible the description of your work that you might give to your friend Joe. Just as you might show him your apparatus or your plots, or perhaps go to the blackboard and make an explanatory sketch, so should you use the same or similar visual aids in your talk. Instead of being shown on paper or on the blackboard, your illustrative material will normally be on charts or slides, prepared in advance with all necessary accuracy, clarity, and neatness. Do not consider, however, that such previous preparation saves much time in the presentation, or that you may present a chart with nothing more than a vague gesture and a remark like "This chart illustrates what I have just said."

Actually, your charts and slides form the backbone of your talk, and each must be presented with utmost effort at clarity. State the subject of the slide, say what the abscissas and ordinates are, explain, if necessary, the special significance of these abscissas and ordinates and of the method of plotting, and, if the origin is not at the juncture of the scales, mention that fact also. Run your pointer along each curve as you describe it, and tap sharply with your pointer at any point on the curve to which you call special attention. (But avoid vigorously rubbing or gouging the projection screen with the pointer, as the glass-bead surface is easily damaged.) Furthermore, the language used while discussing your slides should be appropriate to your use of the pointer. For example, say "This top curve shows . . ." rather than "The upper curve of figure 5 shows . . ." or "You can see in this equation that this term cancels this term and this term cancels this term" rather than "It may be seen in equation (4) that the third and fourth terms on the left side are canceled by the second and fourth terms, respectively, on the right side."

Make every effort to keep your charts and slides simple. As has already been emphasized, your purpose is to get across a few basic ideas rather than to present large quantities of information.

The number of slides and charts to prepare depends, of course, on many factors and can hardly be prescribed by formula. Nevertheless, it may be of interest to note that experienced speakers seem to use, on the average, about one slide for every 2 or 3 minutes of their talks. Presumably, if you use fewer slides, you may be needlessly sacrificing helpful illustrative material, or else you may be trying to crowd too much on each slide, while if you use more slides you may be trying to present too much information. "Two to 3 minutes per slide," of course, is hardly the type of rule to be followed strictly; it is mentioned here only as a guide to the inexperienced speaker. The only rule that is absolutely basic is that your material should be presented as clearly as possible.

Organization and Contents

The organization and contents of a technical talk are, in general, similar to those of the written report, although a certain degree of flexibility is permissible for the purpose of increasing clarity or of maintaining interest. As has already been indicated, thoroughness, completeness, and rigor may have to be sacrificed in order not to present your hearers with more than they can assimilate. Emphasis will be on no more than a very few topics, and all the incidental material that would be meticulously detailed in a printed report will be largely eliminated from the talk. For example, if your experimental results and their implications form the essence of your talk, you should minimize the description and justification of your experimental technique. Here, of course, your language and manner are especially important— while curtailing your remarks on experimental techniques, you must nevertheless give your audience a feeling of reasonable confidence in your results.

Technical talks frequently seem to be organized around slides or other visual material. The talks seem to consist only of descriptions and discussions of the slides, and even the Introduction and the Conclusions may depend on slides. There is no objection to such a presentation, so long as the speaker gets his message across. You must not conclude from such talks, however, that the slides were prepared first and the talk was then composed around them. Slides and charts should be composed along with the talk, not before it. Avoid preparing them first and then trying to decide what to say about them, because a considerable loss of smoothness and logic may result.

The Printed Version

If a printed version of your talk is to be included in published proceedings of the meeting, write it in the more formal style of printed reports; but by no means feel obliged to carry over the same language and coverage into the talk itself. The printed version may, indeed, include data and discussion that had to be omitted from the talk, and may even include figures and tables that were not used in the talk itself. Such extensions of the paper should be held within bounds, however; published proceedings of technical meetings are not usually intended as substitutes for normal published reports.

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