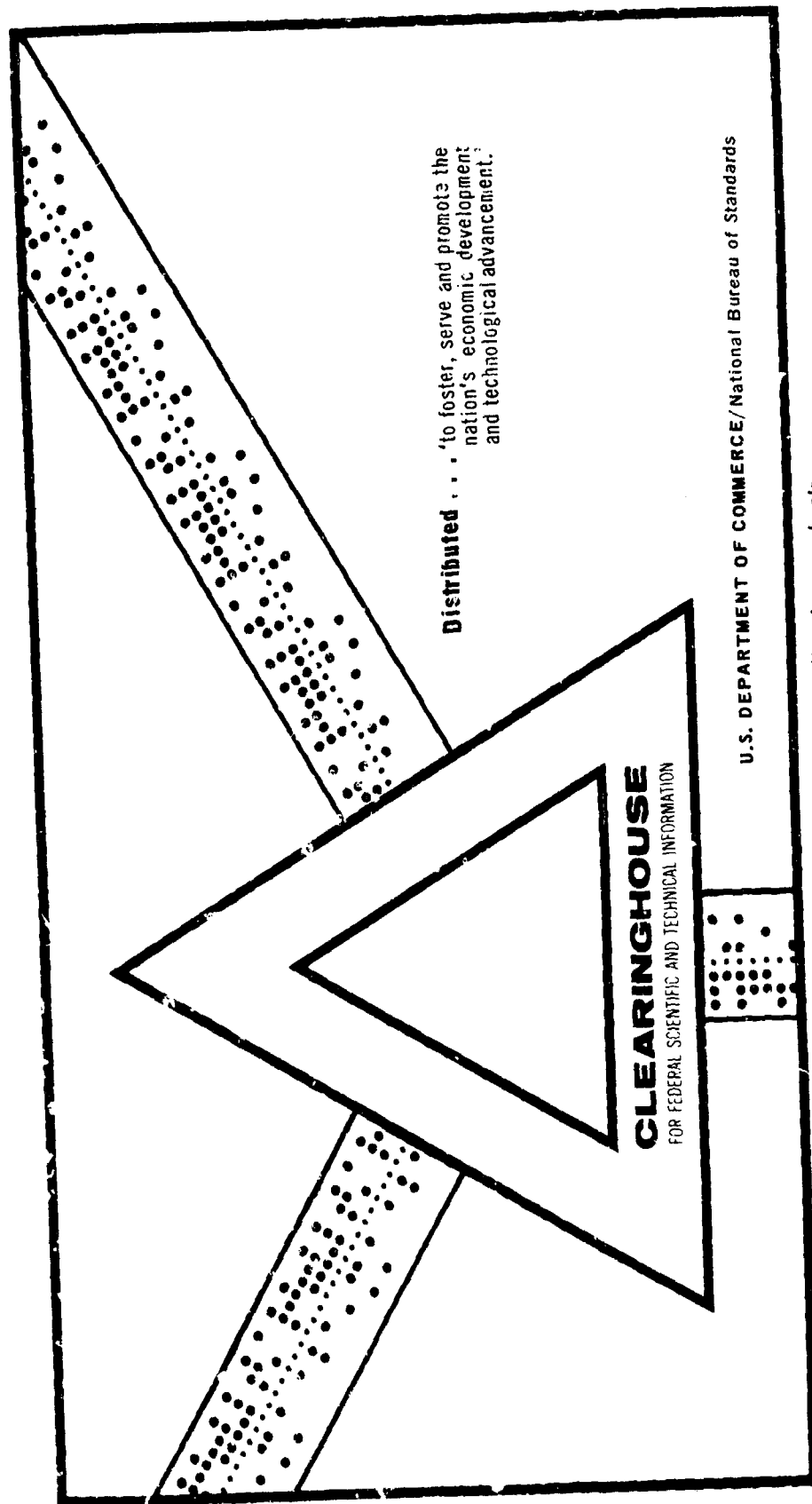


AD 701 133

PREPARING A TECHNICAL REPORT ON AN INVESTIGATION

Arctic Construction and Frost Effects Laboratory
Boston, Massachusetts

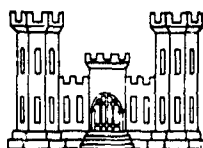
November 1956



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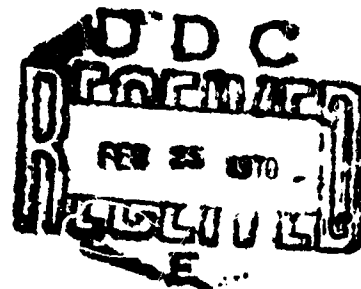
PREPARING A TECHNICAL REPORT ON AN INVESTIGATION

AD 701133



INSTRUCTION REPORT NO. 1

November 1956



Prepared by

Arctic Construction and Frost Effects Laboratory

New England Division

CORPS OF ENGINEERS, U. S. ARMY

Boston, Mass.

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PREPARING A TECHNICAL REPORT ON AN INVESTIGATION

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Preface

This instruction report is intended to assist authors in the preparation of clear and concise manuscripts which can be published as effectively and as efficiently as possible in one of the report series of this organization.

It is not suggested that the outline here set forth is the last word in technical report preparation. There can and should be no frozen rules, nevertheless an office must strive for consistency and hence must have working rules.

We have here given principles to be followed in order to attain at least a minimum of standardization in our reports.

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PREPARING A TECHNICAL REPORT ON AN INVESTIGATION

I. IMPORTANCE OF TECHNICAL REPORT WRITING

What is the importance of the technical report? For the organization, it shows a record of work done which can be referred to after the project is completed or the individual has left the organization, and it also helps to build the reputation for the Laboratory.

It does two things for the author; that is, it keeps his superiors aware of his accomplishments, and it enhances his professional reputation.

For other persons engaged in similar type research and investigation, it may save duplication of effort, and may also provide information, or at least help, in connection with other research programs.

II. GENERAL REPORT CATEGORIES AND COVERAGE

The word "technical," as used here, applies to every type of report which falls outside of the category of administrative reports and their control. AR 335-15 refers to these "technical" reports as exempt reports. It is in this area of so-called exempt reports that the Publications Editor has primary responsibility. As determined by a review of past ACFEL publications, they cover all final, status, interim, contractor, and laboratory reports.

There have been various suggestions made for basic report categories. The OCE "Guide to Good Practice in Technical Report Preparation" (April 1956) lists the following report categories: Technical Report, Research Report, Bulletin, Miscellaneous Paper, Translation, and Instruction Report. This is the grouping we shall use, at least until further notice.

OCE in a memorandum for the record dated 5 October 1955, subject: "Development of Technical Reports Procedure," stated, as its basic philosophy of reports, the following: "Basically, current reports are too voluminous. Material is included which should be retained in the files of laboratories in formalized permanent record form. Fewer photographs should be included and always held to a minimum. The question of which data must be left out cannot be delineated or proscribed and must be determined by the author. The current tendency is to include everything of data category, whereas the desire is to obtain only a minimum of data with the firm knowledge that supplementary data may always be obtained, by the few who need such data, from the laboratory which conducted the investigations."

The above statement does not specify the type of technical report this is considered to apply to. However, it may be assumed to be a report which is prepared for fairly extensive distribution among engineers, scientists, administrators, executives, or officers, within the military agencies of the Federal Government who will, on the average, only wish to make a quick review or scan the contents, and, possibly, read the synopsis and key conclusions.

Certainly, there will also be engineers or scientists who will wish to know complete details of the work reported. On extensive studies, we may need to make compilations which simply assemble the data into usable form. In some cases, the studies may be of such general interest that broad publication is appropriate in order to make the knowledge fully available to the engineering and scientific world beyond the confines of the Department of Defense. Therefore, we must consider the purpose of our report in deciding how much detail to include.

III. PROCESSING THE REPORT

For an extensive investigation the following successive stages of report preparation may be considered:

Data and Computation Book,
Data Report,
Initial Record Report,
Standard Report (for Limited Distribution), and
Publication Report and/or Paper.

These are discussed in the following paragraphs.

a. Data and Computation Book. At the completion of the field work, the first step should be to prepare all data into tables, charts, graphs, photographs, and descriptive material, so organized as to permit ready reference during analysis and, if required, at any time in the future. Charts and graphs should be in pencil form, hand-lettered, neat and legible, but no effort at fancy drafting or lettering should be attempted. Data should be reproducible by the ozalid process, or by photostating, if necessary, and generally during analysis it will be convenient to use prints, rather than originals, as working sheets. Prints can be marked up readily. As this data assemblage is made, such material as original field notebooks and data sheets should be retired step by step permanently to the files, to be referred to only rarely in the future. (Of course, these steps can be anticipated during the investigation, and it may be possible to have this compilation partially or wholly finished by the time the actual laboratory or field test work is completed.)

It is recommended that the working material be placed in a loose-leaf notebook, and record sheets of all significant computations, analyses, and draft sections of text be added in as prepared. The whole thing should always be kept adequately indexed. Try to keep everything in such shape that someone else in the organization can pick it up and make sense of it, if necessary, as if you are out on leave. It is preferable that the book be divided into sections containing like materials, such as Freeze-back, Extraction Tests, Point-bearing Tests, and so on, for easy reference. Remember that all data and computations are U. S. Government property, including original field notebooks. They belong to the Government, and must end up in our official files.

By the time analysis is complete then we will have a detailed compilation of all data and analysis steps involved, which will serve as a permanent and valuable record and reference source. Claremont Dam and Springdale Dike record books are good examples. At the end, the material can be removed from the loose-leaf folder and placed in ACCO-fastened covers or similar type of binder.

b. Data Report. When appropriate, up to as many as perhaps 10 or 12 sets of a comprehensive collection of data sheets may sometimes be reproduced, bound, and forwarded to such other offices as OCE Library, Airfields Branch, SIFRE, and the Consultants for their use and reference as a so-called Data Report.

When an investigation is carried out with another organization, such as the Alaska District, which may have immediate need for the data,

first step in analysis should be to furnish such organization copies of needed graphs, tables, charts, and photographs, even in advance of any analysis.

c. Initial Record Report. It is suggested that, on completion of a substantial investigation, a report be first assembled for working and file purposes which contains all details, large or small, worthy of record. No unnecessary effort should be made in this report toward polishing up English, punctuation, or "prettying-up" of diagrams. It should be readable and understandable by another person of comparable training, if it should be necessary for another to read it, but should not be anything more than that. This type of report has two advantages. First, it provides a basis for organization and preparation of the more polished following report; and second, it protects the office against the possibility that the investigator may not be able to prepare a finished report because of some development beyond his control. The report should, of course, be based upon some sort of more or less logical initial outline, but the care which is appropriate in a final report is not justified. It just doesn't matter in this initial report if the sequence of the various sections actually turns out to be completely mixed up, so long as the substance is there. In case of minor investigations, this report stage may be skipped.

d. Standard Report (for Limited Distribution).

(1) Review Draft. Based upon the data assembled as above, a careful outline should be prepared following the now-approved OCE standards outlined in "Guide to Good Practice," and the material given later here, insofar as practicable. Using this outline, a review draft

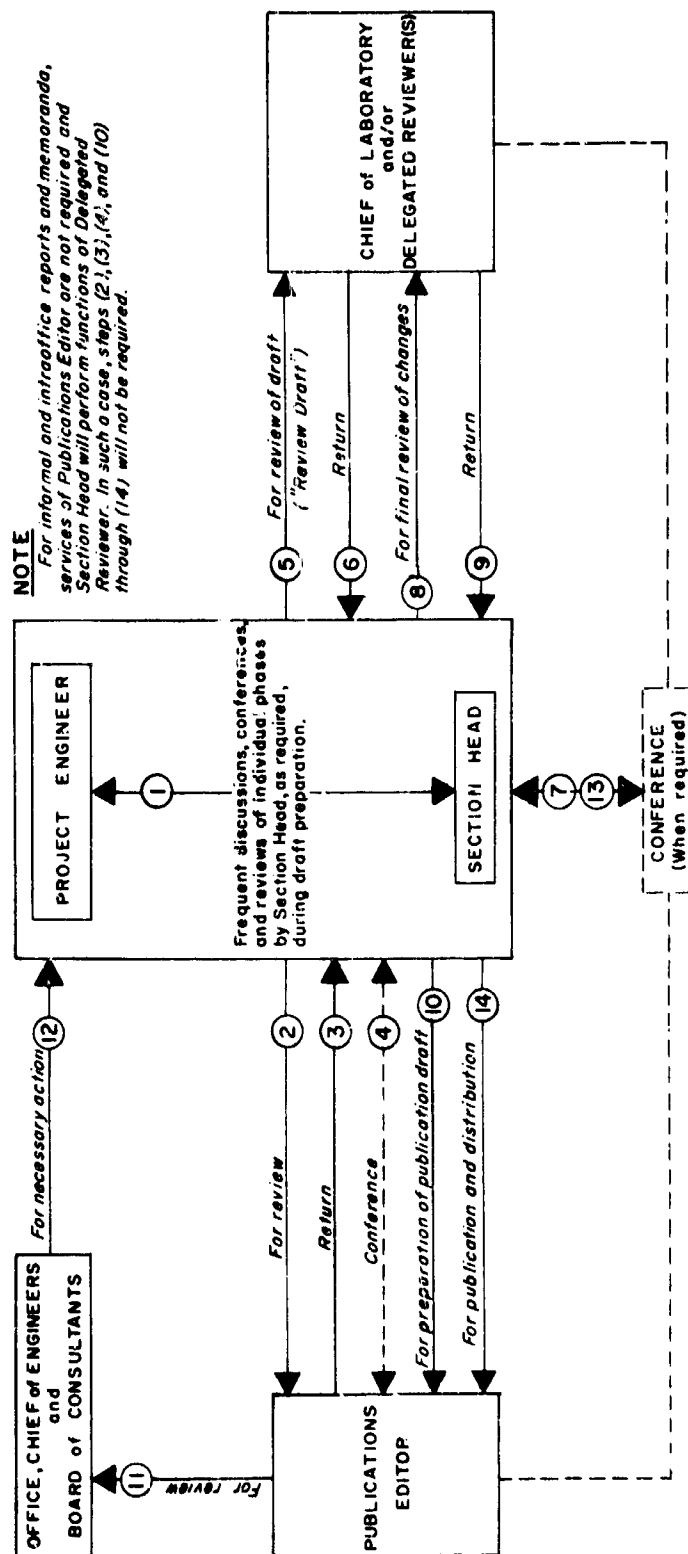
should be prepared. On completion, this draft should be reviewed first by the Publications Editor. See sequence of steps below. When the Project Engineer and the Publications Editor have agreed upon a final form of this draft, it should be prepared in the basic form in which it is intended for final printing and distribution, including cover, title page, frontispiece, preface, synopsis, typed text, tables, graphs, illustrations, and appendixes, except that the written matter will be typed on pink paper and the tabular and graphic materials will be prepared in pencil form, hand-lettered, without refinement, but with all proposed materials completely and accurately shown. The graphs, tables, and illustrations should be in the form of prints, not originals, so that they can be readily blue-penciled during review. This completed review draft should be submitted to the Chief of Laboratory for review or, when necessary, to whoever has been delegated authority by the Chief of Laboratory for such review in the specific case. If properly done, the Chief of Laboratory should be able to read through it quite quickly and should not find any major changes necessary.

In an idealized situation, it will not be necessary for both the Chief of Laboratory and the Delegated Reviewer to examine the technical report under review. Such a situation could be one where the report was prepared by one of our consultants, or by an expert in

a physical science other than engineering, or by a contractor. It is not considered desirable or practicable to accept any report, however high grade the author's regular work may be, without at least tacit approval by the Chief of Laboratory. Conversely, under very unusual or rare circumstances only, will more than one reviewer be delegated authority by the Chief of Laboratory to review a report. It is intended always to keep the number of reviewers down to a minimum and thus avoid the confusion of too many divergent opinions.

(2) Finished Report. When the review draft prepared as above is returned to the Project Engineer by the Chief of Laboratory, it will ordinarily contain numerous suggestions for revisions. A discussion should then be held between the Project Engineer and the Chief of Laboratory, usually including the Publications Editor, at which agreement will be reached on the treatment of the various points raised. The Project Engineer will then complete the draft report in the agreed-upon form; and, upon completion of this phase, should submit to the Chief of Laboratory, for final review, a draft in which by colored pencil or otherwise the parts actually changed are indicated, in order that the Chief of Laboratory will not be required to make a second reading of the entire report..

REVIEW SEQUENCE FOR FORMAL TECHNICAL REPORTS



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Ordinarily, this should result in final and complete approval of the report; after which, the Project Engineer should deliver it to the Publications Editor for reproduction, submission to OCE and Board of Consultants for review and/or approval, and after agreement on any final revisions, for final assembly and distribution.

To summarize the philosophy which should be followed, it is felt that if a report is properly prepared it should be necessary for the Publications Editor and the Chief of Laboratory, or other reviewer, to go over the report only once except for the specific sections in which substantial changes are required to be made. It is believed that by the time the final review report reaches the Chief of Laboratory only minor changes should be necessary as a result of the review. This means the report should be clearly presented, follow a logical and accepted sequence, be easily understandable, be expressed in good English, and present to the reader an impression of an objective, impersonal, and truly professional and workmanlike presentation.

At all stages during the preparation of the report, more especially during the initial stages when the general outline and approach are being crystallized, frequent review, discussions, and conferences should be held between the author and those who will be responsible for review and check. By this means, the possibility of any major changes being required in the final stages should be eliminated.

In the review, care is required in suggesting or making changes. It should be assumed that the author has carefully chosen his method of analysis and descriptive terms. Anyone suggesting changes in a report should be prepared to support them with his reasons why those changes should be made.

e. Publication Report and/or Paper. When a report is considered worthy of greater than the usual limited distribution it may be written originally as a "publication report," or a special version of it may be prepared from the Standard Report for such distribution. Such a "publication report" will ordinarily be printed in the number of about four or five hundred copies and may show a price on the cover. Also, it will frequently be found desirable to prepare technical papers for publication in engineering or scientific journals, in which case, the paper will usually represent a condensation of the material prepared as in paragraphs a through d above.

When an interim or similar report is prepared, which covers only part of a complete study, exactly the same philosophy should be followed as has been outlined above, with such modifications in procedure as are applicable in the specific instance. This includes compilation of data and computation records.

When a contractor furnishes a technical report in partial fulfillment of the terms of his contract, the report will be reviewed by the monitor of the contract in the Laboratory to determine whether the report has sufficient merit for publication in one of our series. If the monitor believes the report should be published, he will thoroughly review the report's contents as the "delegated reviewer" in this instance. However, the report will be examined also by the Chief of Laboratory and the Publications Editor for concurrence or rejection of the monitor's recommendation on publication. If the report is highly technical and requires the services

of a mathematician or other specialist for proper review and evaluation, with the concurrence of the Chief of Laboratory, another individual possessing the required qualifications may be assigned the review responsibility. Occasionally, it may be necessary or desirable to retain the services of an independent expert or consultant for this purpose.

In those instances, where it is agreed by all or a majority of the reviewers of a technical report prepared under contract that it is not worthy of being included in a report category of this organization, the contractor's report will be handled as a "data report" or an "initial record report".

IV. STRUCTURE AND CONTENTS OF REPORTS

The technical report will be composed of the following parts and will include almost all of them in accordance with the data to be presented.

a. Cover and Title Page. The title page will include the following information: Corps of Engineers, U. S. Army; title of report; when applicable, author or authors (name and title); contract number, if any; report series and number (assigned by the Publications Editor); ACFEL; OCE; date; and printing office designation. The cover will contain approximately the same information as the title page, in briefer form, with the one additional factor, the emblem of the Corps, that is, the castle; which will ordinarily appear as shown on example, Inclosure No. 1. Inclosure No. 2 shows typical title page.

For information on use of flyleaf, frontispiece, and key, refer to page 7 of the OCE Guide. Of these three "preliminaries", the frontispiece has the most opportunity to be included in our reports. If it is used, the frontispiece will appear on the back of the title page to comply with printing regulations of the Adjutant General's Office although contrary to accepted and good printing standards.

A frontispiece may be included whenever the author has an unusually fine photograph of an area which may be either the subject or a main part of the study being reported. A detailed map is also considered to make an excellent frontispiece, especially one that the reader will have constant reference to.

The frontispiece does not carry a "Figure No."; however, it may be fully captioned when necessary for clarity or better understanding.

The name of the author or authors will appear on the report title page when it represents exclusively his personal efforts and contribution. Whenever a "team" effort is involved, the names of those ACFEL personnel who have been substantial or principal contributors will be given in the preface, even when a separate acknowledgments section is used at end, and will not appear on the cover, as discussed later. Listing of names only in the preface will be the usual case. In our investigations, for example, one man may suggest the original ideas for the study, another may prepare the detailed plan of action, a third may be responsible for the actual field or laboratory work, a fourth may make a special mathematical study necessary in the analysis, and so on, and the result is so much better than would have been produced by any of the men individually that it would be unfair to give any one of them exclusive credit.

The name of the author or authors will always appear on the cover when it is a paper prepared in form for publication in a technical or scientific journal.

b. Preface. In some offices, there is a subtlety which recognizes the foreword as being prepared by someone other than the author, whereas a preface is something that is prepared by the author. For our purposes, the preface should be prepared by, or for, the Chief of Laboratory, and that it will give the background of the report, authorization, similar or related reports, plans for future work, and comments on the report, including appropriate acknowledgments.

In some instances, a foreword will also appear in addition to the preface in the report. One such instance might be when this Laboratory does not concur with the conclusions and recommendations of a contract report, but does not wish to hold up publication or to continue discussion. This is unlikely to happen when the author is a full-time employee, it is more likely to occur when one of the consultants, or an expert, a part-time employee, or, as stated above, a contractor prepares a report for publication.

c. Table of Contents. In certain instances, the use of a table of notations or a list of symbols will be desirable to acquaint the reader with unusual or uncommon mathematical terms and/or equations expressed in the body of the report. Such a table or list should appear preferably as a preliminary page between the table of contents and the synopsis or sometimes it may appear as a separately lettered appendix.

It should also be noted that tables and figures are listed on separate pages always in front of the above notations. This order is equally true when the tabular and graphic materials, as well as the symbols, appear at the end of the report or are made into separate appendices. Two examples are attached as Inclosure Nos. 3 and 4.

d. Synopsis. A descriptive summary, not exceeding 200 words, summarizing the salient features of the investigation, as covered in the report, and conclusions drawn, will be written by the author. From this summary, an abstract card will be prepared for technical reports as defined in the OCE-approved Guide.

e. Body of the Report. The body of the report will be divided into sections which will be appropriately entitled to indicate the particular information to be contained therein. In the idealized technical or scientific report, it would contain the following sections:

Introduction,
Test Equipment and/or Materials,
Procedures,
Results,
Discussion of Results,
Summary of Results, and
Conclusions.

It will be necessary, of course, to establish the actual sections and designations to fit the particular problem being reported on. Often, sections may be combined, or omitted altogether, depending upon the subject and its

treatment in the report. But in all cases there will be an introduction, and descriptions of what was done, what the results were, and what is concluded therefrom.

The author should have some sort of comprehensive organization plan before he starts to write; but, from this starting point on, methods differ. Some find it works best for them to prepare a very detailed outline which approaches the final text itself, while others seem to prefer to put down on paper all they have to say and then shuffle the parts around until they come up with the most logical order or sequence. However, once the author gets something down on paper, he has only begun. From then on the job is one of rearranging and polishing. Also, it requires constant revision. No one can write a thing the best way at the first attempt. The author must have the willingness to revise; it shows that he has acquired a maturity and a spirit of craftsmanship.

(1) Introduction. It is important that the author begin his report with a polished introduction which gives the purpose and scope of the study and its background. Note that it is the purpose and scope of the investigation, not of the report. The introduction is the author's first chance to interest the reader in his work. Accordingly, the introduction must set the tone of the report.

Beginning at the start and continuing throughout the report, the author must present the subject from the reader's point of view. He must learn to have a dual personality and constantly alternate his viewpoint between that of the author and that of a reader seeing the material for

the first time. Too many of our engineers write only from the author's point of view. The author should try to build up a picture of that reader, just who he is and what his interests are, what he already knows about this subject that the author intends to discuss, what more he wants to know. He should keep in mind the reader's capacity to absorb what is being presented. He may find it convenient to imagine a specific individual reader, such as Dr. Casagrande.

He must be able and willing to subordinate his own prejudiced estimation of his own knowledge, and his probable underestimation of the reader's intelligence. It is true that the reader will probably not know as much about the subject at hand as the author, but the reader's knowledge may be considerable.

In the introduction, the author has his first chance to show the importance of his test, or experiment. It is here that he must indicate any limitations of the study. And, finally, he may broadly suggest the conclusions that have been reached.

Where a number of words or phrases will be used having specialized technical meanings, a "definitions" section should be included in the introduction. When there are only one or two such items, definitions may be given where they first occur, either in the text or as a footnote.

(2) Conclusions. The conclusions must conform with one all-important criterion: They must be drawn solely on the basis of the material presented in the body of the report. Statements which are not properly supported by the data presented in the report cannot be accepted in the conclusions.

All questions raised in the introduction must be answered here. They must not seem perfunctory, but must add to the value of the report by restating the significant findings. They must not present any new material. Conclusions must cover all items of the problem as stated in the introduction. That is, the disposition of all items must be indicated in some way.

A distinction should be made between results and conclusions. Results are factual data resulting from the study; i.e., "the CBR of the subgrade during the frost-melting period was found by test to be 2.1 percent." A conclusion is the result of inference or reasoning based on the facts.

Frequently, it is desirable to insert a separate section just ahead of the conclusions entitled: "Summary of Results," when the report contains a substantial amount of new information, not properly falling in the "Conclusions" category.

f. Recommendations. Paragraph 17 of OCE "Guide to Good Practice" covers the problem of recommendations pretty well. Usually, we find our reports need a "recommendations" section. However, it should be written in general fashion to indicate the work needed to expand the results of the study, without going into details better covered separately.

Recommendations are definitely required in those reports where specific action is indicated. Whereas conclusions state that something is, was, or will be true; recommendations say that something should be done.

g. Acknowledgments. Acknowledgments may be indicated here in a separate paragraph, if quite lengthy. Otherwise, they should appear in the preface.

h. References and/or Bibliography. References will be in alphabetical order, numbered, and appropriately cited in the text. Each reference will include the proper elements, such as author, title, date, in the order prescribed below.

This section may be called references or made part of a bibliography; however, it would be advisable in those instances where certain allied literature which has not been referred to in the text, but may be of interest to the reader, that a supplemental bibliography of this material be prepared quite distinct and separate from the references themselves. In such a circumstance, of course, only the references will be numbered, the bibliography will be unnumbered.

All references should include the following information in the order indicated. For periodicals: Author, last name first; title of article; periodical; volume; page, inclusive page numbers or initial page numbers; and (date). Use of the List of Periodicals Abstracted by Chemical Abstracts for the abbreviations of all periodicals covered therein is preferred.

For books: Author, last name first; title of report or publication itself; publisher; city of publication; number of pages; and (year). If a publication is a compilation of many reports which appear bound in one volume, then it is usually required to list the specific article or chapter referred to in the text. That is done by listing the title of the article and following it with the word In: then the name of the book, and so on.

i. Appendixes. Appendixes are reserved for presentation of large quantities of tabular data and graphic matter that usually require lithographic condensation. Appendixes are also those materials which are lengthy, technical subtopics not essential for a full understanding of the main text but which will be useful to readers with special interest in the field. If this material were included in the main body of the report, it would tend to bury the more important text in a mass of technical detail. The appendixes appear in alphabetical order, designated by capital letters, such as A, B, and they must be kept to a minimum. By numbering pages A1, A2, A3, and B1, B2, B3, appendixes can be reproduced ahead of the main report, as soon as completed.

V. TECHNICAL DESCRIPTION

a. Types of Description. There are just two main types of description, they are: the generalized or broad (impressionistic) type as opposed to the scientific or more specific type of description. Despite the fact that the latter type seems to be preferred, this does not in itself necessarily mean that it is always the best, or that it alone must be used wherever possible. On the contrary, in some instances, a scientific or very specialized description, only, may well lose your reader. Also, both types can often be used to complement each other, and for increased readability.

b. Plan of Description. The author should first give a generalized view of what he is attempting to describe. Then he should describe the details, item by item or phase by phase, in a logical order.

c. Guides in Writing Technical Description. There are ten guides that may be mentioned briefly:

- (1) Clarity is the primary objective.
- (2) Vary the length and structure of the sentences. In other words, don't make the description monotonous or repetitive.
- (3) Where dimensions or quantities are used in describing one item after another, use a table to present the data. The reader can't absorb a flood of minor statistics presented in the text.
- (4) Begin some sentences with modifiers, these may be called additional describers.
- (5) Subordinate points of minor interest.
- (6) Write from an impersonal point of view and always use the third person.
- (7) Usually write in the passive voice, that is, use a verb which represents the subject as the receiver of the action. The passive voice is made up of forms of "be," also "become" or "get," together with the past participle of the principal verb. Individual correct examples of each are as follows: "The soil sample was prepared." "The test section became frozen." "The pile was pulled out, or extracted."
- (8) Use the present tense to describe general features and method of operation.
- (9) Use the past tense to describe a specific use or method of operation.
- (10) Avoid awkward, obsolete, inexact words and phrases. Use a term that fits, not one that nearly fits.

Again, it is advisable to use both main types of description, and not to overemphasize one to the complete neglect of the other. The technical description should be scientific and specific where required, and generalized or both when warranted.

VI. USE OF TABLES, GRAPHS, AND ILLUSTRATIONS

Tables, graphs, and illustrations should be used to the extent that these media will contribute substantially to the effectiveness of the report. For many studies, the ideal report may be one in which the tables, graphs, and illustrations form the heart of the report, the text serving to explain and make clear the graphic material.

Tables will be prepared in accordance with U.S. Government Printing Office standards. Photographs will be properly marked for reproduction, cropping, or reduction; in all instances, drawings and photographs will be designated as figures. Use of the term "plate" will be dropped. Tables and figures will each be numbered consecutively, using Arabic numerals, as closely as possible in the sequence in which they appear in the text. Every item should be referred to in at least one place in the text.

Tables and figures will appear either scattered throughout the text or grouped together at the end of the text, but not both ways, in a single report. That is, it is mandatory to use just one system of arranging tables and figures in the particular report. When tables and figures appear in the appendix, the particular letter used for the appendix must be added to table and figure numbers. However, regardless

of their location in the report, try to reduce all tables and figures to page size or smaller for ease of handling.

There are seven main rules which relate generally to tables and figures, as follows:

(1) In final reports, tables and figures usually are placed nearest the initial reference to them. In drafts, of course, they will usually be grouped together at the end.

(2) Tables and figures should be concise, complete, and clear.

(3) Units of measurement should always be clearly shown.

(4) Good balance should be maintained between tables and figures, on the one hand, and the text.

(5) Items in table or figure must bear immediate and apparent relationship.

(6) Each table or figure should be self-explanatory without reference to text.

(7) Simplicity should be observed in all tables and figures.

For the review draft, graphs should show all test points plotted, so that validity of curves may be evaluated. Points may or may not be left on in final version, depending on the particular case. We have to keep in mind that OCE and the Board of Consultants will review the finished report, and it will frequently be necessary to show the test points in order for them intelligently to evaluate our interpretations.

What are the purposes of tables? They are a convenient means of presenting data, and, thus, the data are more quickly read and grasped than if they were spelled out. However, a table should not defeat its own purpose by being overloaded with a number of variables excessive to the necessary showing of certain phenomena.

Despite the fact that the tables should be limited, some details will require additional explanation. This can be accomplished by the use of footnotes to the table. Each column of the table should be headed with a brief, precise statement of what the numbers represent and in what units they are shown. Units may be designated in either singular or plural as appropriate, except when abbreviated. Columns may need to be numbered for easy reference, but care must be exercised that these numbers are not confused with footnote numbers used simultaneously.

As previously mentioned, figures include graphs, drawings, photographs, charts, and all nontextual and nontabular material. They are not used merely for decoration. However, there is no limitation on the ingenuity of the author for graphical presentation. The figure legends should be clear and complete. As previously noted, graphs should not be made in final form until the report is almost completed and ready for reproduction. While a fine grid (from 10x10 to 20x20) is desirable on draft sheets to aid plotting and checking, final graphs should have a very open grid, generally not finer than $\frac{3}{8}$ x $\frac{3}{8}$ -inch in final reproduction, and going up to say 1 x 1-inch. The grid should be just fine enough to allow the average reader to make approximate interpolations. Any additional lines in the grid are wasted. If more precise results

are wanted by the reader, it should be assumed that he will make a plot of his own, using the data presented in the tables. "Figure No." and "Table No." on illustrations should be the same weight and size on all sheets, throughout the report. A drawing number should appear in the lower left-hand corner on all final full-page drawings. Examples of tabular and graphic material are attached as Inclosure Nos. 5 through 10.

VII. MECHANICS OF WRITING TECHNICAL REPORTS

The report will be written so that its meaning will be clear and unmistakable to anyone of average intelligence and requisite technical background. That is, the presentation of the data should be direct and precise, and without technical jargon.

It is the function of style to insure and facilitate rapid reading, yet at the same time to indicate a thoroughness of treatment by evidence given in the report.

The writer is not being called upon to impress or entertain. However, he does desire to make his style fit the subject matter and the always important reader. It is best to follow an impersonal approach, one free of preconceived notions. He should restrain himself, he should at all costs avoid superlatives, exaggeration, and other devices used in advertising or popular writing. Adjectives and adverbs should be used very sparingly. The approach should be direct, even blunt. That is, he should be willing to get to the point and get there quickly. The report should be concise, and it should conserve the reader's time.

Above all, the writer should strive for accuracy. The text should reproduce the known facts as precisely as possible. Care should be taken to use words which convey the correct shade of meaning. At the same time, avoid surrounding the plain meaning with so many hedges, modifying clauses, and minor explanations that the reader becomes completely confused as to what you are trying to say.

In all questions of style relating to correct use of paragraphs, sentences, figures, punctuation, capitalization, compounding, abbreviations, spelling, numerals, and symbols, the U.S. Government Printing Office Style Manual is the final authority.

The following is a brief coverage of good practice in style guidance for technical reports.

To begin with, all headings in the report should be independent of the text. For example, if your heading in a section of the report is "sampling," and you wish to indicate that "the sampling required two weeks," then the correct way to state it is as follows:

"Samplings: Sampling required two weeks." It should not read "Sampling: This required two weeks," or "the sampling required two weeks."

Paragraphs themselves are logical divisions of subsections into single-thought elements. However, the introductory sentence should summarize the thought contained in the paragraph. Paragraphs should also be connected by transitional phrases. Such phrases include: nevertheless, in a similar manner, and in spite of. Usually, transitions point back to what has already been said, but they may also point forward.

The transitional phrase which points forward rather than backward is one where the author points out that something has already happened in the past and that something will soon take place in the future. It might sound something like this: "Two of the methods have been tried and proved unsatisfactory, the third method, as will be shown below, may prove satisfactory." Or another, "Having completed the survey, it will now be necessary to consider what future work must be done." It is possible to phrase the transitional sentence so that it is not too obvious. Transitional paragraphs, it should be pointed out, can show the relationship of sections and subsections just as transitional sentences show the relationship of paragraphs.

Some general rules on sentences are as follows: They should be varied in length to avoid monotony. They should be complete, complex sentences should be avoided, but long sentences are not necessarily complex. Short words and short sentences are best, although too many short and simple sentences sound childish. Still it is better to err in this direction than toward long, complicated, awkward and difficult-to-read sentences.

Granting that it is not necessary for the author to have an extensive vocabulary, a report writer can develop a good vocabulary by much reading. The author should exercise his terminology. He should vary his words to express the same thought in order to avoid monotony, but he should be very careful lest he use a word that confuses the reader.

There are, of course, the more perplexing although less important mechanics of writing technical reports. Some of these points are not covered in the GPO Style Manual, others are. No differentiation is made here between the two, and they are not taken up in any particular order.

Hyphen. The hyphen ordinarily is used for words combined to form a unit modifier immediately preceding the word modified. It is not used, however, if the first word is an adverb ending in ly or an adverb modifying the second word of a three-word modifier: "second-rate highway", "steeply rising mountain", "vegetation-covered slopes", however, "non-frost-susceptible soils". The hyphen is always used when the second word ends in ed.

Dash. The dash should be used sparingly. Usually, they are made by two hyphens with spaces before and after.

Prefix. A prefix that is not a complete word ordinarily combines without a hyphen unless the combined word is capitalized or unless it ends in the same vowel, sometimes the same consonant, as the first letter of the combining word: "nonmountainous", "un-American", "anti-inflation", "subarctic".

Capitalization. After a place name, "proper" is not capitalized: "Greenland proper".

English generics after a proper name are capitalized. If a foreign name includes a generic, the English generic may be added uncapitalized in parentheses for clarity: "New York State", "Ozero Balkhash (lake)".

Army and Navy are capitalized only when referring to a specific organization or facility: "Canadian Army", "French Navy", "army rations".

Arctic and Subarctic are capitalized when nouns, not capitalized when adjectives.

Comma. A comma is used before and in a series of three or more terms: "climate, soil, and vegetation". They are used in numbers of four or more digits, except in astronomical time and chart numbers: "1,262 miles; 2215 hours; chart number 2117". They separate independent clauses unless other punctuation is used.

Abbreviations. Few abbreviations should be used in the text aside from such as the following: U. S. Army, U. K. Navy (ordinarily, the United States and the United Kingdom are written out), A.M., P.M., mph, °F., °C., Btu, cc and psi. Little use should be made of etc. In tables and figures, abbreviations may be used, but always in the singular. For example, inches, in.; pounds, lb.; feet, ft. Accepted practice is to omit periods in engineering and scientific abbreviations, except where the abbreviation might be mistaken for another word. Such a case would be inch, which would be like in, without the period.

Terms which are infrequently used will, in general, not be abbreviated. Some approved abbreviations which may frequently appear in ACFEL publications follow:

Absolute.....abs	Atomic weight.....at.wt
Alternating current.....ac	Audio-frequency.....af
(as adjective).....a-c	Average.....avg
Altitude.....alt	Barrel.....bbl
Ampere.....amp	Boiling Point.....bp
Ampere-hour.....amp-hr	British thermal unit.....Btu
Angstrom Unit.....A	Bushel.....bu
Ante meriden.....A.M.	Calculated.....calc
Antilogarithm.....antilog	California Bearing Ratio....CBR
Approximate.....approx	Calorie.....cal
Atmospheres... ..atm	Centigrade.....C.

Centigram.....cg
 Centiliter.....cl
 Centimeter.....cm
 Centimeter per second
 (cm per sec).....cm/sec
 Chemically pure.....cp
 Circa.....ca
 Coefficient.....coef
 Cologarithm.....colog
 Constant.....const
 Cosine.....cos
 Cotangent.....cot
 Cubic.....cu
 Cubic centimeter.....cc
 Cubic feet per second.....cfs
 Cycles.....cy
 Cycles per second.....cps
 Decibel.....db
 Decigram.....dg
 Deciliter.....dl
 Decimeter.....dm
 Degree.....deg
 Degrees Kelvin (absolute).....°K
 Degrees Celsius (centigrade).....°C
 Degrees Fahrenheit.....°F
 Diameter.....diam
 Direct Current.....dc
 (as adjective).....d-c
 Electromotive force.....emf
 Equation.....eq
 Erg.....erg
 Exponential.....exp
 Fahrenheit.....Fahr. or F.
 Farad.....f
 Figure.....Fig.
 Focal length.....f
 Foot.....ft
 Foot-pound.....ft-lb
 Frequency modulation.....FM
 Gallon.....gal
 Gallons per minute.....gpm
 Gallons per second.....gps
 Grain.....grain
 Gram.....g
 Horsepower.....hp
 Hour.....hr
 Hydrogen ion concentration.....pH
 Inch.....in.
 Inch-pound.....in-lb

Indicated horsepower.....i hp
 Inside diameter.....ID
 Kilocalorie.....kcal*
 Kilocycle.....kc
 Kilogram.....kg
 Kilogram-calorie.....kg-cal*
 Kilogram-meter.....kg-m
 Kilogram per square
 centimeter
 (Kg per sq cm).....kg/cm²
 Kiloliter.....kl
 Kilometer.....km
 Kilovolt.....kv
 Kilovolt-ampere.....kva
 Kilowatt.....kw
 Kilowatthour.....kwhr
 Kips per square foot.....ksf
 Latitude.....lat
 Limit.....lim
 Linear.....lin
 Liter.....l
 Logarithm (common).....log
 Logarithm (natural).....ln
 Maximum.....max
 Megacycle.....mc
 Melting Point.....mp
 Meter.....m
 Meter-kilogram.....m-kg
 Microampere.....μ a
 Microangstrom.....μ A
 Microfarad.....μ f
 Micromicrofarad.....μμ f
 Microinch.....μ in
 Micromicron.....μμ
 Micron.....μ
 Mile.....mile
 Miles per hour.....mph
 Milliampere.....ma
 Milligram.....mg
 Milliliter.....ml
 Millimeter.....mm
 Millimicron.....mμ
 Million gallons
 per day.....mgd
 Millivolt.....mv
 Minimum.....min
 Minute.....min

* kcal and kg-cal are synonymous and can be interchanged.

Month.....month
 (Jan, Feb, Mar, Apr,
 May, June, July, Aug,
 Sep, Oct, Nov, Dec)
 Number.....No.
 Observed.....obs
 Ohm.....ohm
 Ounce.....oz
 Outside diameter.....OD
 Page.....p.
 Pages.....pp.
 Parts per million.....ppm
 Per.....per
 Per centum.....percent
 Pint.....pt
 Post meridian.....P.M
 Pound.....lb
 Pound-foot.....lb-ft
 Pound-inch.....lb-in
 Pounds per cubic foot
 (lb per cu ft).....pcf
 Pounds per square foot
 (lb per sq ft).....psf
 Pounds per square inch.....psi
 Probable error.....pe
 Quart.....qt
 Radio-frequency.....rf
 Radius.....rad

Revolutions per
 minute.....rpm
 Root mean square.....rms
 Saturated.....sat
 Second.....sec
 Section.....sect
 Sine.....sin
 Specific gravity.....sp gr
 Square.....sq
 Tangent.....tan
 Tensile strength.....ts
 Ton.....ton
 Tons per square
 foot.....tsf
 Ultra-high fre-
 quency.....uhf
 Very high
 frequency.....vhf
 Vol⁺.....v
 Volume.....Vol.
 Watt.....w
 Watthour.....whr
 Week.....week
 Yard.....yd
 Year.....yr
 (Military, no apostrophe,
 56 (1956); nonmilitary '56)

As an arbitrary rule, use abbreviations in the singular only;
 exceptions are abbreviations preceding numerical values such as: Figs. 1
 and 2, Vols. 1 and 2, Nos. 1 and 2.

Numbers. GPC says, although not absolutely, that numerals under
 ten ordinarily will be spelled out. ASTM, however, says that numerals
 under thirteen will be spelled out. The new trend is toward writing all
 numbers as numerals. However, any number is spelled out when it begins a
 sentence, or if successive numerals would be ambiguous. For example:
 "Eight miles of road were built". "There are three 7-foot cliffs on this
 island." On the other hand, small numbers are always expressed as numerals
 when compared with large ones: "The tide varies from 4 to 25 feet." Million
 and billion may be written out.

Ordinals are written out, except in proper names: "Third," "Nineteenth or Twentieth Century," but twenty-fourth division is "24th Division."

In tables, and generally in figures, numerals are used throughout.

Measurements. English measures are used where practicable. Where results will be useful in engineering applications, English measures are used. Where results are strictly of a laboratory or research nature, metric units are frequently preferable (for example, millimeters, centimeters, and milligrams.) When a metric figure is approximate, the approximate equivalent is used. When the profession usually works and thinks in terms of some common unit such as pounds per square foot, that unit should be used.

Decimals are used instead of fractions where practicable.

The eight major compass points should be written as one word without capitals: east, northwest. Intermediate directions are hyphenated, e.g., south-southwest, and should be abbreviated where two or more occur in the same sentence, i.e., N, NE, NNE, or whatever direction is indicated.

The words latitude and longitude need not be written in giving locations: $23^{\circ}11' \text{ N}$, $62^{\circ}15' \text{ W}$.

Percent is spelled out, as one word.

Special Signs or Symbols. In general, avoid the use of special signs or symbols. Do not use (') for feet or (") for inches in either text or tables; their use is permissible in illustrations. The symbol for percent (%) should not be used in the text, but may be used in tables when lack of space requires it.

Spell out names of companies using the ampersand (&) only between proper names. Abbreviate "Company" and "Corporation" in firm names. For example: "Brown & Sharp Manufacturing Co.," but "Pennsylvania Coal and Coke Corp."

Parentheses. If a complete sentence is to be inclosed in parentheses, the closing parenthesis is placed outside the period. If only a phrase at the end of a sentence is inclosed in parentheses, the closing parenthesis is placed inside the period.

Quotation Marks. Quotes are always set outside the comma and the period; inside the colon and the semicolon; and either way with exclamation and interrogation marks, depending on whether those marks do (quotes outside) or do not (quotes inside) belong to the quoted matter.

Figures. In referring to figures, the word see usually is not needed; the word figure is spelled out when used in the text, but abbreviated when in parentheses (Fig.). A common noun, such as figure, used with a date, number, or letter merely to denote time or sequence, or for the purpose of reference, record, or temporary convenience, does not form a proper noun and is therefore not capitalized. However, it is capitalized when followed by its title and when abbreviated or in parentheses.

Miscellaneous. Expressions such as than does or as is should be used only if necessary to avoid real confusion.

The adjective due should be used only where it modifies the subject noun or pronoun, otherwise owing to or because of is preferred. The following usages are correct: "The difficulty of transportation is due to the numerous gullies." "Transportation will be difficult because of the numerous gullies that lie across passes."

Velocity properly includes direction as well as rate of movement; speed is preferred when there is no directional frame of reference.

VIII. TYPING THE TECHNICAL REPORT

In order to maintain high standards and uniformity in the final preparation and presentation of the technical reports, the following standards should be followed.

Typewriter marginal stops should be set for a 6-inch line; the width of a typed line on a page should not exceed 6-1/4 inches, preferably 6-1/8 inches. The left-hand margin should be 1-1/4 inches, for a right-hand page, and 3/4-inch for a left-hand page; first line on a page should be 3/4-inch from top, and last line 1-inch from the bottom. Page numbers should appear 1/2-inch from the bottom of the page equidistant from the sides. On the duplimat master, typing should begin on line 3, should end on line 55, and the page number should be on line 58 for both right- and left-hand pages; however, the typing should appear between lines 21 and 93 on the horizontal margin for a right-hand page, and between lines 15 and 87, horizontally, for a left-hand page. For short reports where only one side of the sheet is used, pages will be all right-hand ones. Inclosures Nos. 11 and 12 illustrate the format to follow in typing duplimats.

The cover and sometimes the title page will be prepared by the drafting section, based on information obtained from the author of the technical report.

Pagination of technical reports is as follows: Preliminary pages (title page, preface, table of contents, notations or symbols, and synopsis) have small-cap Roman numerals, such as i, ii; main text pages including appendixes have Arabic numerals, such as 1, 2, and A1, B1.

First page of main text and first pages of major subdivisions always, and minor subdivisions sometimes, should each start on a right-hand page (odd). This will occasionally result in a blank, unnumbered left-hand page at the end of the preceding section, but it has the advantage in that it permits main sections to be handled as complete units, separate from other sections of the report.

Paragraphs are numbered consecutively; subparagraphs are both lettered and numbered. As in all military correspondence, no numbered or lettered heading is used singly, i.e., there is no 1 with a 2; and no a unless there is a b. As already stated, the main paragraphs begin at the left margin $3/4$, $1-1/4$ inches or 9-15 elite typewriter spaces from the left side of the paper, for left- and right-hand pages, respectively. Thereafter, indentations are at regularly increasing 5-space intervals for all lettered and numbered paragraphs. Indent only first lines, second lines go back to margin. However, all first lines of unnumbered or unlettered paragraphs or subparagraphs are indented only 5 spaces from the left margin, even though the preceding and succeeding paragraphs may be indented 10 or more spaces. Depending on the number of subheadings required, one of the following heading arrangements should be used:

I. MAIN HEADING.

A. MAJOR SUBDIVISIONS.

1-01. MINOR SUBDIVISIONS.

a. Paragraph Headings. Text beginning on same line.

(1) Subparagraph Heading or Text.

(a) Subparagraph Heading or Text.

*1 Subparagraph Heading or Text.

*a Subparagraph Heading or Text.

If report is short and the outline being used consists of four headings or less (not major subdivisions), the paragraph arrangement should start with 1 (not 1-01) at the left margin for the main heading; followed by the paragraph headings a, b, first lines of each indented 5 spaces; and then by the subparagraph headings (1), (2), and (a), (b), first lines of which are indented 10 and 15 spaces, respectively; however, in a longer paper, where more subdivisions and subparagraphs are required, obviously the type of listing given first above should be followed.

Webster's New International Dictionary is the authority in the spelling and division of words. Hackh's Chemical Dictionary is used for chemical and physical words and terms. Authorities for the spelling of geographic names, both local and foreign, are listed below in the order of their preference: Decisions of the United States Board on Geographic Names; United States Postal Guide; Columbia Lippincott Gazetteer of the World; Webster's Geographical Dictionary; New World Loose Leaf Atlas; and Rand McNally Atlas.

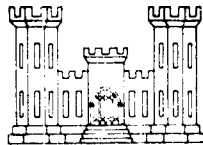
* As much as possible, avoid necessity for using these subparagraphs by using more main paragraphs.

STUDY OF ICE FORMATION IN SOILS

by

Kenneth A. Jackson and Bruce Chalmers

Contract No. DA-19-016-eng-3903



TECHNICAL REPORT NO. 65

UNDER CONTRACT
WITH

ARCTIC CONSTRUCTION AND FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION
BOSTON, MASSACHUSETTS

FOR

OFFICE OF THE CHIEF OF ENGINEERS
AIRFIELDS BRANCH
ENGINEERING DIVISION
MILITARY CONSTRUCTION

May 1956

Incl. I

CORPS OF ENGINEERS, U. S. ARMY

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Incl. 2

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TABLE OF NOTATION

<u>Symbol</u>	<u>Name</u>	<u>Usual Unit</u>
A	Combined cross-sectional area of standpipe and manometer tube	sq in.
C	Volumetric heat	Btu per (cu ft) (deg F.)
$\bar{C}$	Volumetric heat for a soil "lump" of unit area and thickness T_h	Btu per deg F.
d	Distance between centers of adjacent lumps	ft
h	Analog head	in.
k	Thermal conductivity	Btu per (hr) (ft) (deg F.)
L	Latent heat	Btu per cu ft
$\bar{L}$	Latent heat for a soil "lump" of unit area and thickness T_h	Btu
Q	Rate of flow	cu in. per min
q	Rate of heat flow per unit area	Btu per (hr)(sq ft)
R_a	Resistance of analog resistor	min per sq in.
R_p	Thermal resistance between centers of adjacent lumps	(deg F.) (hr)per Btu
T_s	Time Scale	min per hr
T_h	Thickness of a soil lump	ft
t_a	Analog time	min
t_p	Time in nature	hr

TABLE OF NOTATION (cont'd.)

<u>Symbol</u>		<u>Usual Unit</u>
U_s	Thermal energy scale	cu in. per Btu
V	Stored water volume	cu in.
V_L	Latent heat well volume	cu in.
V_s	Temperature scale	in. per deg F.
$\overline{u}$	Thermal energy in a soil lump	Btu
v	Temperature	deg F.
x	Abscissa of surface temperature curve	in.
y	Ordinate of surface temperature curve	in.

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Appendix A

List of Symbols

M, Mass L, Length, T, Time, θ , Temperature

<u>Symbol</u>	<u>Text or Equation</u>	<u>Meaning</u>	<u>Dimension</u>
a	9, 10, 13, 16	Constant	-
a	23	Temperature gradient coefficient	θ/L
a	24	Intensity of radiation	M/T^3
b	10, 13	Constant	-
b	17	Adsorptivity of a surface	-
b	21	Intensity of radiation	M/T^3
c	22	Volumetric specific heat	$M/T^2L\theta$
c	23	Constant	-
c	24	Gravimetric specific heat	$M/T^2L\theta$
d	13	Constant	-
e	10	Base of natural log- arithms	-
$e_1, 2, \dots$	16	Partial water vapor pressure at points 1, 2, ...	M/LT^2
f	13	Constant	-
g	7	Acceleration of gravity	L/T^2
g	13	Constant	-

TABLE 1

ADDITIVES TRIED AS FROST MODIFIERS

ITEM NO.	TRADE NAME	DESCRIPTION	SUPPLIER
1	-	Vegetable Pitch	General Mills, Inc., Minneapolis 13, Minn.
2	-	Tall Oil	General Mills, Inc., Minneapolis 13, Minn.
3	-	Vegetable Residue	General Mills, Inc., Minneapolis 13, Minn.
4	-	Asphalt Emulsion	American Oil Products Co., Somerville 43, Mass.
5	-	Polyamide Resin	General Mills, Inc., Minneapolis 13, Minn.
6	-	Portland Cement	-
7	Possolith	A Calcium Lignosulfite	Master Builders Co., Waltham, Mass.
8	Floggal	A Modified Starch	W. A. Scholten's Chemicals, Fabrieken, Netherlands
9	CRD-197	Sodium Salt of a Polymer	Monsanto, Everett Station 49, Boston, Mass.
10	Quartec	Polygalactosamine	General Mills, Inc., Minneapolis 13, Minn.
11	Krilium	Maleic Polymer	Monsanto, Everett Station 49, Boston, Mass.
12	Agrilon	Sodium Polyacrylate	American Polymer Div., Taubody, Mass.
13	-	Copolymer of Styrene and Methosulfate	Koppers Co., Inc., Pittsburgh 19, Penna.
14	P.V.A.	Polyvinyl Alcohol	E. I. duPont de Nemours & Co., Grasselli Chemicals Dept., Boston 10, Mass.
15	Quadrafos	Sodium Tetraphosphate	Rumford Chemical Works, Rumford 16, R.I.
16	-	Sodium Tripolyphosphate	West Vaco, New York 17, N. Y.
17	-	Sodium Hexametaphosphate	West Vaco, New York 17, N. Y.
18	Veramate	Sodium Salt of Ethylene Diamine Tetra Acetic Acid	Barnworth Chemical Co., Framingham, Mass.
19	Tamol 731	A Sodium Salt of a Carboxylic Acid	Rohm & Haas, Wellesley Hills, Mass.
20	Daxad 11 and 21	Formaldehyde - Condensed Naphthalene Sulfonates	Dow & Almy, Cambridge 40, Mass.
21	Marasperse M and C	Lignosulfonate Salts	Marathon Corp., Rothschild, Wis.
22	Lignosol	Lignosulfonate	Marathon Corp., Rothschild, Wis.
23	SC-5C	Sodium Methyl Silicate	General Electric Co., Pittsfield, Mass.
24	IS-1	Sodium Methyl Methyl Propyl Silicate	Dow Chemical Co., Midland, Mich.
25	-	Potassium Phenyl Silicate	Monsanto, Everett Station 49, Boston, Mass.
26	Triton E-60	Stearyl Dimethyl Benzyl Ammonium Chloride	Rohm & Haas, Wellesley Hills, Mass.
27	Volur	Methacrylate Chromic Chloride	E. I. duPont de Nemours & Co., Grasselli Chemicals Dept., Boston 10, Mass.
28	Quilon	Stearate and Chromic Chloride	E. I. duPont de Nemours & Co., Grasselli Chemicals Dept., Boston 10, Mass.
29	Hyamine 1622 and 2389	Fatty Quaternary Ammonium Salts	Rohm & Haas, Wellesley Hills, Mass.
30	-	Triethylene Tetramine	Eastman Kodak Co., Rochester, N. Y. Distributors: Howe & French, Boston, Mass.
31	-	Hexamethylene Diamine	Eastman Kodak Co., Rochester, N. Y. Distributors: Howe & French, Boston, Mass.
32	-	Di-N-Butylamine	Olin Mathieson Chemical Corp., East Rutherford, N. J. Distributors: Howe & French, Boston, Mass.
33	Primene 81-R	Tertiary Alkyl Primary Amine	Rohm & Haas, Wellesley Hills, Mass.
34	Cartowax 200 and 6000	Polyethylene Glycol	Carbide & Carbon Chemical Co., New York 17, N. Y.
35	Arquad 2HT	Di-Octadecyl Dimethyl Ammonium Chloride	Armour Chemical Div., Chicago 9, Ill.
36	Armoel 18D	Octadecyl Amine	Armour Chemical Div., Chicago 9, Ill.
37	-	Dimethanol Urean Amine D Acetate	Hercules Powder Co., Wilmington 99, Del.
38	-	Monomethanol Urean Amine D Acetate	Hercules Powder Co., Wilmington 99, Del.
39	-	Peat Fines	Martha's Vineyard, Massachusetts

TABLE 1

Incl. 5

TABLE 2
SOILS USED IN GOLD ROOM TESTS

LAB. NO.	SPECIMEN IDENTIFICATION SYMBOL	SOURCE	CORPS OF ENGINEERS' UNIFIED SOIL CLASSIFICATION		GRAIN SIZE - 5 FINEST SIEVE					WATER LOSS ON DRYING %	SPECIFIC GRAVITY (TOTAL SAMPLE)	COMPACTION CHARACTERISTICS		ATTERBURGH LIMITS (1)	
					U. S. STANDARD SIEVE										
					#4	#10	#20	-							
			DESCRIPTION	SYMBOL	#4	#10	#20	0.075	0.02			MAXIMUM DRY DENSITY (pcf)	OPTIMUM WATER CONTENT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX
	FW	Oremland, TN-250	Sandy GRAVEL	GM	30	15	4	2.0	-	-	2.72	148 (2)	-	-	Non-plastic
	DPB	Dow AFB, Banger, Maine, B-11	Sandy GRAVEL	GM-GP	42	12	5	2.4	-	-	2.73	139 (2)	-	-	Non-plastic
	DPB	Dow AFB, New Orleans, Maine, B-10	Sandy GRAVEL	GM-GM	49	18	8	3.2	-	-	2.69	139 (2)	-	-	Non-plastic
10-11	MC	Ellsworth AFB, Weaver, South Dakota	Silty Sandy GRAVEL	GM	56	30	12	8	-	-	2.76	-	-	19	2
10-12	CL	Canton County AFB, Wilmington, Ohio	Silty Clayey GRAVEL	GM-OC	53	25	15	9	-	-	2.74	-	-	25	7
10-17	LT	Loring AFB, Lancaster, Maine, Subgrade Frost Test Section	Clayey Sandy GRAVEL	GC	68	52	41	30	-	-	2.73	137 (4)	7.5	22	8
10-21	SP	Spokane AFB, Spokane, Washington	Gravelly SAND	SM-GM	70	15	8	4.0	-	-	2.82	-	-	-	Non-plastic
10-12	LH	Lincoln AFB, Lincoln, Nebraska	Gravelly SAND	SM-SM	67	24	6	4.7	-	-	2.65	133 (3)	-	-	Non-plastic
10-60	MS	Fairchild AFB, Spokane, Washington	Silty Gravelly SAND	SM	88	33	19	10	-	-	2.77	142 (2)	-	22	3
10-54	PAFB	Portsmouth AFB, Portsmouth, New Hampshire	Silty Gravelly SAND	GM-SM	68	45	23	14	2.1	-	2.71	139 (2)	-	-	Non-plastic
10-17	SP	Sioux Falls Airfield, Sioux Falls, South Dakota	Silty Clayey Gravelly SAND	OC-SM	72	28	15	8	-	-	2.74	-	-	24	6
10-9	PT	Patterson AFB, Fairfield, Ohio	Silty Clayey Gravelly SAND	OC-SM	58	34	21	15	-	-	2.74	-	-	22	6
10-16	HE	Offutt AFB, New Hampshire (New Hampshire Salt)	Clayey SILT	ML-CL	100	100	99	77	-	-	2.74	110 (3)	14.7	24	6
10-66	FB	Fort Belvoir, Virginia	Sandy CLAY	CL	97	88	68	46	-	-	2.73	115 (3)	16.1	41	19
10-12	MC	North Cambridge, Massachusetts (Boston Blue Clay)	CLAY	CH	100	100	100	94	-	-	2.78	106 (4)	20.2	53	26

* Dual symbols used are not in strict accordance with unified classification system but are modified as a result of visual examination of material.
(1) On material passing the U. S. Standard #40 sieve.
(2) Previous Vibrated Density Test.
(3) The maximum dry density was obtained by compacting soil (minus #4 sieve material only) in a 4-in. diameter cylinder, 1/30-in. ft. in volume, using 5 layers, 10-lb. tamper and 10-in. drop, 15 blows per layer.
(4) Corps of Engineers Modified AASHTO Density Test is made by compacting soil in a 6-in. diameter cylinder, 1/10-in. ft. in volume, using 5 layers, 10-lb. tamper and 10-in. drop, 55 blows per layer.

TABLE 2
Incl. 6

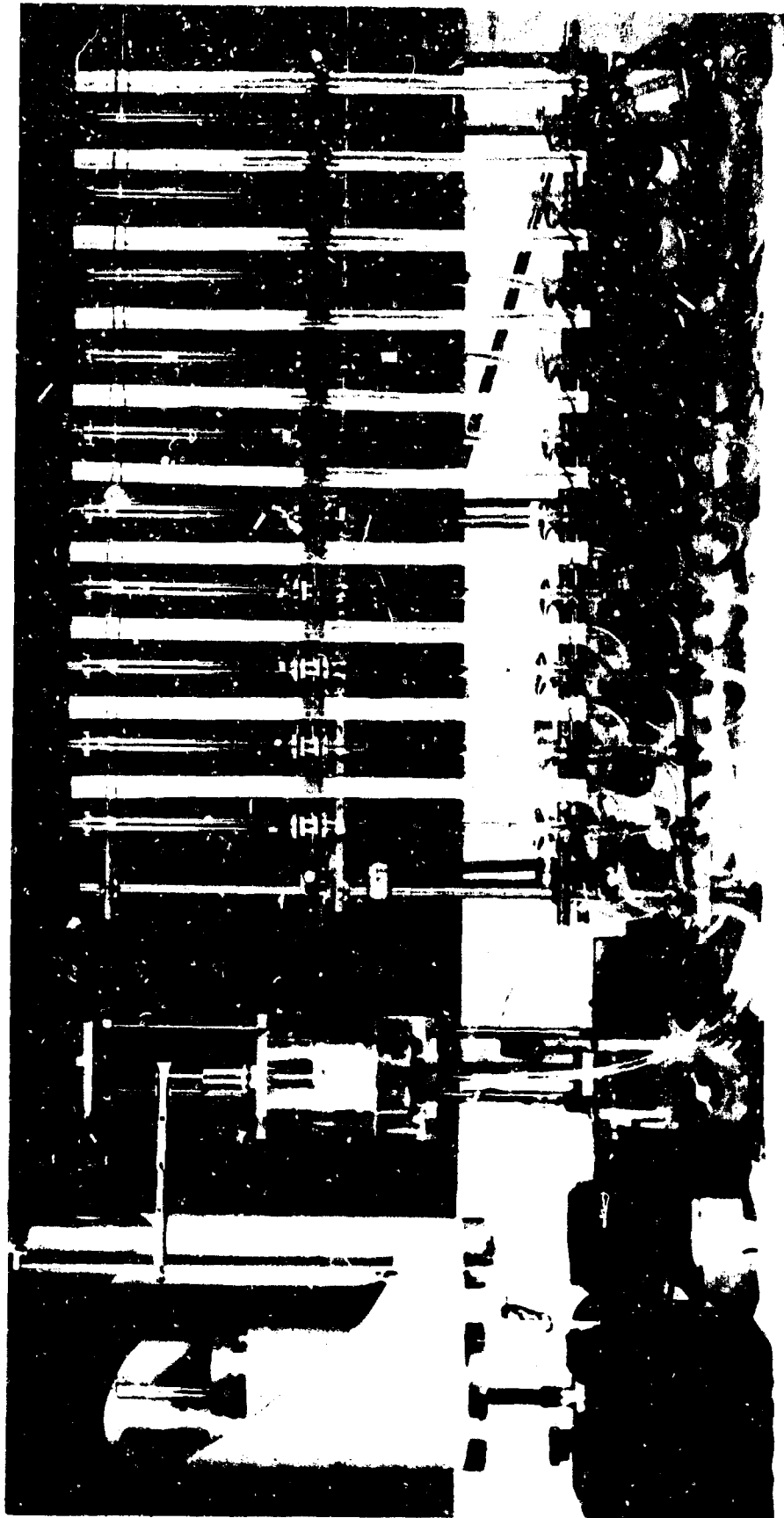


Figure 2. General view of the hydraulic analog computer. The motor-driven template, left, is cut to conform to ground surface temperature variations and by means of an on-off servo motor is converted into corresponding variations of water level.

FIGURE 2
Incl. 7

The results in Figure 21 indicate that each foot increase in depth of fill will raise the thaw line in the subgrade approximately 8 in. in a thaw season similar to that of 1954, and that to prevent any thaw of the subgrade would require approximately 6 ft of fill. However, it is considered that the depths of thaw shown in Figure 21 would be maximum values in the next complete thaw season, in that after that season, with melting of the winter snow cover, moisture content of the road fills may be substantially higher than was assumed for the first year. Where ample moisture is available, depths of thaw below the road surface, at the center line, may be as shallow as those plotted in Figure 20 for the undisturbed ground.

Thaw of ice beneath fill. A tentative solution for the amount of ice which will melt below a fill has been determined using the temperatures measured in the ice during 1954 investigations

and by means of the hydraulic analog computer presently being developed by the Arctic Construction and Frost Effects Laboratory.

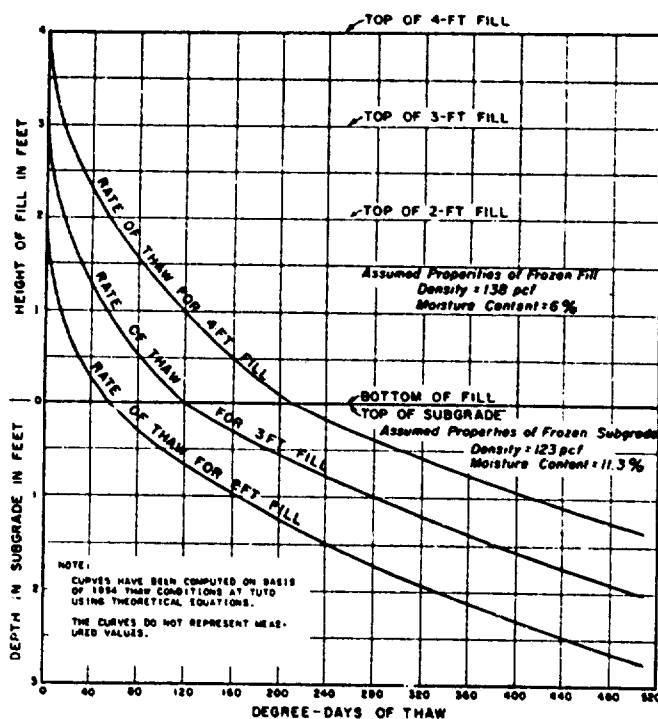
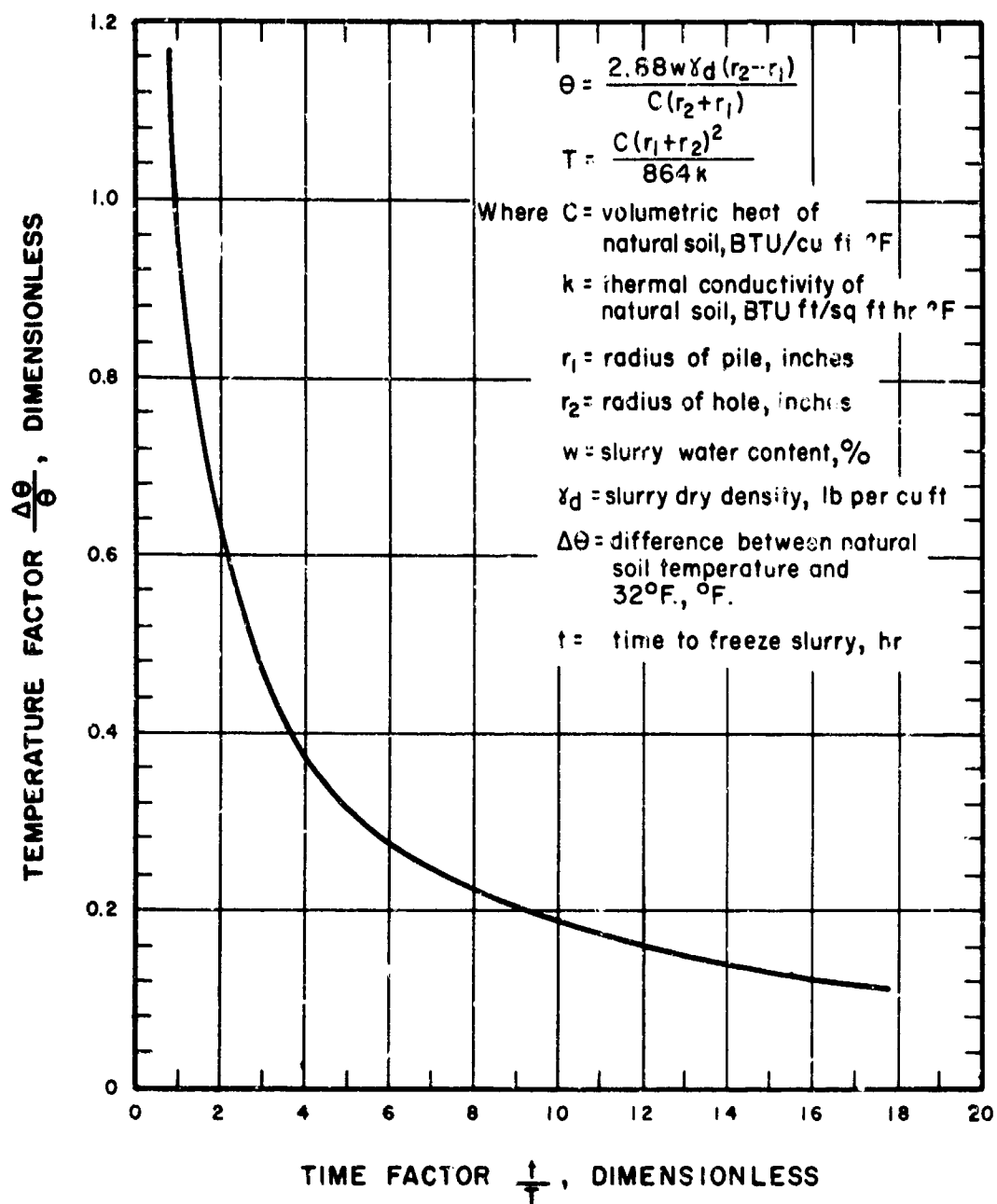


Figure 21. Influence of depth of fill on thaw depth in soil subgrade.

has been neglected in the foregoing computation is solar radiation. While degree-days of thaw based on air temperatures decrease steadily with distance from the edge of the ice and with increase in elevation, incoming radiation should be a nearly constant factor, by comparison, and must be the predominant factor as the air thawing index approaches zero. Dr. Schytt measured the amount of incoming radiation at the Ramp station, one mile from the edge of ice. His computations and analysis of the effect of radiation on the snow and ice surface indicate that radiation is at least as important as convection in determining the amount of ablation at the Ramp station. No measurements were made by Dr. Schytt in connection with gravel road surfaces, so that no data are available to evaluate radiation effect for these conditions. While the absorption of heat by the gravel surface will be greater than the ice or snow surface, much of the heat will be expended in warming the gravel and underlying ice or will be lost by convection at these interior ice cap locations. Therefore, while inclusion of the solar radiation contribution in the heat balance computations would increase the indicated ice melt beneath a 2-ft depth of gravel fill, the amount would not necessarily be of practicable significance.

Figure 22 shows the computed thicknesses of ice which will melt under 2-, 3- and 4-ft depths of fill for any given number of accumulated degree-days of thaw. These values are approximate and tentative, pending additional information. Note that a straight line relationship has been assumed between the amount of ice melt and degree-days of thaw; this assumption is only a rough approximation. There would be practically no melt of the ice surface under 3 ft of fill at or beyond the location of Test Lane 3. With 2 ft of fill there would be nearly 2 in. of melted ice at Test Lane 3, slightly over 1 in. at one mile inland from the edge of ice and no melting at 5 miles from edge of ice.

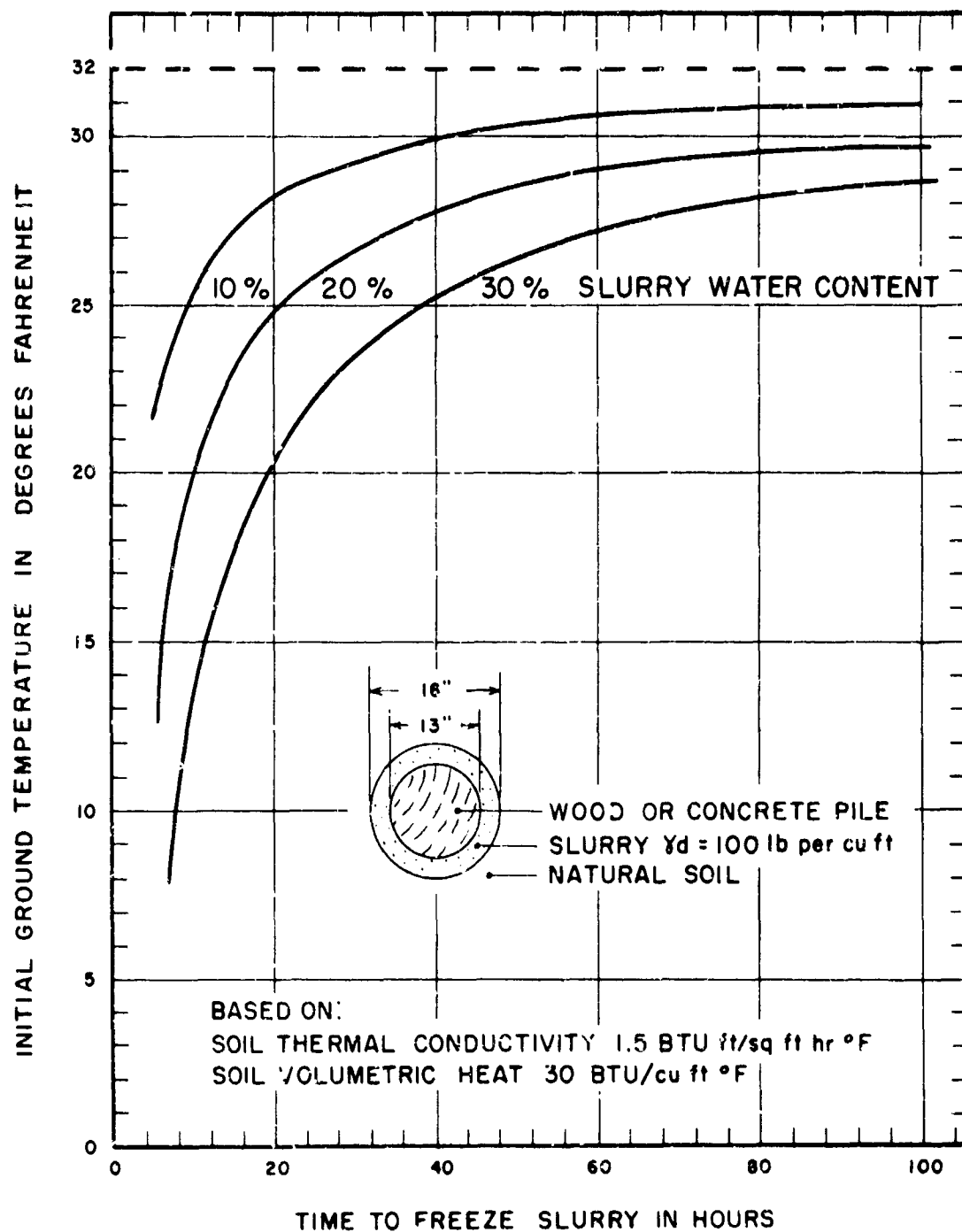
An important factor which



TIME REQUIRED TO FREEZE SLURRY
AROUND A PILE IN PERMAFROST

FIGURE 1

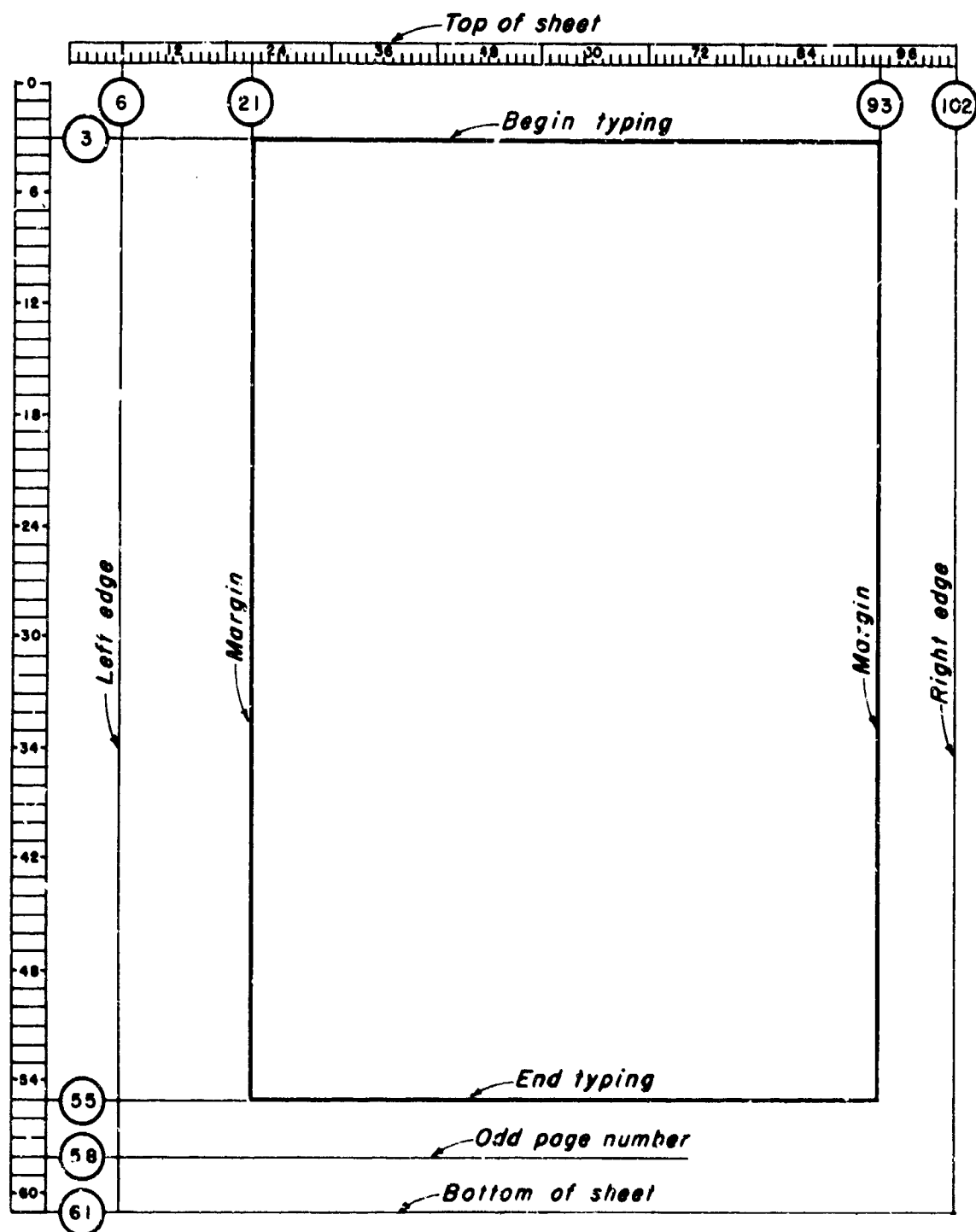
Incl 9



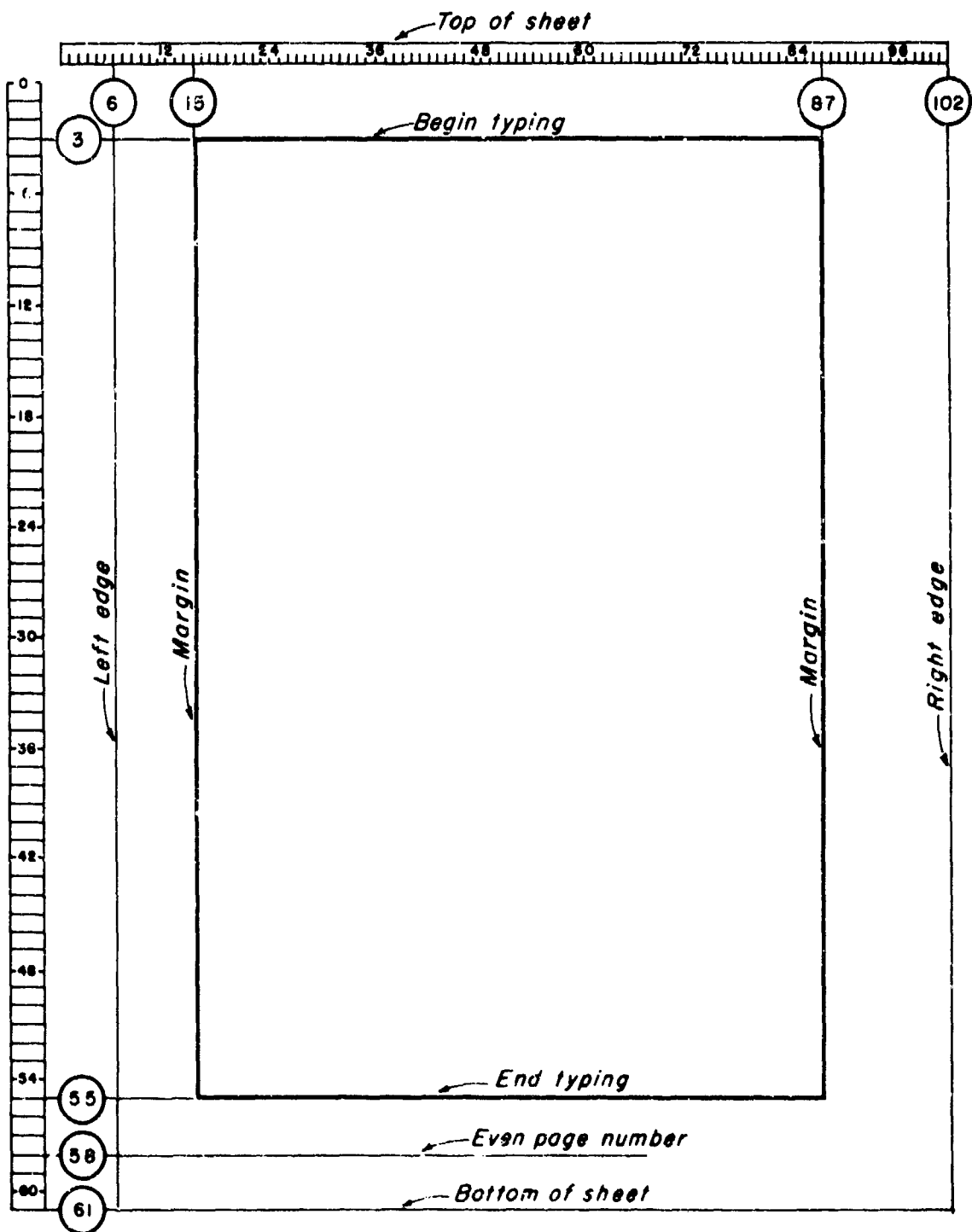
SPECIFIC SOLUTION OF SLURRY FREEZING PROBLEM

FIGURE 2

Incl. 10



FORMAT FOR TYPING THE TECHNICAL REPORT
ON A DUPLIMAT MASTER



FORMAT FOR TYPING THE TECHNICAL REPORT ON A DUPLIMAT MASTER