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General Guidelines for Writing a Scientific Report

Intended for students of the Industrial Energy Systems Laboratory

Everything should be made as simple as possible, but not simpler.
Albert Einstein

Lausanne, September 15th, 2010

Abstract

This document is designed to guide students through the writing of a scientific report. The reader will learn that a report should be concise and synthetic. Nevertheless, its content must be comprehensive, rigorous, and persuasive. The clarity of its structure is essential and the consistency of its forme facilitates reading and understanding.

The structure and the content of a scientific report are explained thoroughly. In particular, three indispensable parts are highlighted: the abstract, the introduction, and the conclusions.

Among the numerous recommendations disseminated in this document, emphasis is put on the *guiding thread* that directs the discourse and guides the reader to communicate the message as effectively as possible.

Finally, a report being the fruit of a study, some principles are pointed out to rationalize and to organize it.

Some keywords: accuracy, argumentation, brevity, clarity, communication, concision, consequences, exactness, guiding thread, persuasion, precision, proofs, rigour, simplicity, synthesis.

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1. Introduction

These *guidelines* are widely inspired from a document [1] of the "Laboratoire de thermique appliquée et de turbomachines" (LTT).

The purpose of this document is to guide students of the Industrial Energy Systems Laboratory (LENI) in writing a scientific report. Indeed, too often, the quality of the reports is poor and therefore prejudicial to the student, even if its study is excellent from a scientific point of view. Nevertheless, weaknesses of a report may also reflect the lack of preparation and organization throughout the work. This is why this document treats also, briefly, of essential principles for the preparation of a work plan (appendix B, p. 8) and for the fulfilment of the work itself (appendix C, p. 9). These steps are an integral part of the study and greatly facilitate the writing of the report if they are properly conducted.

The nature of the project (experimentation, modeling …) influences how to prepare, to carry out, and to document the work. However, the majority of the principles stated in this document applies generally.

Recall that writing a report is very instructive since it allows its author to take some hindsight, to see the outlines, and to take a stand on the results. Furthermore, the document is also a business card for the author and his laboratory.

Firstly, some general recommendations are proposed. The basic structure of a report is then given along with its typical content. Several useful indications are gathered in appendixes, including in particular "Seven Gold-plated Tips" (appendix A, p. 7) and a "Check-list" (appendix D, p. 9).

2. General Recommendations

A report is not only meant to be read; it is first of all a means to *communicate information* and *transfer knowledge and know-how*. The report must follow a few rules to achieve its objectives:

BREVITY AND **ACCURACY** are two essential qualities of a good report. It should contain all necessary information and nothing more.[1] **CONCISION**.

ITS **CONTENT** must be *comprehensive*, *rigorous,* and *persuasive*.

The reader must find all the information he seeks about this subject. Mention also negative results and encountered problems: knowing what does not work is part of the know-how and prevents others from wasting time. However, the reader will be grateful not having to read a plethora of pages without clear benefit. Thus, ensure to:

1. give to the different tasks performed the importance they really have;
2. never complain about the difficulties encountered;
3. avoid getting lost in speculations.

(1) The interest of a problem is not measured by the time and the resources it requires. Admit that one sentence sometimes summarized the work of several weeks.

(2) Just mention once the encountered obstacles, along with the modifications in approach or work plan that result from them. A good engineer must clear up all problems encountered.

(3) Keep factual and credible when interpreting the results. Argue your words and support them using literature advisedly for documenting your study. Arguments that lead to decision-makings have to be stated clearly.

[1] For instance, the space allocated to a publication in some scientific journals is limited to eight pages.

ITS **STRUCTURE** must be *clear*.

The report must not be a maze where the reader seeks fragments of a puzzle. Follow a guiding thread (Ariadne's red thread) from the definition of the purpose until the conclusion; no superfluous studies, a report is not a book. The information must be easily found and understood. Do not forget to attach a numbered caption to figures and tables (appendix G, p. 11) and to refer to it in the text. Discipline is also required for conventions of notation (appendix E, p. 10). Put yourself in the reader's shoes.

ITS **FORME** (writing style and formatting) must sustain reading and *understanding*.

Short and simple sentences encourage reading, as well as precise formulations facilitate understanding.

Avoid vague expressions such as *probably*, *it could be*, *maybe*. Likewise, "hollow" words — that do not alter the facts— are often indicative of a lack of accuracy. Example: The difference is *very* large. *Very* provides only scant qualitative and relative information. Prefer to quantify the magnitude (20%).

A scientific report is written in a passive or indirect discourse. In other words, avoid pronouns such as *we* and *I* as well as their derivatives. Example: I made some simplifying assumptions. ⇨ Some simplifying assumptions were made.

Take the time to check spelling and grammar and ask a trustworthy person to read your report (verification of clarity). The content of a report, although scientifically excellent, is likely to be misjudged if it is riddled with errors perturbing the reading. Take advantage of the spelling and grammar checkers, but do not trust them blindly.

The formatting is simplified by using "styles" and "templates," available in all modern word-processing software (appendix F, p. 11). Without getting lost in details, make use of the forme to qualify your words, to point out the key elements and thus convey your message at best.

Be careful to always put yourself in the reader's shoes, and therefore, to know the audience you are addressing. It will be grateful to you and the message will arrive at destination. What is obvious to you is not necessarily for the reader.

Case of writer's block? Inspiration comes with writing, in the same way that appetite comes with eating: get started.

Get caught up into the game, and surprise yourself to write with pleasure a document of high quality. This is a great way to valorise your work.

3. Three Indispensables

Often the whole work is judged by the three key parts that are:

- THE **ABSTRACT** of the *report*,
- THE **INTRODUCTION** of the *subject*,
- AND THE **CONCLUSIONS** of the *study*.

A hurried reader will often only read these parts. If they awaken his interest, he will then deepen its reading of the report: your objective.

It is therefore necessary to invest a lot of care and attention to the writing of these parts, which will be detailed in section 5, p. 3.

4. Structure of the Report

The structure presented hereinafter is a general canvas that can be adapted as needed. In particular, some sections are sometimes advantageously merged or on the contrary split into subsections. The parts indicated with an asterisk (*) may be omitted in some cases. The content of the sections is detailed hereafter.

- Title page
- Abstract
- Acknowledgements
- Foreword or Preamble*
- Table of Contents
- List of Figures*
- List of Tables*
- Nomenclature
- Introduction
  - Objectives
  - Description of the Problem
- Methods and Equipments
- Results
- Analysis and Discussion of the Results

} Development

- Conclusions
- References
- Appendixes*

5. Content of the Report

THE **TITLE PAGE** contains:

- title and possibly subtitle,
- full name of the student,
- full names of the persons in charge (supervisor, assistant …),
- name of the laboratory (institute, school …),
- indication of the potential partners,
- place and date.

THE **TITLE** must inform at best with a minimum of words (max. 10 to 12). A subtitle may be used if necessary (preferable to an extensive title).

THE **ABSTRACT** must briefly:

- define the subject,
- describe the means and the methods employed,
- enumerate the main results and their consequences.

Pay attention not to mix up the abstract with the introduction. That one *summarizes* the essential of the report while this one *introduces* the subject of the report.

THE **ACKNOWLEDGMENTS** are part of the propriety. They can also be placed before the abstract. It would be ill-advised to relegate them at the very end of the report.

A **FOREWORD** OR A **PREAMBLE** may sometimes be useful.

THE **TABLE OF CONTENTS** must be easily legible: maximum three levels of headings should be referenced, with their page number. The hierarchical organization of the document should be limited to three numbered levels. If more divisions are required, it is preferable to mark them using the formatting.

THE **LIST OF FIGURES** AND THE **LIST OF TABLES** are worthwhile only for very voluminous reports containing a large amount of figures or tables —, which then have more in common with a thesis or with a book than with a report …

THE **NOMENCLATURE** is strongly recommended in order to provide a quick reference to the reader. It should contain the list of *symbols*, of *sub- & superscript*, as well as *acronyms* used. The nomenclature indicates the symbol of the quantity, its signification, and its units.

However, at the first occurrence of an acronym or a symbol, it is advisable to make it explicit: comprehensive form of the acronym; signification and units of the quantity.

THE **INTRODUCTION** aims to present as clearly as possible the subject of the study and its purpose. To this end, you must be especially careful to put yourself in the reader's shoes in order to bring him along from the general situation to the particular problem. Hence, you must:

- situate the context of the problem;
- present the problem;
- summarize the state of knowledge in the field (reference the main works);
- evaluate and criticize these works in an objective and constructive manner;
- identify weak points and open questions where there is a lack of knowledge;
- define the objectives[2] of the proposed work (outcome of previous points);
- bring out the technical and scientific importance for answering open questions;
- highlight the originality of the proposed solution (main idea).

Depending on the nature of the study and of the problem, it may be wise to deepen the definition of the **OBJECTIVES** and the **DESCRIPTION OF THE PROBLEM** in (sub)-sections separated from the general introduction such that this one remains synthetic.

THE **DEVELOPMENT** of your work constitutes the heart of the report and contains the three sections: *methods & equipments*, *results*, and *analysis & discussion of the results*.

THE **METHODS AND EQUIPMENTS** serve to explain thoroughly the approach whereby the resolution of the problem has been addressed. Display the original contributions of the author (improvements brought). The descriptions of "classical" methods or experiments are advantageously abbreviated by referring to other descriptions.

The reader must find in this section the arguments of the author, the tools developed, as well as all explanations necessary to understand how the results were obtained. It is about describing:

[2] It is usually a question or a set of questions, which the author wishes to answer through his study.

- the principles of the method (theoretical or experimental),
- the experimental setup or the modeling,
- the computer programs coded by the author,
- the method for extracting results,
- the variables estimated and the parameters,
- the hypotheses and the simplifications,
- the judging criteria,
- the possible errors,
- the problems encountered and their solution(s),
- the technical or theoretical limitations (range of validity).

This section is particularly dependent on the type of work undertaken. Thus, both its content and its form will have to be adapted to the topic. Likewise, its title and those of its subsections may vary but typically contain keywords such as methodology, modeling, experimental setup, tools, description, etc.

THE **RESULTS** are the fruit of the work. It is a matter of:

- giving an overview of the tasks performed;
- selecting relevant and representative results (in full in appendixes);
- presenting the results in a logical manner (classification);
- privileging the visual aspect (graphs, illustrations …);
- moderating the amount of information on a figure (avoiding an excessive mixture);
- proving the quality and the accuracy of the results

(e.g. standard deviation of measurements, reproducibility, justified assumptions, indicators).

THE **ANALYSIS AND THE DISCUSSION** of the results is a fundamental part of any study. This stage allows you to extract the sense of the fruit of the labour. It consists of:

1. explaining the results thoroughly;
2. discussing the validity of the results;
3. discussing the predictive capabilities of the models;
4. deducing consequences from the results;
5. indicating clearly the original contribution of the results.

(1) To quote values or figures is not sufficient: explain them. Why *these* results were obtained? What do they show? Are they consistent with the theory, measurements, literature?

(2) Since decisive choices can arise from the results, it is important to ensure their validity. Put side by side your results with those of the literature. Compare theoretical models and experimental results. Any interpretation should be supported by other experiences or other theoretical models. It is necessary to validate the models. Their range of validity will be determined by observing their behaviour at the boundaries. It is often useful to compare the results with a model by applying it in a simple case —for which a well-tried literature or analytical results are available. It is not enough to assert; *convincing evidence* must be *provided*. A criterion based on variables inferred from non-quantifiable appreciations lead to subjective findings.

(3) Results are not just numerals. They are a set that contains information about the problem. They allow to link causes to effects and to derive laws of physical models, which in turn enable to understand a phenomenon in order to be able to predict a behaviour under given conditions. Propose experiences that could verify the predictive capabilities of the laws. This step allows you to "keep your feet on the ground," to have a critical eye and to be confronted with the reality.

(4) Results alone are of little utility. Interpret them to extract consequences: understand a mechanism, predict a behaviour, assess a system, come to decisions, etc.

(5) Show why your results are useful: insist on the improvements or the expansion of knowledge to which they lead. As Richard W. Hamming wrote, *"The purpose of computing is insight, not numbers."*

THE **CONCLUSIONS** constitute one of the essential sections of the report. The answers to the questions that were posed by the objectives are given therein. It is thus very useful to check the development of this section.

The conclusions may be split between methodological aspects and technical consequences of the results. It is important to underline the original contribution of the study as well as the major results and what they imply.

Have a critical mind on the work accomplished and mention the improvements or future works that can be achieved. Depending on the extent of the discussion, these can constitute a wholly section and then be summarized in conclusion.

THE BIBLIOGRAPHIC **REFERENCES** *must be given in full*. On the one hand, it falls under deontology and copyright not to appropriate ideas or works of others. On the other hand, the reader must be able to find all the information necessary for the understanding of the approach and for the reproduction of the results. Nevertheless, it is important to *select* the most relevant literature at the time of the presentation of the "state of the art."

Follow conventions for formatting references. These conventions differ from an editor or from a company to another. However, you will find general rules in the reference [4], for instance. Specify page numbers when information is localized.

Avoid as far as possible references to Web pages, which have an ephemeral character. The URL address is not enough: provide precisely the way to find information (title of the page, author/company, access date …).

To facilitate their use, references can be grouped by genre (books, articles, corporate documentations …).

THE **APPENDIXES** must be used to provide any additional and relevant material that would otherwise disrupt the course of reading in the body of the text.

Nevertheless, current computer resources allow yielding excessive amounts of data. It is therefore advisable to identify the elements deserving to be printed. Others will be ideally stored on an electronic medium (CD/DVD).

6. Conclusions

In sum, writing a scientific report requires all the qualities of a good engineer: he must appeal to his creativity to solve the compromises necessary for the transmission of a message simultaneously clear, synthetic, accurate, and convincing.

Draw up a good report is not an easy exercise. Like any other exercise, it needs to practise. Do not hesitate to consult other sources to deepen the subject, e.g. [2]. Likewise, it is worth to take inspiration from good reports …

Get caught up into the game, and surprise yourself to write with pleasure a document of high quality. This is a great way to valorise your work.

7. References

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8. Appendixes

A. Seven Gold-plated Tips

1. Situate, define, and assimilate the subject of study.

Be sure to know the context, the objectives, and the motives of the study *before* starting to work. If this is not the case, define them and insist until everything is clear. Besides, making the state of knowledge largely contributes to situate the problem; the consultation of existing literature should enable to assimilate the subject.

2. Anticipate the results.

It is obviously primordial to know which physical quantities are involved. Furthermore, you will spare a lot of time by asking yourself about the desired results *before* starting to work.

- Which quantities are parameters (constants)?
- Which quantities are variables? Which ones will be measured or calculated?
- What *values* are typically foreseeable for these quantities?

This last point is particularly important. First of all, estimate representative values with a simple analytical model or with a similar case in literature. Regarding an experimental setup, simulation tools can advantageously be used for predictions, too. The comparison between the expected result and the measurement or the calculation is very stimulating and rewarding. Nevertheless, beware of preconceptions: to estimate is not to prejudge.

3. Call into question.

Neither measurements nor calculations testify to the reality. No theory or model is perfect. Accordingly, it is essential to always have a critical mind and argue your words. Exhibit the evidence. Confront your results with those of the literature. Compare theoretical models and experimental results. Any interpretation should be supported by other experiences or other theoretical models. (See also *The analysis and the discussion*, p. 5.)

4. Anticipate and organise the writing.

Do not underestimate the usefulness of taking notes continuously and rigorously: work diary, records of proceedings, and listings of computer established clearly and logically.

Consider sufficiently in advance the analysis and the presentation of the results. Raw results are rarely good indicators: define criteria of judgment. Moreover, systematize what can be as much as possible.

Structure your report by following a plan (see the basic canvas, p. 3). Write the report progressively, or schedule enough time in the calendar.

5. Ensure to convey the message.

The main objective of a report is to communicate information. Concision, simplicity, and accuracy guarantee respectively its transmission, its understanding, and its integrity.

The report must contain all information necessary for understanding but must be written and *structured* so that an overloaded manager can grasp an *overview* in 15-20 minutes. It is imperative to polish the abstract, the introduction, and the conclusions.

Guide the reader and orient your discourse by following a red thread from the definition of the objectives to the conclusion. Organize the document into a hierarchy. Present results unambiguously. Make sure that the transitions between paragraphs are logical.

6. Check the evolution of the work.

Mark out the work and the writing with checkpoints in order to avoid:

- letting yourself be caught out and being overwhelmed;
- losing track or digressing.

Throughout the work, as well as during the writing of the report, always remember the objectives and the motives of the study, which indicate what is essential.

Moreover, for long-term projects it is recommended to plan for an intermediary presentation to determine the progress of the work. Mention pending problems and suggest tracks.

7. Focus efforts on what is essential.

The appearance of the report is secondary: avoid perfectionism. Remember the principle "20/80": 20% of work wisely invested allows achieving 80% of the maximal result. The experience says it takes about 5 times more work to get a flawless document. Furthermore, it is important to remember that a partial report, not quite complete but finished in time, is *more useful* than an exhaustive report available too late, that will end in a drawer without being read.

B. Preparation of a Work Plan

At the beginning of any work, the plan for the accomplishment of this work must be prepared. From this moment, reflexions about the report must be undertaken. Besides, some parts of the report may be written well before the first experiments or calculations are carried out.

A few key points must be considered to prepare a work plan.

- Assimilate the subject of study: its context, its objectives, its motives.
- Consult the literature to establish the state of knowledge in the field.
- Identify the main steps to achieve the final purpose.
- Ask yourself about the results to which the different steps must lead.
- Itemize the means available to obtain the desired results.
- Identify those among them that are applicable for the targeted purpose.

- Evaluate the staff and materials needs, costs, and delivery times.
- Estimate the amount of work to prepare the equipments (experimental setup).
- Estimate the amount of work to extract the results, to develop programs of analysis in case of need.
- Prepare a logical schedule of the workflow (Gantt chart).
- Define checkpoints.

C. Fulfilment of the Work

- Accomplish steps according to the work plan.
- Catalogue the sources used as you go along in order to find and quote them.
- Extract and check results continuously.
- Keep track of all observations, reflexions, hypotheses, simplifications, etc.
- Analyse and comment on the results progressively; writing arises from notes.
- Check the progress of the steps with respect to the work plan (calendar).
- Adapt if necessary the plan or the objectives of the work after consultation with and approval of the person in charge.
- Identify interesting consequences of the results.
- Focus on the consequences and the originality of the results/methods in the report.

D. Check-list

At the very latest after completing your report, and with a clear head, answer the following questions while trying to put yourself into the reader's shoes:

- *Title:* appropriate?
- *Abstract:* concise, clear, and complete?
- *Introduction:* situating the context and defining the subject of study clearly?
- *Description:* accurate, for the problem and its objectives?
- *Originality:* highlighted, for the results/methods?
- *Conclusions:* precise, conveying the main message?
- *Structure:* logical? (red thread)
- *Transitions:* smooth, between paragraphs?
- *Style*: suitable? (spelling, grammar …)
- *Illustrations:* clear, complete, and legible?
- *Numberings:* up to date, as well as references of the fields? (figures, tables, equations, sections, table of contents, bibliography …)
- *Nomenclature:* complete? (in the *SI*)
- *References:* complete and correctly formatted?
- *Appendixes:* regrouping the details, no superfluous subject?

Ideally, the final report should be proofread two or three days after the end point, by proceeding through several readings, each with a specific aim (clarity, spelling, numbering …).

E. Nomenclature

Please use the notation conventions of the book of thermodynamics [3]. Here is an example of nomenclature for the most recurrent quantities at the LENI; the complete list is on pages 779-785. For quantities that are not referenced, the main instruction is to opt for a consistent notation.

Symbols	Quantity	Units
c_p	isobaric specific heat	J/(K kg)
c_v	isochoric specific heat	J/(K kg)
E	technical mechanical energy	J
E	technical mechanical power	W
H	enthalpy	J
h	specific enthalpy	J/kg
M	mass	kg
M	mass-flow	kg/s
m	molar mass	kg/kmol
N	number of kilo moles	kmol
P	pressure	Pa
P_i	partial pressure of constituent i	Pa
Q	heat (energy)	J
Q	heat rate or heat power	W
S	entropy	J/K
T	thermodynamical temperature	K
t	time	s
V	volume	m^3
V	volume flow	m^3/s
ε	system effectiveness (First Law efficiency)	—
η	exergy efficiency of any system	—
Θ	Carnot factor	—
λ	air factor	—
μ	coefficient of dynamic viscosity	kg/(m s)
ν	coefficient de kinematic viscosity	m^2/s
π	pressure ratio	—
ρ	density	kg/m^3

F. Help with Formatting – Styles and Automation

All modern word-processing software allows defining *styles* for different parts of the text (heading levels, paragraphs, captions, table of contents, quotations, etc.). Their use is worthwhile.

- It enables you to edit flexibly any text defined in the same style, with a single operation.
- It guarantees a uniform and neat layout.
- It allows you to automate the construction of the table of contents or of any other list of references (figures, tables, references …).

It is advisable to define the styles *before* you start writing, and to edit them later if necessary; modifications will then be made automatically in the entire document.

Microsoft Word and *OpenOffice Writer* allow the management of styles, but $LaTeX$ offers far more advantages for automating the formatting and for the management of the fields (numbers of sections, captions, references, table of contents …).

G. Numbering and Paging

The pages before the introduction should be numbered in lower case Roman numerals (that is *i*, *iv*, *ix* …). Arabic numerals mark the beginning of the body of the report: the introduction starts on page 1.

The caption of figures and tables contains a label indicating its kind, its number, and a brief description: "FIG. 1 – Evolution of pressure as a function of time." They are referenced in the text by the kind and the number: "see figure 1." If they are numerous, it makes sense to number them by chapter. By convention, captions are placed below figures but above tables.

The appendixes are alphabetized with upper case letters (*A*, *B*, *C* …).

The references are usually numbered in the order of their appearance in the text.