How to Write a Technical Paper
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ABSTRACT— The Association for the Advancement of Cost Engineering International "Official Guidelines for Preparing Papers" describes how to structure and format a paper for publication, yet writing a 5,000 (CCP Technical Paper word count is 2,500) word paper is intimidating. This paper describes a useful story board technique and a basic organizational format to get most technical authors past the "writer's block." The paper is intended to assist the first time author, as well as the seasoned author. Sensitive items such as addressing copyright, legal review, and proprietary data will be presented. Advanced writing tips will show how to select an editor, avoid common grammatical mistakes, incorporate technical reviews, and how to address the audience. The goal is to transform knowledge authors into recognized world-class authorities by helping them communicate their ideas on paper.

Keywords: Authors, copyright, formatting, legal reviews and technical writing

In the past few years, the AACE International Technical Board has noticed that the quality of manuscripts submitted for Annual Meetings has sharply deteriorated. Papers are submitted without a table of contents, bibliographies, and sometimes there are no papers at all for many presentations. The Association for the Advancement of Cost Engineering International (AACE International) has author guidelines published on its website [1]. One page in the guidelines addresses the minimum essentials for bibliography, units of measurements, style, etc. of the structure for technical papers submitted for publication. Technical papers serve as a reference library to the membership and future AACE International members in developing Recommended Practices. Therefore, it is important to seek to develop a common style and minimum standard to better serve the project controls community. This paper provides explanation on the format, and general guidelines that AACE International expects in a technical paper.

The Title
The title is the author's introduction of the subject to the reader. An effective title will be descriptive and easy to remember. If the title can be remembered, then chances are the reader will take the time to remember the author's name as well. To be effective, a title should be about six words or less.

Technical papers should not have ambiguous titles such as "10 Things We Remembered in the Bog After the Big Storm". It would be more appropriate to title the paper, "Project Control Issues After Hurricane Katrina." The reader is given several items of interest: a period of time (Hurricane Katrina), a location (US Gulf Coast), a subject (project controls).

Ambiguous titles do not clearly convey the topic to the audience. Instead they indicate that the paper is only useful to a small local audience of people who already know the author, or it is a paper to attract people seeking entertainment instead of continuing their education. If the title is unclear, the paper may not attract the intended audience.

Address the Audience
The first decision of authoring is to decide what audience will benefit the most with the material.

Potential audiences for technical material include the following.

- Those who are new to the subject, industry, or discipline.
- Those who have an intermediate level of experience and want to expand their knowledge. And,
- Those who are experts in the field who are looking for multiple applications of similar ideas.

It is important to pick an audience and write the paper to meet their experience level. This will keep their interest and allow the author to leave out non-essential elements. For example, writing a paper to an audience new to oil refining will require more definitions for terms related to the industry. Basic refining terminology can be abbreviated when writing the same paper for experts in the field who are more interested in the advanced application and not the basic theory.

If the technical material is not understood, then it is meaningless because there is no audience that will understand it. The material should always be instructive. Sometimes, when an author writes for a fixed circle of readers, the material becomes dependant on these "insiders" knowing what is trying to be conveyed. Always write for complete strangers. If writing on thermodynamics, it may be appropriate that the audience should be familiar with thermodynamics. If introducing a new concept in thermodynamics, then it would be appropriate to first build a brief introduction leading to the new concept.

Getting Started
Start collecting data a year or two ahead of time. Technical papers are generally focused on data, data interpretation, validation, and application. Otherwise, it is not a technical paper. For any paper, plan on a few weeks to write a 5,000 (CCP Technical Paper word count is 2,500) word paper. For technical papers, be sure that the data is solid, the equations are correct, and that the results are repeatable. If the results are not repeatable, then the paper has limited value to contributing to the advancement of the technology body of work.

Always start with the abstract and be sure that the paper addresses all the points of interest of the abstract when the paper is finished. The paper is "sold" to the reader by the title and the abstract. If the paper fails to meet the reader's expectations of the title and abstract, then the author looses creditability.

A technical paper should be self contained and not dependant on a publisher to make it useful. A magazine publisher will drop the table of contents, equation, and figures if they are not needed. A book publisher will incorporate these into a single master table at the front of the book. However, a technical paper is the most useful standalone instrument an author has to place themselves into the technical community.

A technical paper is the reflection of the author. This paper does not address publication issues, but it makes it far easier on the publisher if the author can show the publisher how the paper is intended to look for clarity.

Storyboarding

Writer's block can paralyze an author and result in ideas not being shared. Most authors find it easier to discuss their ideas than to commit ideas to paper. They can weave a good story to present their ideas and most authors are really good at the art of story telling. Story telling to a technical mind is nearly abhorrent behavior. Technical minds want to convey facts and data. They do not want to tell "stories." There has to be a compromise.

Storyboarding is the process of taking events or facts and placing them into an order that makes sense to an audience. This process is useful to the technical minded author; the ordering facts from basic input to the final conclusion. To start the storyboard process, place every idea, fact, figure, on a separate piece of paper. Do not attempt to organize the ideas at this stage.

Next take each of the idea sheets and tape them to a wall or place them on the floor or table. Start organizing the ideas from inputs to final conclusion. Review the story to be sure that it flows smoothly. If there is a gap in the flow, then create another sheet of paper with the idea to fill the gap. Remove redundant ideas.

There are many styles of technical papers. The style of a technical paper follows an outline set by the table of contents. Each subject in the table of contents should have a heading in the paper. Each subject should have a few paragraphs to develop the topic and explain why it is important. It is more important to understand what is going to be interesting to the reader than using the paper as a dumping ground for ideas. Where possible, connect the following topic from the previous topic to transition the reader through the paper. A collection of disjointed or dissimilar topics is like reading a dictionary. If a topic appears out of place, either reorganize the paper, consolidate the topic with another similar topic, or decide if the topic can be removed without seriously affecting the content. If in doubt, ask a technical reviewer or the editor to assist.

Once ideas flow smoothly, it is time to insert transitions between ideas. Transitions are working examples of the idea to bring about clarity. Be brief and do not create a story behind the example because it is not important and could detract from the technical presentation. An example is only to be illustrated to move from the last point into the next. Illustrations help readers get a mental picture of the point so that they are prepared to move to the next new topic in the story.

Now that the storyboard is complete, the paper is ready to write. Take the first paper and create a header and write a paragraph about the idea. Create doodles/hand sketches of figures for transitions. Once the story board has been converted from a set of ideas into a set of paragraphs and sketches place them on the wall or floor again and read through the paper for clarity. This would be a good time to have a technical reviewer look through the paper for clarity.

Finally, work can begin in earnest. It is time to commit each idea sheet into a fully developed set of paragraphs and convert sketches into final figures. When this is done, a draft copy is ready for commenting by the editor and technical reviewers. Do not throw away the storyboard because in the process of commenting, the storyboard serves as the master outline of the paper. This storyboard will also be useful in preparing the presentation. Resist major changes at this time. Major changes should have been addressed during the storyboard phase.

Getting Comfortable

When converting the storyboard into a final paper, it is not unreasonable to find a place (both mentally and physically) to get comfortable while writing. Keeping disruptions to a minimum is good. Consider taking a few weeks of vacation away from work. There is always that favorite chair, desk, room, and even a season of the year that helps an author get into the same writing mode as last time. Writing is a tactile event. This

means that it is a habit that is improved by physical objects. For example, some people can not read the morning paper without drinking coffee from their favorite coffee mug. Once a writing habit has been created, that habit will serve the author well on the next paper.

The Abstract
The purpose of an abstract is to entice potential customers to purchase the material or attend the presentation. Abstracts between 100 to 175 words are generally well received. Longer abstracts tend to be short versions of the material. Once a potential customer has finished reading the long version, there is a high likelihood that they will not attend the presentation or purchase the material.

When writing an abstract, keep the best material in the paper. Do not give away good ideas for free. Authoring a paper is a commercial enterprise. The abstract sells papers, books, invites authors to conferences, etc.

Length of Paper
The length of a technical paper is not to exceed 5,000 (CCP Technical Paper word count is a minimum of 2,500 words) words [1]. This includes everything from the title to the final bibliography. If the subject requires more, then consider writing a second paper. The length of a technical paper is about right for a chapter in a book. Most authors do not start out writing a book. However, most authors tend to write many papers in their area of expertise and eventually have enough material for a book. Also, the length of the paper allows for multiple authors to contribute to a book.

Units of Measure
Units of measure should be international (metric). Experienced audiences will be quick to judge and evaluate data using their reference, metrics. Consider including both international (metric) and English units for data. This would allow the reader to use their metrics to judge the data in the paper for authenticity. If the reader can quickly assess that their data experience matches the data in the paper, then the reader will continue to read. Otherwise, if the reader has difficulty relating to the units used in the paper they will quit reading.

Language
It pays to have a translator. Translate the paper into the language of the country in which the paper is going to be published. For example, a paper intended for an audience comprised mostly of readers from the US, should use the regularly used syntax of those readers. The same would apply also if the technical paper was to be published in Spanish for publication in Spain. Many great ideas are lost in a poor translation.

The biggest common mistake in translating into English is using run-on sentences. Run-on sentences have multiple ideas forced into one sentence. Keep sentences simple. A technical paper is a tough assignment. Most of the best books are those which the author uses one idea per sentence.

Tenses such as has, had, been, will, and would need to make sense through out the paper. Pick a tense and keep the theme of the paper in that particular tense. The easiest tense to choose is the present tense.

Selecting an Editor
The function of an editor is to review the technical paper for clarity. For this reason, choose an editor who is not a technical expert because they bring objectivity to the review. It is good that they have a general understanding of the topic so that they can suggest improvements to style and content. When multiple authors contribute to writing a paper, an editor can help them adapt their style to ensure that the paper reads as though it was written by a single author. When readers have to try to understand ways in which multiple authors express the same ideas in the paper, the paper's value is questioned. Again, not only must the paper have grammatical clarity, it must also be written with a common style and expression.

Once an editor has been found and the author is happy with the level of success the paper has acquired, then consider using the same editor in future papers. Editors control the image, the expression, and the style of the author. Editors help maintain the standard expression of the author, which is protected by copyright laws. If there is any infringement case, then the author's best defense is to demonstrate that over time and through many papers, that the expression of the author remains unchanged. If it can be shown that the author's expression in papers has persistent changes, then there may be some doubt of authorship cast upon the author, and the author may not have a solid case for pursuing infringement. Many companies, organizations, and highly successful authors go to extremes to protect the "look and feel" of their body of work.

Technical Review
Choose technical reviewers for the expertise they have in the field related to the paper. It is important to be confident that the paper is checked for deficiencies in data, theory, and application.

It is important to have different reviewers for every paper that is written. Fresh reviewers that are familiar with the area of expertise but may not have any association with the author are the best technical reviewers. They have no vested interest, nothing to gain or lose from the paper; therefore, can offer the most constructive criticism. Reviewers can range from theoretical to application. The target audience will help determine the mix of reviewers. If the paper is mostly theoretical, then having more doctorate reviewers would be appropriate. Practitioners in the field would be best suited for how the subject works in the real world. Always include both where practical. The practitioners will tell you if they can apply the methodology and the doctorates will point out deficiencies in concepts.

Equations
When using an equation such as the example that follows, show the equation and then explain each of the variables from left to right. When text is read from left to right, the reader can easily follow the variable explanation from top to bottom.

$$dS/S = \exp(\mu \ X \ (dT) + std \ X \in X \ (dT)^{1/2})) \hspace{3cm} (equation \ 1)$$

exp	=	the inverse of LN, the natural logarithm of number
dS	=	change in the variable's value from one step to the next
S	=	previous value
μ	=	the annualized growth or average increase between steps
dT	=	change in time from one step to the next
std	=	annualized volatility, or standard deviation
$\in$	=	value from a probability distribution (Monte Carlo)

Endorsements/Advertising
Avoid endorsing a product, company, or organization unless the technical paper is intended for commercial purposes. A technical paper is meant to share ideas among other technically-minded individuals. The paper is a "how to," not a commercial for buying services. The best approach for technical papers is to present data and facts.

Similarly, avoid using names of people in the paper as endorsements or to gain credibility. This can often be more confusing than helpful. For example, to state that this paper is sheer "Einstein-ian" could be confusing because it is unclear if readers know who Einstein was, what he contributed to science, or how people use his name as an adjective. However, it is appropriate to mention a name when giving proper credit for their work.

Organization or Company Names
When referencing a company name, verify that the name is used properly. For example, it would be incorrect to reference "AACE International" as "AACEI" or "AACE, Int." Company or organization names are registered trademarks and to alter the name is incorrect. In the case of AACE International, the association name should always be listed with International spelled out.

Do not use a name as a plural or as a possessive because it is a trademark and is protected. It would be correct to state that AACE International requires copyright releases to be notarized, but incorrect to state AACE International's requirements are to have copyright releases notarized.

Abbreviations
An abbreviation may be used if it is first referenced in parentheses immediately following the first occurrence of the spelled out name in the paper. Thereafter, the abbreviation can be used instead of the name. This helps save space in the paper and makes the paper more readable. AACE International, for example, is more readable than "Association for the Advancement of Cost Engineering International."

Copyright
A copyright is a form of protection provided by law to protect the original work of an author. This area of law can be highly contentious. It protects the expression of the author but does not protect facts, historical accounts, ideas, etc. Copyright is a gray area of law, and every country has some form of copyright law.

Copyright allows the author to profit from the work, display it in public, revise it, and generally use and alter the work however the author deems necessary. In order to use copyrighted material, permission must be obtained from the author. When a company or organization also owns the copyright, permission may need to be requested of that company or organization in addition to the author.

There is, however, a "fair use" doctrine that allows use of copyrighted material in another publication. "Doctrine" means that there is nothing specifically written down in law books, but there is a general, "unwritten" consensus of agreement. This means it is highly subjective to the moods or political environment of future law makers. How much copyrighted material can be used under "fair use" is indeterminable. The final determination of what is allowed by "fair use" is subject to the original author's determination. If too much material is used, then there may a legal problem with infringement. Infringement of copyrighted material could be a problem if the original author deems that their work has been devalued by the author citing their work.

Quoting from copyrighted material and providing the reference in the bibliography does not constitute permission to use the material. When in doubt, always get the author's permission. If copyright permission can not be obtained, then consider an alternative source to accomplish the objective of citing. A better practice, though not guaranteed, is to use the least amount of quoting possible and best to discuss the reference as a concept and not quote the reference directly.

Confidentiality
Any references to proprietary data or information that is not publicly available could be considered a matter of violating laws in the general area of confidentiality. Using data that could be considered confidential is outside of copyright laws, and there is no "fair use" doctrine. If using data that could be considered confidential, then it is highly recommended that a copy of the data from the public source be kept on file. When using company data, always have the company review the publication and sign a release statement. Then, if there are any legal contests in the future, the author has a clear paper trail to the releasing of the data for public use.

Figures and Tables

When including figures and tables, color and resolution are important considerations. Consider that the paper is going to be in circulation and will be copied several times despite copyright laws. Assume that the paper will be copied on a black and white copier. Resolution of the figures for original publication must be at least 300 dots per inch (DPI). The most common copier only produces 200 DPI. Take the original copy and make 20 more copies. Each copy should be a copy from the previous copy. The purpose of this exercise is to determine if the original work is too complex and intricate. If the last copy appears distorted, consider simplifying it.

Figures in technical papers are not artwork. Colors are used to illustrate and distinguish between points of interest. Consider also that many people have some form of color blindness. It is best to select a few primary colors, and to use a few distinct patters such aa stripe, shade, and a polka-dot. The optimal figure is one that can be printed in black and white with few annotations and still retains data clarity.

Also, remember to keep the figure title to six words or less. Consider a descriptive noun-verb like "Estimate Multiplier." Short titles help the reader remember the figure.

Tables
Include a table of equations and figures. Technical papers are references. Readers need milestones to remember where they found items of interest. Most technical readers will check the table of contents, figures, and equations when trying to remember where to relocate information.

Footnotes and Endnotes

Do not use either footnotes or endnotes.

Any material that is taken from another source or author MUST be presented in quotation marks and cited in the Bibliography (format below). If material from other sources is not placed in quotes and cited in the Bibliography, that material could be considered unattributed material.

Bibliography Format
It is a recommended practice in research and technical papers to provide a few reference works. This is for the sake of the readers to get other information about the subject. The following example illustrates what is required for a reference. If a reference is made in the body of the paper then a reference number can be included in hard brackets i.e., [1].

Example:
1. Breyfogle, F. III. *Chapter 9, Six Sigma Measurement*, **Implementing Six Sigma: Smarter Solutions Using Statistical Methods**, First Edition. New York: John Wiley & Sons, Inc., 1999: 144.

Far too often authors think of themselves as their own reference source and exclude reference material. By excluding reference sources, the audience can not check the author's facts or find more information on the subject. Consider the bibliography a list of material for "further reading." Do not consider the list as detracting from the paper or diminishing the authority of the paper; instead, it adds creditability to the paper.

This paper is not exhaustive and is intended as a basic guide for new authors. The storyboarding has helped even seasoned authors that wrestle with writer's block. Many technical writers do not consider legal problems associated with copyrights and proprietary data. Therefore, some awareness has been provided, but not in itself exhaustive either. This paper has provided some of the basics that have taken a few years to learn and have resulted in numerous papers being published in conferences and international trade magazines.

REFERENCES

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