SO YOU WANT TO BE AN ENGINEER

- A PRACTICAL GUIDE -

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Preface

The purpose of this booklet is to describe the education and skills required to become a successful engineer. A career in engineering can be exciting and rewarding both from a job satisfaction standpoint and financial compensation.

It is primarily aimed at potential engineers working in the Process and Manufacturing Industries working in Engineering Management, Maintenance Engineering, Maintenance Managers, Reliability Engineering, Maintenance Staff Engineering, Plant Design Engineering and other job functions that insure high efficiency production.

The following are guidelines, principals, and laws, outlined in this booklet, that I followed throughout my career:

- Engineering is application not invention.
- Failure is not in an engineer's vocabulary.
- Good engineering is first identifying the problem.
- Pareto's Law or 80/20 rule.
- Lusser's Law of Reliability.
- The positive and negative aspects of statistics.
- Be a leader not a manager.
- Continuously, Learning, Be "Curious"!
- Anticipate! Anticipate!

Many of the described skills can be used in multiple fields of engineering.

I would like to thank my parents and my favorite grand-mother, Ida Belle Self who continuously stressed education and that: "A job not worth doing right was not worth doing."

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Chapter 1
What is an Engineer?

So you want to be an engineer? What is an engineer? Webster's Dictionary gives the following: "One who applies science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people." Another definition that was used in a project engineering course I taught was: "A person that applies the various techniques and scientific principles for the purpose of defining a device, a process or a system in sufficient detail to permit its physical realization."

The Engineer's Council for Professional Development defines engineering as: "The creative application of scientific principles to design or develop structures, machines, apparatuses, or manufacturing processes, or works utilizing them singularly or in combination: or to construct or operate the same with full cognizance of their design: or to forecast their behavior under specific operating conditions; in respect to its intended function, economics of operations and safety to life and property." "Whew!!"

A good short definition of engineering is: Engineering is the application of math and science to create something of value from our natural resources. My own definition of an engineer is one who applies the laws of math and science to solve problems.

The key word in all the definitions is the word "application." Engineers are not inventors, scientists, or physicists! Engineers <u>apply</u> what inventors, scientists, or physicists develop.

An Engineering professor of mine wanted to illustrate that engineers apply the practical. He asked the class if anyone knew the difference between an engineer, a scientist, and a physicist? No one answered. He said a physicist takes all his data, squares it, takes the square root of it and guesses at the answer. The scientist cubes all of his data; takes the cube root of it, and guesses at the answer. The engineer; Hell, he just guesses at the answer!

Also, a scientist will take the data, accurate to at most 25%, plug it into a formula, raise it to the third or fourth power and carry out the final answer to six decimal places! Why have any decimal places?

The same professor used another story to illustrate his feelings that engineering was straying too far from practical applications. He said that he put through a requisition for equipment he needed for an experiment. He wanted a milk bucket and a set of milk scales; costing twenty six ($26) dollars. The requisition was rejected. He noted that if the requisition included a volumetric container; accurate to a millionth of a liter, and an electronic scale; accurate to a millionth of a gram; costing twenty six thousand ($26,000) dollars, the requisition would have been approved and he will already have the equipment! He just wanted a milk bucket and milk scales!

There is a joke or story that I was told: There was a contest between a mathematician and an engineer. The contest was set up in a room. There was an entry door and a naked lady for the having was at the wall opposite the door. The contest leader indicated the rules were simple. You entered the room with one step. Each subsequent step was to be one-half of the previous step. The Mathematician said that there was no use in trying because it was mathematically impossible to reach the lady. The Engineer was grinning from ear to ear. The leader asked the engineer if he wanted to try? He said, “Sure”! The contest leader said you just heard the mathematician say that is was mathematically impossible; you still want to try!!?? “Sure”! He is right, but I can get close enough! All the examples illustrate that engineers must work with the mind set of the practical world.

The previous text could apply to any engineering discipline. The remaining text will mainly apply to engineers that are intending to work in the process industry of manufacturing. Jobs could include Maintenance Engineering, Engineering Managers or Maintenance Management.

Chapter 2
Engineering Application

More about application. Any required part or component of a machine or a process probably already exists. You don't have to invent the part or component. It is out there somewhere. At the most, you will have to modify the part or component. Remember, we are not inventors!

Early in my engineering career, there was a good example of this. There was a plant project that I was involved in with Corporate Engineering. A weight scale was required to measure and track the amount of a chemical in a drum as it was being used. The Engineer designed his own load cell scales and electronic system. The system was sensitive to position on the scale platform and the electronics did not work very well. When I inherited the responsibility of the project, I went to a brand name scale company, and ordered a standard one from a catalog that was not sensitive to drum location and it worked very well. We are not inventors; we apply existing parts or systems!!

Another story illustrates the engineer's proper role: The company I worked for built a manufacturing plant in a Caribbean country. The physical plant was within 100 yards of the Caribbean Sea. The corporate engineers had designed and installed a large air-cooled chiller.

The air-cooled condenser was purchased from a large HVAC equipment manufacturer. The equipment manufactured recommended a special condenser designed for salt atmosphere.

The condenser coil lasted only one year, suffering severe corrosion. The plant personnel were having no satisfaction in getting the situation corrected. Warranties were discussed with no resolution in site.

I was asked to correct the problem quickly. Instead of going in circles with the equipment manufacturer, I simply asked myself: "Who would be the expert on air-cooled coils in a salty atmosphere?" The United States Navy!! I contacted the Navy, requested their specifications, found the Navy supplier, and the rest is history. The new coils have lasted for years. I received my hero badge and went on to the next problem.

Another example of the engineer's role in solving problems by application. My company decided to go to a high-rise automated warehouse as part of a new manufacturing plant. Per the vender's design the picking, stacker cranes ran on American steel rails. The rails were installed on a concrete floor, being supported at defined intervals with steel plates and anchor bolts. The loads carried by the stacker cranes were essentially pallets of water. After several years of operations, problems with the rails became severe. It was taking two mechanics full time to replace broken bolts. The flexing of the rails placed cyclic stress on the bolts caused fatigue failures. Broken bolts caused more flexing of the rails. The flexing rails were deteriorating due to cracking. I was approached by warehouse management for some help. After investigating the problem, I asked myself: "What industries have rail systems, carrying heavy loads, inside manufacturing facilities? Steel Industry! The steel industry was a good possibility. I made some inquires and found that grouting the rails was the secret. A grout company was contacted. They had a special design with special grout for this type of application. The rails were replaced with the grouting design, - no more problems! The two examples are good application engineering, but also, good examples of maintenance engineering.

Chapter 3
Engineering School

Now that you want to become a particular engineer, what kind of education is required?
Any good engineering school will teach you the basics. There are several skills that are extremely important that you master. The following are areas of expertise that are needed when you graduate.

- Basic Electrical Power
- Basic Statistics (The world runs on statistics)
- Metallurgy (Both theory and practical)
- Engineering materials
- Machine Design

There is one skill that you must prevent from "mastering" you is the computer! The correct view of computers for an engineer is a must! It is a powerful "tool" and that is the way it must be viewed. It does not think for you and, or solve your problems.
When I attended my last engineering class before graduation, the professor made a statement that served me well throughout my career. He said that as we get ready for our engineering career, we would be walking right into the computer age. It is upon us. He indicated that the Engineering College had done absolutely nothing to prepare us for it; but we

would do fine, if we remembered one thing - - "It is just a fast moron!" This view is still applicable today! You have heard the adage, Garbage In - - Garbage Out!
Just remember - - an answer from a computer is really an answer from a human programmer - - Does he have an engineering degree? - - Does he have good engineering skills?

This brings us to a concept that worked without computers, but is extremely more important with computer programs. You should always have a ball park answer in your head before you work out an answer with a written formula or formulas or computer programs.

There is an area called "Rules-Of-Thumb." "Rules-Of-Thumb" keeps an engineer from making a large mistake. The HVAC engineers use Btu's/ft2, CFM/ft2, etc, when calculating HVAC requirements for a space. Whatever area of engineering you work, you should develop "Rules-Of-Thumb." The more experience you have, the easier this becomes.

There is another area of engineering that the computers affected during my generation - - "Safety Factors." Engineers in machine design were taught how to calculate stress on a complex shape. Simplify the shape to a plain geometric figure, taking the shape in the "worst case" direction and calculate the stress. This procedure added an additional safety factor. Complex shapes can now be evaluated with computer programs, eliminating the built-in safety factors.

Another area affected by computer controls is metallurgy. For 410 grade stainless steel, per specifications the chromium content range is 11.5 to 13.5 with old batch mills you could count on a value mid-range around 12% with a new modern computer controlled mill, you can expect a very low value, say 11.56.

This situation actually happened in the manufacturing of a corrosion resistant item for a company. At approximately 12% the item would have been a success but at 11.56%, the item was a total failure costing the company two million dollars!

Another area that requires discussion is statistics. H.G. Wells said: “Statistical thinking will one day be as necessary for efficient citizenship as the ability to read.” Wikipedia defines statistics as “The science of the collection, organization, and interpretation of data. It deals with all aspects of this, including the planning of data collection in terms of the design of surveys and experiments.” BusinessDictionary.com defines statistics as “A branch of mathematics concerned with collection, classification, analysis, and interpretation of numerical facts, for drawing inferences on the bases of their quantifiable likelihood (probability). Statistics can interpret aggregates of data too large to be intelligible by ordinary observation because such data (unlike individual quantities) tend to behave in regular, predictable manner. It is subdivided into descriptive statistics and inferential statistics." – Whew!

A Simple definition – makes it possible to make an inference about a population based on information contained in a sample. For the plant engineer statistics is a "Tool." Statistics can be used for design of experiments, reliability engineering, and manufacturing procedures. In the area of manufacturing quality control, suppose a manufacturer of a product, produces roughly a half million units per day. The manufacturer is concerned about customer reaction to the quality of their product. The problem can be solved in two ways. First, test all the half million units. This would be cost prohibitive. Second, a method for determining the fraction that are defective would be to select 1,000 units and test each one. The fraction of units could be used to predict the defects in the entire production run. Now the other side of statistics! Some say that statistics can be made to support anything. Other say it is easy to lie with statistics. A famous 17th century British politician, Benjamin Disraeli, was quoted as saying, "There are three kinds of lies: Lies, damed lies, and statistics." Another old saying:

"Figures don't lie, but liars figure." Statistics is an excellent tool but you must understand its limitations.

Many engineering schools have co-op programs and internships that provide a great opportunity for engineering students to gain invaluable experience in areas of maintenance and management principles.

This author was a co-op student. I was able to gain a lot of engineering skills that I otherwise would not have mastered

Co-op and intern students get to see firsthand engineering jobs with real engineers. This helps clear-up in their mind if a particular job function relates to what you desire. A lot of job movement and lost time is prevented by this knowledge.

If you choose a career in plant operational management and higher advancements, an associate degree in Corporate Finance is highly desirable. An engineer with Corporate Finance training is highly sought after by many companies.

Chapter 4
Project Engineering

The one important area that you must master before taking an engineering job is project engineering.

Project engineering is an area that is not usually taught in engineering schools. It is an area that most engineers fail at. Corporate systems range from no project engineering systems to very sophisticated systems. It is recommended the new graduate engineer enroll in a good project engineering course to learn the basics. The following text will present an abbreviated lesson in project engineering:

To start with, some terms must be defined: What is a project? A project is an undertaking that has a beginning and an end and is carried out to meet established goals within cost, schedule, and quality objectives.

What is project engineering? The project engineer brings together and optimizes the resources necessary to successfully complete the project. These resources include the skills, talents, and cooperative effort of a team of people, facilities, tools and equipment information systems, techniques, and money.

The Project Engineer must have value engineering skills that will provide structured problem solving process based on Function

Analysis. Value engineering is an important skill set when trimming cost out of a project.

The following are attributes of a good project engineer:

- Excellent team leader
- Anticipates
- Good diplomacy and negotiator
- "Failure" is not in the definition
- High level of credibility
- Motivator
- Is less likely to make assumptions and judgments
- First identifies the problem
- Understands the relationship of the project to the business financial/strategic plan

One of the most important attributes is they take for granted that there will be problems with any human enterprise and approach them as challenges. Believe in Murphy's Law: If everything seems to be going well, you have obviously overlooked something!

The following are miscellaneous "Tricks of the Trade:"

- The two (2) most important phases of a project are the first 10% and the last 10%. The first 10% is when you lay the foundation for the project. The last 10% is cleaning up the unfinished details. This applies Pareto's Principle - - The 80-20 rule. The value of the Pareto Principle is that it reminds you to focus on the 20% that matters. You can apply the 80/20 rule to almost anything, from the science of management to the physical world.

- The estimate format should be the same as the tracking format which will allow good cost tracking during implementation.
- Do not forget sales tax and shipping costs.
- Remember to include start up cost for manufacturing projects in the capital document. Start up cost is the value of the loss of performance due to not meeting manufacturing standards during the start up phase.
- On estimates, use an allowance of 10%. If notes or bids are available – 5 to 7%
- Organize an excellent engineering file. Five years after the project is complete, another engineer unfamiliar with the project, in reviewing the project file, can easily determine the "what" and "why" of the project.
- Be a good diplomat and negotiator. Probably none of the individuals involved in the project works for you!
- Document and track all project financial transactions.
- Document all correspondence and communications.

- Always have an excellent set of drawings and specifications.
- Always have client approval of scope and drawings.
- Always include a detailed "scope of work" in the specifications.
- Have a goal of zero field orders; however, allow 10% of contract funds!

Communicate!	Communicate!	Communicate!
Follow-up!	Follow-up!	Follow-up!
Details!	Details!	Details!

Chapter 5
Your First Job

You should go into your first engineering job with the premise that the learning experience has just begun!! In my initial meeting with my first "Boss." Just out of engineering school, he told me that my Engineering diploma and 25¢ might buy me a cup of coffee. I fully understood what he was telling me. The door has been opened for the learning process.

Learn! Learn! Learn! Be "Curious"! Learn from experienced engineers. Learn from other engineering fields. Learn from your mistakes and other engineer's mistakes. There is an old saying: "Learn from other peoples' mistakes, you are not going to live long enough to make them all yourself." Learning from a related field, even small things, can pay-off in the future. The following example will illustrate the benefit: I was working for a defense contractor as a Senior Engineer Designer. It was in the early days of printed circuit boards. I was assigned the mechanical design responsibility. The specifications presented called for relative humidity control of ± 1%. I made an appointment with the spec writer to discuss this close control of relative humidity. I asked why the close control? The specification could be met, but I just interested because of the unusual tight control of relative humidity in manufacturing. We had a 10 minute discussion on the impact of plastics and moisture. Several years later, I was working for a pharmaceutical company in a device plant that utilized plastic and rubber components in manufacturing of various devices. The company had been on a program of automation. There were numerous problems with auto-feeding and processing. My assignment was to fix the feeding and processing problems. I was told to fix the equipment. I reviewed the manufacturing environmental system, keeping in mind my discussion on plastics and moisture. After some design work, the company paid a mechanical contractor $1,800.00 to modify the controls for humidity control. Surprise! 80% of the problems ceased to exist! The company thought I was a genius! Some years later, I was transferred to a plant that manufactured plastic containers from roll film. The process had struggled for years. Again, I reviewed the manufacturing environmental controls the company paid the same mechanical contractor the same $1,800.00 to modify the controls for humidity control. Manufacturing was asked to bring the roll film into the manufacturing space, 24 hours prior to use. Surprise! Surprise! 95% of manufacturing problems ceased to exist! Again, the company thought I was a genius! All I did was to apply what I had learned in a 10 minute conversation.

You have entered the real world that is nothing like school. The only skill that remains the same is "how to think like an engineer."

There is one area of school that you must continue to do - - homework! If an important meeting is to be held the next day and you are not totally familiar with the facts, do your home work! If you address your work with always being prepared, you will develop a reputation for having a broad knowledge of all subjects.

As an engineer early in his/her career, do not avoid risky tasks, projects or assignments. Do not worry about failure: remember failure is not in the engineer's vocabulary. A difficult task is an opportunity to advance your career opportunities more quickly. Most engineers avoid risky tasks, thinking failure would hurt his/her career.

Early in my career, my manager called me to his office. He wanted to see if I would like to take on a special task. He asked if I had heard about a special polymer plant being built at a very accelerated schedule. I indicated that I had heard of the project because it was being built directly from research and engineering, skipping the pilot plant phase. He indicated that part of the project that was our division's responsibility was start-up of the Dowtherm heat transfer system. He asked me if I could start it up in two (2) weeks? I told him that I had heard that the normal start-up time was six (6) months. Someone had previously started one up in three (3) months, but almost blew it up. My manager said, “That is correct, can you accomplish it in two (2) weeks?” I told him that let me pick the start-up team and we will make it happen.

The start-up team quickly got together to develop a plan. The key part of the plan was to determine the time consuming start-up items. 80% of the start-up time will be consumed by 20% of the start-up items. (The 80/20 rule)

The plan was executed and the system was operational in two (2) weeks!!!

This accomplishment did great things for my career.

Opportunities can be few and far in-between, take advantage of them!

Another area that young engineers must be aware of especially in maintenance engineering, is the loss of good work that is lost in the bureaucracy. Most manufacturing and process companies do not have a formal system to track engineering improvements. Some work is repeated several times.

Early in my career as a maintenance engineer, I was assigned a task of reducing maintenance of a new waste heat incinerator system. The goal was to reduce maintenance costs from $150,000 to $50,000 (1964 Dollars).

The system was a Rotary Kiln with a waste heat boiler. The company trash was burned and low pressure steam was generated for use in chemical manufacturing.

I worked two (2) years on the problem. The main problem was the firebrick cost. Metal in the trash caused the firebrick to deteriorate very quickly. Total removal of all the metal was not a viable option.

I filled up six (6) 4 inch notebooks with test data and study information.

The goals was achieved, and I was assigned a different project. The responsible for the incinerator system was assigned to a different department. I turned over all my work to the responsible group.

Some months later, I went to an old golfing buddy of mine to see if he wanted to play golf the following weekend. He had been assigned the incinerator in the responsible department. He indicated that he could not play because he had some work to perform on the incinerator. He indicated that they were installing Castable Firebrick material. I told him that it would not work because I had tried the same material a year before! I asked what had become of my work notebooks? He said that they were thrown away!

My first thought was - all that work for nothing! It bothered me for awhile. I realized that this will probably happen again, so keep doing good work. Do not become disillusioned; keep performing professional work.

An engineer working in the process of manufacturing industry as an Engineering Manager, Maintenance Manager, Maintenance Engineer, Reliability Engineer or Staff Engineer must understand and apply the following guiding principles:

- <u>Cost of Production Downtime</u> – Cost of production downtime must be used as a guide for decisions on maintenance, reliability, preventative maintenance and design engineering. An example was a situation that I witnessed in a manufacturing plant. A manufacturing line went down and there seemed to be no activity on fixing the production. After some time, the Plant Manager went to the Maintenance Manager to find out the problem of no activity. The Maintenance Manager described the situation and indicated it would be a costly repair and he did not have the funds in his budget. The plant manager told him that the repair amount had already been lost while they were talking!! Know how to prioritize your problems.

- Pareto's Law – Principle or 80/20 Rule – The 80/20 rule means that in any enterprise, 20 percent of items are critical and 80 percent are non-critical. You can apply the Pareto Principle to almost any part of your engineering work or life.
    - As management of engineering functions, the value of the Pareto's Principle is that it reminds you to focus on the 20 percent that matters. Identify and focus on those things. Work smart on the right things!
- Lusser's Law – Per Wikipedia, Lusser's Law is a prediction of reliability named after Robert Lusser. It states that the reliability of a series system is equal to the product of the reliability of its component subsystems. Understanding of this law helps you identify the 20 percent critical items.

    - To illustrate Lusser's Law, I was trying to explain the law to a subornate Engineer. I could tell that he was having trouble understanding the law. I indicated that a production machine on one of our lines has three automated stations and one manual station. If I gave you the project of automating the forth station. If the overall reliability of the production equipment is 97 percent, what would have to be the reliability of your new automated station to maintain status quo? He thought for a second and exclaimed – "100 percent!" I said "correct." You will have to improve the reliability of the other stations to prevent loss of output. If NASA had not understood Laser's Law, the trip to the moon and back would have been impossible.

If your first job is in the process and manufacturing areas, the following are survival tips:

- Do not B.S. or spin on any subject. Always present "facts" (you are an engineer). You may not prevail at first, but if you keep presenting the facts you will prevail in the final analysis.
- Always be Professional - - you are a professional!
- Learn, research, and become an expert on any subject encountered.
- Anticipate! Anticipate! – Simply Put - - never have your boss ask you a question that you had not anticipated, and have the answer.

Chapter 6
The "Game" of Work

The "Game" of work chapter is for engineers who have chosen operations management as a career.

In any business organization a "Game" exists. It is part of the real world. As a member of an organization, an engineer must understand the "Game", including the "Rules", if the engineer is part of a management team in the manufacturing or process industries.

Advancement in plant management is a highly competitive "Sport". If you work hard and are good at your job, it's like walking thru a mine field. Someone once said that as you are walking down a hallway, you need to always look up and back to see if the buzzards are circling or someone is trying to stab you in the back. If you decide to play the "Game", the following are items you need to consider:

- What personal values are you willing to sacrifice?
- Are you willing to work 24/7 and sacrifice some family life?
- Know the people that you are dealing with:

Your competition, your superiors, the personnel that you manage. What makes them "Tick". For example: Is your boss a morning or evening person? If your boss is not a morning person, address difficult items during the afternoon, etc.

A lot of your counterparts are non technical. As an engineer with tends to deal in absolutes and straight forward solutions, you can be at a disadvantage. You have an advantage in dealing with facts. Never spin or BS, know the facts. If you keep throwing out the facts, you will ultimately win-out.

Become a leader versus a manger.

- Leaders inspire people, but managers depend on systems. You have often heard, “We’ve got to make the system work.” Only a manager would say that. A leader says, “We’ve got to make systems that will allow people to work.”
- Managers attempt to adjust to change, but leaders attempt to produce it. By definition, leaders are people who promote, encourage and even provoke change. Without change there can be no progress. So simple is this idea that it is often ignored, but the very essence of progress

means that things have changed from a previous state. Still, change represents some degree of threat to the smooth functioning of a well-managed routine. Managers recognize that change is necessary ("The absence of growth is death") so rather than resisting it, they attempt to adjust when change comes.(1)

Remember a highly successful organization is a team effort. As an engineer, you have "Book" knowledge of systems and processes. The technical personnel working on equipment and processes have practical knowledge. If you combine the two, highly successful operations are the result. <u>Do not</u> micromanage!

Remember, be professional, learn, learn, anticipate, anticipate, do your homework!

Good Hunting!

References

(1) From Airline Magazine in the 1970's. Name of author unknown.

(2) Mendenhall & Ott: Understanding statistics. Massachusetts Duxbury Press. 1976.