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Written Communication for Engineers

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Introduction to the text

This course packet sequences several documents engineers typically encounter in the workplace culminating in a final paper that presents and interprets research findings to address a problem or need in a specific industry or organization. The materials comprise assignments followed by award winning student responses to those assignments and tips to facilitate writing.

How does it work? The course packet shows the student how to apply audience and purpose-based technical communication knowledge to a particular topic and assumes a targeted reader. The student learns how a research project unfolds and leads to a final report containing Discussion, Method, Results, Conclusions, and Recommendations, all designed to benefit the intended reader in the workplace.

The primary assignments the student will write are an unsolicited Proposal, a Progress Report, an email research inquiry, and a Formal Report replete with useful supporting visuals. The student will also present the main findings of the research in a visuals-centered presentation. Each assignment proceeds logically from the one before so the student can understand how such a research project develops. (The packet also covers secondary, unrelated assignments such as the Job Application process and documents that numerous students have attested helped them to secure interviews, internships, and full-time permanent positions)

The main objectives of this course packet are first that it should foster student accountability to a designated, authentic reader in an organizational context the student selects (the student will write very few of the assignments for the technical writing instructor; instead, most of the documents target engineers, decision-making managers, and technicians). Second, students learn to ground their research in a real or else realistic workplace problem or informational need. This means the student must understand and account for the professional goals of the executive and engineering target readers, which requires audience analysis skills. Next, the student is exposed to persuasive strategies and demonstrations of credible persona that make documents successful. Finally, because it is grounded in a specific writing context, this approach mitigates any tendency a student may have simply to borrow and submit a paper, or parts of one, another writer has produced.

Additional strengths of these materials include explanation of the differences among facts, conclusions, and recommendations and associated terms. Also, the research method is firmly anchored in research objectives: the student needs to determine first what the organization would need of a successful research topic (for example, the most efficient processes to reduce manufacturing rework by 13%) before deciding on the research tasks that would fulfill those objectives.

From the student's perspective, the usefulness of the text lies in the many excellent document examples written by their peers that serve to instill confidence and develop writing strengths. The materials also allow the student to see how the theory covered in class translates into practice. Particularly, the course packet shows the student how to integrate borrowed work and source it properly; it demonstrates varied document genres; it teaches the student how to cold contact an expert in the field for answers to research questions and possibly engage in networking; it lists and explains all the component parts for building a Formal Report that a decision-maker and an expert can use; and it explains how to develop and practice a persuasive speech.

The course packet can be supplemented with materials on documentation, ethics, organizational patterns, persuasive techniques, and grammar and technical writing style or with an ancillary text. Furthermore, as the student assignments reflect solid writing principles, users may adapt those principles to whatever medium they prefer, whether any of the myriad electronic delivery methods or traditional hard copy.

Ultimately, proof of the value of the text lies in the opinions of its users and its ability to prove itself. Within the last few months, in an unofficial poll, 62 out of 63 students declared the text indispensable to their learning, and for many years it has been the foundation of the Written Communications for Engineers class, yielding 44 Technical Writing Competition winners, nearly 50% of all first, second, and/or third place winners since the start of the yearly competition (in any given year, the course accommodates as many as 390 students).

Student Course Packet Objectives

1. Learn to understand the needs of an audience and the purpose behind a technical document to write informatively and/or persuasively.
2. Learn to interpret information and give conclusions and recommendations based on it.
3. Learn to gather, select, and integrate information ethically from current, reputable sources both electronic and print.
4. Learn to construct/select and integrate visual aids appropriately for reports and oral presentations.
5. Learn to use common document types: proposal, progress report, email, formal report.
6. Learn to present information correctly, clearly, and concisely.
7. Learn to adopt and preserve a professional persona in communicating in the workplace.

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Unit 1: Project Planning

The Project Planning unit is a laundry list, essentially, to get the student who may be thinking in general terms after choosing a topic to determine how that topic will wind up in a research report for stakeholders. It also addresses audience and context and the three typical research directions the student will choose from depending on the type of topic. The unit contains the following documents:

1. Project Planning
2. Background for English 415 research reports

Project Planning

Formal Report Definition

In its most generic form, the Formal Report is a written presentation of the results of research. A more specialized definition also applies: The Formal Report offers the engineer's fact-based results, conclusions, and recommendations of a problem-solving or innovative investigation (so, you may solve a problem, design or redesign to improve efficiency, or conduct a review of literature to present useful information to your organization). NOTE: Your topic need not be large or world-changing; your main goal is to save/make the organization quantifiable time/money.

Student Accountability

Since accountability to the reader is a conceptual pillar of the course, we need to incorporate it into the research and reports. So, not only will you write up your results but also plan a realistic framework within which to do the research: Create a role for yourself as an engineer in an organization under the realistic constraints of time, money, and personnel. The organization can be large or small, profitable or not so profitable, with various personalities. You may choose the constraints, but once you do so, you are bound by them, so select wisely and logically. The topic must be realistic, and the facts and findings must reflect engineering integrity and truth (thus, you should be comfortable having certified engineers evaluate your content).

KEY: You aren't just working with facts; you are working with professionals and their needs.

Audience

Keep in mind you aren't presenting research results in a vacuum; the company you hypothetically work for has professional needs, goals—short term, long term, ongoing, small and large. Your job is to investigate an idea and eventually recommend action to meet any or several of those needs.

What kind of needs? Those based on efficiency: Better record-keeping; improved benefit/cost ratio; improved employee morale; increased production; less overhead, and so on. You define such needs and seek to fulfill them with your research and recommendations. Plan to exercise knowledge of Engineering Economics; you need to know how to cost something out.

A major dimension of this research is persuasion. You must be able to persuade readers you have the best solution, design, or body of information for their particular needs. Persuasion in Technical Writing has its roots in credible claims, evidence (facts, numbers, and expert testimony) and reasoning.

Background for English 415 Research Projects

1. Choose a topic that really interests you. If you don't care, your readers will pick up on this; your papers will lack enthusiasm and possibly credibility, and you may not persuade readers.
2. Let's look at your research avenue options:
    a. Problem-Solution: You see/create a problem in your hypothetical organization (or real one if you are lucky) where you work that you'd like to solve. Maybe you want to research voice recognition software for vehicles to reduce accidents caused by distractions or fuel cell arrays for power plant co-generation. If so, such research is a Feasibility Study if you are comparing options (including the option to leave things as they are). However, if you test a prototype or conduct experiments on faulty equipment to correct flaws by systematic observation and experiment, you are doing empirical research. Research goal? The *best* solution.
    b. Design or Redesign: You may design something and explain in the Formal Report why it works well, how you designed it, and why the company should test it to implement. The Design itself would be in Appendices in the Formal Report.
    c. Literature Review: You would gather, select, and present information on a topic that is very new to the industry but that will be useful to your organization in the future. So, if you think your organization will inevitably expand into graphene based energy for electronic devices, you would gather the most recent research for bosses to decide if, how, and when to break into the field. Good topics are fledgling products (organic 3D printers?), services (on-site 3D printing from a truck?), or technologies not yet widely implemented. The final product of a Lit Review is the information itself (rather than a solution or design as above). As a Lit Reviewer, you would have to conclude on your findings but not recommend.

3. What to do when you settle on a topic:

    For any of the three options, you must have done extensive preliminary investigation (presented in the Proposal) to prove a need for research exists. This is because you have to have a solid base from which to convince your bosses that the research is worthwhile. Persuasive tactics include the following: showing the probability of future profits and savings and proving inefficiencies in cost, productivity, power, and so on. As you research, keep in mind a major goal: Determine the specific needs your readers would expect you to fulfill and then the tasks that can enable you to meet those goals. For instance, if you think you may want to recommend more up to date equipment, you must first convince your boss in the Proposal where operations are deficient because of the lack of that equipment. Report readers look for lower operating costs, greater efficiency, increased safety and morale, and so on. Of course, research needs vary from one company to another; choose the needs relevant to your organization. While you may make up your organization and its constraints (budget, personnel, location, goods and services) if you don't have a real audience with a problem to solve, nevertheless, you must have a believable context (realistic if not real), and NO research may be made up.

4. Your research goals:
    a. Write for a specific target audience (engineer(s) and executive(s) either real or made up.
    b. Identify a need for research you target readers would agree with and be prepared to argue persuasively that it exists.
    c. Choose one of the three research avenues listed.
5. Do's and Don'ts:
    a. Do consider choosing a topic from a company you have interned with (with their permission).
    b. Do narrow the scope of your project to keep the research manageable. Researching options to increase the recharge rate of the Ogallala Aquifer would be a very large project. Researching best management practices for a corporate farm to reduce its waste of water drawn from the aquifer would be more manageable.
    c. Do choose a context that makes you answerable only to primary readers, those in your organization.
    d. Don't feel restricted. If you like a topic, talk to me; perhaps we can make it work.
    e. Don't choose a topic you are researching for another class. The College of Engineering and the Dept. of English prohibit such duplication.
    f. Don't choose a topic that requires research or writing from other students. Do all the work yourself.

Unit 2: Job Search

The Job Search unit, while clearly unrelated to the research project, does offer an opportunity to learn how to respond to reader expectations effectively. Requiring students to respond to a job advertisement for which they are presently qualified (either full-time entry level position or an internship or co-op), the unit has the following documents:

1. Job Packet Assignment
2. How to do the Job Packet Assignment
3. Considerations for the Job Application Process
4. Student Research Experience for Undergraduates Advertisement
5. Student Resume
6. Student References page
7. Student Letter of Application

Job Packet Assignment

Please submit a **one** page resume (check with me first if you think your resume may be longer), a **one** page cover letter, a **one** page references page, and a complete Job Description that must detail requirements for the position.

Also submit additional corporate profile information clarifying the company's mission statement and values. You may have to consult additional library or online sources for this information.

Note: **The assignment is incomplete without the Job Description and additional company information.** You may have to write up the company profile information if you find the company has not published it on the web.

Please incorporate all lecture information into this assignment, including the ppt presentation and jobpkthowto file in Canvas. Also, include the following:

1. Boldface the degree rather than the institution.
2. Use white space, headings, indentation, bolding, capitals, dates to organize information.
3. List items in each category in reverse chronological order except where you want to highlight most important information by putting it first—eg. internships.
4. Use this order: Name/contact information, Objective, Education, Employment (thereafter, you may add categories that suit your skills).
5. Job Objective must state the type of department and the name of the position or area you are after.
6. Under Work Experience, use strong verbs to describe duties you did.
7. References: Have 3, 4, or 5, and identify each as academic, employer or personal. Make sure the resume says: "References See attached sheet." Give name, rank, organization, address, phone number and e-mail for each reference.

How to do the Job Packet Assignment

First, choose a job for which you are qualified *now* (full-time permanent if you graduate in the next few months, otherwise an internship). Get a job ad from any source (word of mouth, Job Choices Bulletin, Engineering bulletin board, newspaper) and read it for technical requirements of the job and for key words (leadership, commitment, innovation) stating company values. Underline the skill sets you have and their values that you can demonstrate.

Then, read the assignment carefully; you need to include all parts for a passing grade and follow the guidelines on the page scrupulously.

Next, write a resume using the models in this unit, but do not make your resume look like the ones you see; adapt yours to suit your skills. Select skills that best meet the needs of the company whose job ad you chose. Make sure format options are clear, consistent and useful for the resume reader. Include all contact information, dates, & make your resume *look* good.

Now, using the models, write a cover letter with an introductory paragraph identifying who you are, what job you want, and a crutch linking you more closely with the company (eg. my room-mate worked for your company, or, I have used your equipment in labs).

In the next paragraph, make an overall claim about your **academic** accomplishments, and spend the next several lines proving that claim with examples and other evidence. Finish the paragraph by telling the reader how those skills would benefit the company you wish to hire with.

In your third paragraph, make a claim as to your **employment** skills and again support that claim with lots of useful evidence. (Remember to use key words from the job ad. Eg. Pro-E and C++, and remember to use those key words from the job ad. to mirror their corporate values) End this paragraph by telling the value of your employment skills.

If you need to fill out the page, use this recipe for another, optional paragraph detailing your activities in various structured organizations. (You want the page to look full and be full of useful accomplishments/activities)

Finally, end your letter by directly requesting an interview and stating your availability. Don't forget to sign your letter, and don't forget to use the name of a person to whom you address the letter if one is available.

Some more considerations for the Job Application process

1. Out of 100 resumes, yours must make the top 5
2. Most resumes are submitted online
3. Do a chronological resume not a functional one until you have acquired a few years' experience
4. Non-engineering work experience is valuable to show soft skills: leadership, reliability, etc.
5. Job objective is only useful if you give specific information: position (company name), preferred sector.
6. Specificity is more important than length because readers want skills: hard & soft
7. Companies keep stats on schools/students. They track GPA, family, and so on, which signify turnover
8. Good writing alone conveys good communication skills
9. Don't use borders; placement of information should give illusion of borders
10. A generic resume signals a generic candidate; fill your resume and letter.
11. If you get no response to the Job Application, the company could be waiting to see if you are truly interested.
12. What if you get an offer before your favorite company responds? Send out all your job applications in the same week to maximize the number of responses in the same time frame. It will increase your chances of being able to choose.
13. What if you can reduce hiring costs by being in the area?
    Sometimes, a less than ideal on candidate on paper will ace an interview for which the company did not have to pay travel costs.
14. No right or wrong interview responses exist; only good and bad ones exist.
15. Don't put a letter for Honeywell into an envelope that goes to Hewlett Packard.
16. Choose a job for which you are qualified; eg. US citizenship requirement.
17. Put Relevant Courses under EDUCATION as a subset not as a separate category.
18. A verbal agreement to work for a company is binding. Changing your mind is not professional, and it gives KSU a bad name.
19. The purpose of the job app is to get you an interview not a job.
20. If you have very little for the EMPLOYMENT section, add volunteer work, study abroad, or a course project section under EDUCATION.
21. Be sure your social media and email/phone are professional or change them.
22. If you get no response, follow up two weeks later.

Chemical Engineering

REU Program Information

Kansas State University Sustainable En…

NSF funding for 2016 has been received. Applications are sought from motivated undergraduate students studying science or engineering to take part in a ten-week research experience (May 31, 2016 - August 5, 2016) at Kansas State University in the area of sustainable energy for participation in this National Science Foundation Research Experience for Undergraduates (REU) program.

Program Description

During the last 20 years, there has been a growing realization that sustainable development must receive a higher priority in the years ahead. There is a particular need for scientists and engineers with expertise in sustainability who can develop innovative solutions to the problem of dwindling natural resources. This REU offers talented undergraduate students the opportunity to become engaged in research that addresses the area of sustainable energy and to develop the skills and viewpoints necessary to be part of the solution to the issues associated with sustainability. The title of the REU represents the wide variety of sustainable energy sources the students will explore: "earth" represents the growth and harvesting of energy from biomass, "wind" represents using the wind to generate electricity, and "fire" represents harvesting solar energy.

Students selected for this program will conduct research as part of a multidisciplinary team on one application of sustainable energy. The research environment will be vibrant, with interaction with faculty and graduate students from different disciplines and with other REU students.

In addition to the research component, students will learn about sustainability in a one-hour seminar course, will conduct a team outreach project related to sustainability, and will attend a professional development seminar. Students will also have the opportunity to tour an ethanol plant, a wind farm, and a hydroelectric plant. Social activities are planned throughout the summer to give participating students a view of the unique nature of Manhattan, Kansas and the surrounding area.

Financial Support

Participating students will receive a stipend in the amount of $5000 for the ten-week period and $2500 for food and lodging expenses. Funds will be available for REU students to travel to conferences to present their REU research.

Application Procedure

A complete application will consist of: a completed application form, an essay of up to two pages describing the student's general interest in sustainability, research interests, and professional goals, an academic transcript, and letters of recommendation from two individuals. Preference will be given to applications that are received by February 19, 2016.

Applicants need to fill out the Application Form (/reu/app/) and Material Form (/reu/app/materials/) online.

Any questions about the REU can be addressed to any of the program co-directors: Keith Hohn, Placidus Amama, or Larry Erickson at reu@ksu.edu (mailto:reu@ksu.edu?subject=REU%20Questions).

Program Information

The “Earth, Wind, and Fire: Sustainability in the 21st Century” REU program is designed to provide both an in-depth technical exposure to one aspect of sustainable energy, and a broader exposure to sustainable energy and its impact on society.

Undergraduate participants obtain an in-depth, hands-on exposure to sustainable energy research by undertaking a research project under the guidance of one of the dedicated faculty mentors from fields as diverse as chemical engineering, electrical engineering, geology, and chemistry. Participating students report on their research project during weekly research seminars, attended by all REU students and by the REU coordinators. Final research results are summarized in a poster that is presented at a final poster session held the last day of the REU.

To provide students with a broader perspective, all REU participants attend a sustainability seminar (CHE 670) that describes how sustainable energy can be produced and how it impacts society and the economy. The schedule for the 2013 sustainability seminar can be found here (/docs/reu/2012-projects/CHE_670_Sustainability_Seminar_for_Summer_2013.pdf). In addition to the sustainability seminar, all students will participate in a group outreach project related to sustainability. This project will be designed by the REU participants themselves. Potential projects include designing and delivering an exhibit related to sustainability at the Discovery Center (a Manhattan, KS science museum) or developing and giving a presentation on sustainability to K-12 students.

In addition to these activities, field trips are taken to sites relevant to sustainable energy. In previous years, field trips have been taken to the Meridian Way Wind Farm near Concordia, KS, the Jeffrey Energy Center, the Nesika Energy ethanol plant near Scandia, KS, several solar panel installations, and to a small hydroelectric plant in Lawrence, KS.

Numerous social activities are also incorporated in the sustainable energy REU. Participants meet once a week to have lunch and discuss topics related to sustainability. Participants also are invited to an opening picnic, a hike on the Konza Prairie, “Pizza and Movie Night” at one of the coordinator’s houses, and the Cosmosphere air and space museum in Hutchinson, KS.

Results from this REU Program

This REU site builds upon the success of an REU site in sustainable energy held at Kansas State University from 2009 through 2015. This site engaged 97 students (68 supported by the REU site, 27 by the NSF EPSCOR project, and 2 supported by other research grants) in cutting-edge research on sustainable energy. REU research (/reu/results/) led to sixteen publications/conference proceedings and twenty-six conference presentations (three of which received awards). Of REU participants who have finished their undergraduate degree, more than 50% have gone to graduate school. Students indicated that the REU program enhanced their understanding of their technical discipline, led to an improved understanding of sustainability and how to conduct research, and enhanced their interest in advanced studies.

Montgomery Baker-Fales

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OBJECTIVE – Seeking a summer internship position at the Kansas State University Earth, Wind, and Fire REU

EDUCATION

Kansas State University (KSU), Manhattan, KS — Expected: May 2017
Bachelor of Science in **Chemical Engineering** — Honors Program – 3.87 GPA
Relevant Coursework: Chemical Process Analysis, Computational Techniques, Thermodynamics I & II, Transport Phenomena I & II, Surface Phenomena

Jefferson County North High School, Winchester, KS — May 2013
Valedictorian

ACADEMIC EXPERIENCE

Undergraduate Researcher — March 2015 – Present
KSU Chemical Engineering, Manhattan, KS

- Research in morphological catalyst effects on carbon nanotube growth
- Assisted in research on catalyst preparation effects on Fischer-Tropsch (gas to liquid) synthesis of hydrocarbons
- Gained competencies with Raman Spectroscopy, IBS/e, CVD, and electrochemistry

Vice President — May 2014 - Present
KSU Chapter – Society of Petroleum Engineers (SPE), Manhattan, KS

- Founded Chapter in conjunction with three other individuals
- Worked to recruit members and grow organization to current size of approximately 35 regular attendees
- Served as Secretary with duties of producing posters, sending targeted emails and advertising chapter meetings
- Secured more than $3000 in funding from College of Engineering (CoE) and the Student Governing Association (SGA) for multiple trips to educational events including the Permian Basin Oil Show in Odessa, TX and the SPE Student Summit in Oklahoma City, OK

Development Lead — December 2013 – May 2015
KSU Biodiesel Initiative, Manhattan, KS

- Responsible for leading optimization and addition of processes to biodiesel production facility
- Identified opportunity to optimize process by implementing methanol recovery through waste distillation which resulted in savings of $10.84 per batch
- Worked with team in all processes to produce over 1500 gallons of biodiesel used in KSU maintenance vehicles

Leaders in Freshmen Engineering (LIFE), Manhattan, KS — September 2013 – May 2014

- Served in freshmen honorary extension of the KSU Engineering Student Council to organize campus events, including E-Week activities, providing snacks for students during finals, and more
- Personally Coordinated Dinner with the Deans, communal meal for members of LIFE and the Engineering Deans

WORK EXPERIENCE

Self Employed, Oskaloosa, KS — June 2010 – July 2014

- Maintained grounds, led calculations for building garage, and aided in general labor for private individual

Blaufelder Construction, Oskaloosa, KS — June 2011 – July 2011

- Served as general construction labor in residential setting

REFERENCES - See attached sheet

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February 2, 2016

Larry Erickson
Professor of Chemical Engineering
104 Ward Hall Kansas State University
Manhattan, KS 66506

Dear Dr. Erickson:

I am a junior in chemical engineering at Kansas State University. I am writing to apply for the National Science Foundation Research Experience for Undergraduates (REU) internship offered at Kansas State University. Earth, Wind, and Fire: Sustainable Energy for the 21st Century is the focus of the REU program, and after extensive research on the program I believe that my academic background and laboratory work experience make me a good match for the KSU Earth, Wind, and Fire REU.

At Kansas State University I have strived to attain a competitive academic edge and show myself as a technically qualified, highly motivated candidate for the research setting. I have taken several high-level math and science courses, such as organic chemistry 2, surface phenomena, and partial differential equations. These courses are beyond the required coursework and, with my 3.87/4.0 GPA, show my desire and ability to engage in difficult topics. In addition to coursework, I have also shown significant leadership outside of the classroom as co-founder and vice president of the KSU chapter of the Society of Petroleum Engineering (SPE). SPE was founded in the absence of a petroleum engineering presence as a much needed bridge to provide information about and exposure to the oil industry to KSU engineering students. As vice-president of SPE I have personally worked to secure over $3,000 in funding for educational trips to the Permian Basin Oil Show in Odessa, TX as well as the SPE Student Summit in Oklahoma City, OK.

Outside of clinical engineering knowledge, I have also engaged in more hands-on experiences to gain more holistic experience. One such experience was an internship at the KSU Biodiesel Initiative during the 2014-2015 school year, during which I helped lead a team to produce over 1500 gallons of biodiesel used to power KSU maintenance vehicles. As treasurer of the Biodiesel Initiative, I identified an opportunity to optimize to production process by implementing a methanol recovery system through waste distillation. In addition to work for the Biodiesel Initiative, I also have undergraduate research experience in the Catalysis and Nanotechnology Research Laboratory (CNRL) of Dr. Placidus Amama at Kansas State University. As an undergraduate researcher of CNRL, I have assisted in ongoing carbon nanotube research which is approaching publication. Furthermore, I have gained significant background on many nanotechnology, surface chemistry, and electrochemistry topics. I have also gained experience in operating laboratory equipment, including chemical vapor deposition (CVD), ion beam sputtering (IBS), and Raman Spectroscopy. These experiences have helped me develop knowledge that goes beyond the classroom education.

I would like to formally request an interview for the REU internship position available. If any additional information is needed of me, do not hesitate to call or email. Thank you for your time.

Sincerely,

Unit 3: Research Topic Review

The Research Topic Review unit asks the student to choose and start researching a technical topic (or an efficiency-based engineering topic for Industrial Engineers) that interests them. The goal is to find a topic that will sustain a student's interest and likely benefit a workplace target readership by offering 'measurable benefit' of some sort at the end of the research period. This assignment foreshadows the Formal Report and builds student confidence in the topic preparatory to writing the Proposal. The unit contains the following documents:

1. Research Topic Review Assignment
2. Research Topic Review Assignment Addendum
3. Student Research Topic Review

Research Topic Review Assignment

Please write a review of the topic you wish to research this semester to prove to me you have done some research. I want you to use at least four sources from the literature (pull from the guest lecture on how to search for and find source material for a research paper). Your guidelines for this assignment follow:

1. Consult your class notes on research carefully and abide by them.
2. In the first sentence of review, state why the topic is useful one (to industry or researchers) and why it interests you. State potential target reader.
3. Include the following headings for your paragraphs: Introduction, Background (on the topic), How it works, Benefits, Drawbacks, Cost, and Conclusion.
4. In the Introduction, explain why you chose your topic and give its purpose.
5. In the Background, give a definition of your topic and a description of what it looks like (if it exists in the 3D realm) and How it works. Give examples of where/how it is in use.
6. Under Benefits, list each major advantage of your topic and say why that advantage is important.
7. Under Drawbacks, list each major drawback and say why each is important and what is being done to overcome it.
8. Conclude by telling me what direction the research on your topic seems to be going.
9. To gather all this material, search for at least four scholarly sources (Not scholarly enough: Wikipedia, Popular Mechanics, Howstuffworks)
10. Legitimate sources: Conference proceedings; emails from industry or academic professionals; journal articles; reputable online sources.
11. Have a References page at the end of your two page assignment where you correctly cite the sources you used. At appropriate places in your report, insert in-text citations. For both in-text citations and Reference page entries, use APA 6th edition. (You can consult the OWL link at Purdue University for extensive coverage of the APA style guide)

Research Topic Review Assignment: Addendum

1. This Assignment is designed to help you jumpstart your understanding of engineering library resources you heard about in class.
2. Ideally, you will have chosen a topic for the assignment that you will develop during the semester, but if you have not, do not worry; keep thinking, and plan to settle on a topic by the time we cover Proposal.
3. Your goal is convince me you have read and analyzed four sources and that you have cited and referenced them correctly according to the APA style guide (https://english.purdue.edu/owl).
4. I would like you to identify the sort of reader who might be interested in your topic; identify the type of professional you have in mind. Focus on specific needs the reader could face in the workplace.
5. Don't forget to give clear headings in your Research Topic Review.
6. On this assignment, bad grammar/usage errors will be penalized, but technical writing style faults will not; however, I will point out any style issues so you may learn from them.

By_______________
Research Topic Review
For Marcella Reekie

This document summarizes my preliminary research on the economic feasibility of implementing a process for shot peening small radius holes at GE's Strother facility. The final formal report, to be submitted to the head of Component Repair and the Strother management team, will analyze the costs and benefits of choosing one of several potential options, the additional training required for operators, and any other changes to the current shot peen process.

Background

Turbine jet engine parts are subjected to extreme cyclic conditions throughout their lifespan that can cause serious detriment and premature failure. These fluctuating stresses are most prevalent at the surface of a part (Bozdana, 2005). Thus, a primary goal for component manufacturers is to surface treat these expensive parts in order to increase the number of cycles an engine can stay on-wing before they must be replaced. One of the most common surface treatment methods is shot peen. As Luan, Jiang, Ji and Wang (2009) explained, "Shot peening [is] an effective method used widely in industry, [and] can considerably improve fatigue strength and fatigue life of cyclically loaded components" (p. 2454). A nozzle shoots tiny metal or ceramic beads that are propelled by air at a specified pressure toward the surface of a part. Each impact converts the kinetic energy of the shot into plastic deformation on the work piece surface (Koch, Xin, 2009). The combination of all the impacts creates a uniform layer of permanently deformed material at the surface of the work piece. This deformation results in residual compressive stresses that are much higher than the ultimate strength of the material. Because cracks propagate through a material by means of tensile forces, the residual compressive stress pushes cracked material back together, effectively stopping the crack from forming or expanding (Brown, 1998).

Shot peen is a proven method for improving fatigue strength and surface properties of flat surfaces, but traditional methods are ineffective when attempting to peen internal surfaces with small radii or unusual geometries (Burney, 1969). Serious limitations include lack of space for a nozzle to reach the area, tight geometry causing the shot to ricochet against the walls, and difficulty attaining uniform coverage over a given area. Areas such as holes, dovetails, and fillets are stress concentration points where cracks tend to originate. Thus, it is imperative that these areas are shot peened to improve fatigue life.

Several methods have been developed for shot peening small holes: quadrant peening (QP), deflector pin peening (DPP), deflector lance peening (DLP), and rotary lance peening (RLP) (Bozdana, 2005

Deflector pin peening makes use of standard shot peen equipment to peen small holes that are open at both ends. A small pin with a 45 degree conical tip is inserted into one end of the hole, while a pressure nozzle is aligned with the axis of the hole at the other end. As shot is blown into the hole, the pin is rotated, deflecting the shot uniformly onto the walls of the hole at the ideal 90 degree angle (Barker).

Deflector lance peening improves on the flexibility of deflector pin peening by attaching a hollow lance to the pressure nozzle that can be used to peen holes with access from only one direction (Bozdana, 2005). At the end of the lance is a 45 degree deflector that reflects the shot onto the walls at the ideal 90 degree angle. DLP is used to peen very long inner diameters such as those in fan and low pressure turbine shafts. In order to ensure uniform coverage, the part must be rotated because the lance does not rotate. However, fixturing that is already in place to rotate parts for external peening can be used to rotate them for DLP.

Rotary lance peening is the most flexible of the interior peening methods (Bozdana, 2005). A deflector lance is fitted with a mechanism to rotate it about the lance's axis. RLP can peen holes or geometries in parts that are difficult to rotate because of their size or the location of the holes (not on the central axis). Additionally, RLP can be coupled with a CNC manipulator for complex geometries (Barker).

Shot peening is a highly effective process, but "the intensity of shot peening must be carefully controlled, because peening at intensities both above and below a critical range will not harden the component properly" (Baiker, 2003, p. 3). Typically, this intensity is determined by performing the Almen strip test in which a thin hardened steel coupon is shot under a variety of conditions. The curvature of the strip is measured, plotted, and extrapolated to determine the ideal blast duration (Smith, 1972).

<u>Benefits</u>

Implementing a lance peen process at Strother has a variety of benefits over the current practice of sending out all parts with repairs requiring internal peening. Further research into these benefits will help prove the monetary gain this will generate for Strother.

Keep Repairs In-House

The largest percentage of repairs on an engine occurs on components in the fan and high pressure compressor sections of the engine. The fan and compressor blades in these sections are connected to disks by dovetail slots which transfer all dynamic loads between these components. In order to maintain proper fatigue life, the dovetails on all of these parts are shot peened (Bazdona, 2005). Being able to peen these dovetails, as well holes in any other components in-house increases the profit margin and keeps operators busy. Additionally, engine turn times can be reduced if the engine is not waiting for parts to return from other repair shops.

Utilize Existing Equipment

There are several options for controlling lance peen operations. For small holes that are accessible from both sides, DPP can be instituted. The existing nozzles can be used, and rotary fixtures that can be modified to turn the deflector pin already exist. If DLP is desired, the lance can be affixed to the existing nozzle, and the part can be rotated by the same fixtures already used to peen the outer diameters of these parts.

Minimal Training Required for Operators

Two options are available for controlling RLP operations: CNC and semi-automatic (Green, 2003). A CNC-Robotic system controls a single nozzle and lance in four axes (horizontal, vertical, pitch, and yaw) to control peening of highly complex parts. Pre-installed computer programs handle a variety of geometries and can peen multiple areas of a single part with no operator input following initial set-up. A semi-automatic system controls rotation and vertical motion of the lance, while an operator intervenes to set up each individual peening cycle (Green, 2003). Operators at Strother are already trained to set up peening runs on a wide variety of parts at any position because no two parts come in with identical damage needing repair. Training for these operators would simply include changing the machine from traditional pressure blast to lance peen mode and how to run test curves for small diameter repairs. This training could be completed in less than half of a shift.

Drawbacks

The traditional Almen test for determining optimum blast duration is only effective for flat surfaces. In order to create accurate saturation curves, the operator will have to perform a new type of test. A new strip holding apparatus will have to be purchased, and the operator will need to mask the test strip, as only a small portion of the strip is peened (Smith, 1972). After the operator's portion of the test is complete, the engineer will either need to mathematically relate the test results to the Almen scale or will need new computer software to develop saturation curves directly from the small radius test (Smith, 1972).

Additionally, no CNC devices currently exist in the shot peen area at Strother. All apparatus for controlling an RLP system and for rotating the lance in RLP would need to be purchased. If a new booth is required to install a CNC system, there is no space in the current shop configuration for an additional booth. Furthermore, pressurized air supply and shot sources would have to be diverted to the new booth, both at a very high cost.

Cost

Depending on the method of lance peening selected, both cost of implementation and profit return can vary widely. DPP would have very little cost—only the cost of purchasing deflector pins and operator training time—but also has the smallest amount of applicable situations and therefore the lowest profit return. DLP would likely have a similar cost to DPP, but again has limited application. RLP would have the highest development cost. Deflector lances would have to be purchased, as well as a mechanism to orient and rotate the lance. However, once the equipment is installed and the operator is trained, RLP will have the largest scope of usability, and therefore the largest profit increase. Finally, a CNC-controlled RLP system would likely have too high of a cost to make installing it more cost-effective than sending parts to a vendor for repair.

Conclusion

Strother is currently missing an opportunity to complete additional repairs in-house. A number of options for lance peening exist that are well within the capabilities of Strother facilities. With simple upgrades, the existing equipment and operators can perform the desired repairs. We need to complete additional research to further weigh the advantages and disadvantages of each method of lance peening. With this research, the best option for the Strother facility can be chosen.

References

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Unit 4: Email Inquiry

The Email Inquiry Assignment unit asks the student to cold contact a peer professional, an expert on the student's topic, to ask for answers to research questions that research so far has not yielded. Students who receive responses may use that sourced information in any of the relevant documents: Proposal, Progress Report, Formal Report, or Speech. The Email Inquiry Assignment unit has the following documents:

1. Email Inquiry Assignment
2. Email Inquiry Research Background
3. Student Email Inquiry Assignment

E-mail inquiry assignment
(Note: In part, I am testing your ability to follow instructions)

In *general*, tell who you are, what you are doing, what you want, why you chose that source/person; solicit answers to research questions the literature hasn't got.

1. *Specifically*, do the following in the first paragraph:
    a. Have a subject line with topic and purpose of contacting reader
    b. Introduce yourself by year and discipline;
    c. tell how/why you chose that source/person;
    d. tell the purpose of the e-mail (ie. Make your request);
    e. give a truthful due date for completing your *research* (not Report due date).

2. In the middle of the e-mail, <u>list, number, and separate</u> three specific questions demonstrating your intelligence and prior investigation of the topic. Ask questions out of the reader's direct experience with the topic.

3. You may add 'why' at the end of a question to generate more information.

4. Be sure to frame three questions so they <u>don't</u> ask for only yes/no or one word answers. (If you need to ask such a question, make it an additional one)

5. Clearly exit the e-mail, and if you wish, offer a copy of the Formal Report.

6. Tone: Do not use words that demand a reply; you are asking a favor.

7. Consider sending identical e-mails to more than one expert to increase your chances of a reply. Of course, substitute different names, routing information.

8. **Do not send an e-mail until after I have graded one hard copy**; this way, you can revise before hitting the send button.

9. Make a hard copy for me to grade (please do not send work electronically).

10. When you use words like 'change,' 'different,' or 'more' to suggest comparison, you must clarify: Changed from what? Different from what? More than what?

Email research inquiry

1. Today, we will talk about e-mail as a professional correspondence medium. The guiding principle here is that you treat on the job e-mail as you would any other business contact: professionally.

2. The e-mail assignment has a clear purpose: To solicit answers to particular questions you have concerning your research (think of issues you have not seen covered in the literature you have read so far).

3. When is e-mail ideal to use as a correspondence medium? (Think of its characteristics)

4. How should you approach formality and correctness in e-mails? What is expected in the workplace.

5. What sort of tone pitfalls should you avoid with business correspondence? (Think about the 'you' attitude)

6. What does honesty in your communications show for both the reader and about you?

7. What are the basic elements of an e-mail?

8. What is netiquette? Give some examples of rules

9. Now, let's turn to the assignment: Please write a short e-mail (no more than one page) to a peer professional asking for answers to three specific research questions.

    a. *NOTE: If you offer a copy of your finished Formal Report, don't forget to send one.
    b. Ask questions out of the reader's direct experience with your topic (to reduce the chance that information has been published and you have overlooked it).
    c. *Ask only open-ended questions (so you'll get more feedback than 'yes' or 'no').

10. Please use any or several of the reference sources below to help you search for a useful contact person for this assignment.

    Types of contact:
    Professor elsewhere (ask ref. Librarians for contact info.);
    Author of article you read (check journal for profile of author and his/her location);
    Company using/selling/manufacturing product you're researching.

    Check out companies in these directories: Thomas Register of American Manufacturing; Million Dollar Directory; Billion Dollar Directory; Middle Market Directory; Standard & Poor's; Company Information Database; Ward's Business Directory (& ask the librarian for more examples. Note: the Library 415 page has links to business directories, companies, and sources)

To: bozdana@gantep.edu.tr
Subject: Deep Hole Shot Peening Questions

Dr. A Tolga Bozdana:

I am a junior in mechanical engineering at Kansas State University in Manhattan, KS, and I am conducting research on the cost and feasibility of implementing lance peen operations as a reliable method for peening deep holes in turbine engine components. I read your article, "On the Mechanical Surface Enhancement Techniques in Aerospace Industry—A Review of Technology," published in the Aircraft Engineering and Aerospace Technology Journal (2005) and found it very useful in my research as it addressed the basics of each process. My research has led me to a solid understanding of how each process works, but I am now wondering about some of the details of putting these processes into practice. I was hoping that you would have the time to answer a few of my questions.

1) With an automated shot peen apparatus already in place, would you believe it to be more time and cost effective to implement deflector lance peening and develop a mechanism to rotate the work pieces or rotary lance peening and institute a fixture to rotate the existing pressure blast nozzle? Would new nozzles be required?

2) What is involved in, and how much time is required to train an experienced operator to run lance peen equipment?

3) Because typical saturation curve development involves peening a flat or large radius surface as opposed to the tighter radius of a hole, how do calculations of blast pressures and durations vary?

4) You mentioned that RLP is very flexible with ability to cover a wide variety of geometries, but is CNC-controlled equipment required for feasibility?

I value your time and input, and appreciate any information or references you are able to share. Thank you for your time.

With regards,

Unit 5: Results, Conclusions, Recommendations

The Results, Conclusions, and Recommendations unit focuses on building critical thinking skills: Can the student differentiate between a fact, also known as a Result, and a Conclusion, which interprets two or more facts? This is important because workplace readers do not want only facts in a document; they want to know what those facts mean. In other words, they want the writer to interpret research facts so as to signal benefits to the organization potentially. This Results, Conclusions, and Recommendations unit covers ideas and evaluations also in the following document:

1. Results, Conclusions, and Recommendations: Or how to interpret the worth of your research findings.

Results, Conclusions, and Recommendations

Or how to interpret the worth of your research findings

Purpose of this information

- You will need to extract results, conclusions, and recommendations from your material and put each, listed, in a separate subsection of your Formal Rep.
- Why? To emphasize for your reader the worth of the data you have researched.
- (Start learning to discriminate between facts and conclusions as you write the Proposal.)

Definitions

- Facts
- Interpretations:
  - Ideas
  - Evaluations
  - Conclusions

FACTS

- A fact is a truth known by observation and/or experimentation:
  - Example: A square is a four sided figure with equal angles and lengths.
  - This is a provable fact.
  - NOTE: Facts can change as knowledge grows.

INTERPRETATIONS

- An interpretation is a meaning given to two or more facts. It is an umbrella term housing specific types: **idea** (which can lead to a hypothesis); **evaluation**; **conclusion**.

- An *idea* results from the mind’s working or the exercise of imagination. It is yet to be proven, so it is the start of research, the first step. The second step is investigation.
  - Example: Dr. Nicholle’s idea that typhus spread among people via fleas.

- An *evaluation* is a judgment (usually a fact also) based on the relationship between 2+ facts. It may lead to a conclusion.
  - Example: Simple Truth foods are more expensive than Kroger brand foods

  NOTE: This statement is neutral; it contains no sense of which is better or more valuable

  NOTE: The claim is based on a standard of cost.

- A *conclusion* is a statement of worth or value that derives from an evaluation or more than one. It is based on comparison to determine which option is better or more valuable.
  - Example: Kroger brand is better than Simple Truth because its products are cheaper (if the standard was to find the healthiest brand, we might conclude in favour of Simple Truth)

Conceptual Components

- Topic
- Standards
- Results (aka Facts)
- Evaluations
- Conclusions
- Recommendations

Concept in Action:1

Topic:	Spaceship's air supply
Possible **Standards**:	Availability, price
Research Facts: (**Results**)	Density of 02 gas is 1.43 gr/litre Density of liquid 02 is 1200 gr/litre 02 gas costs 30% less per litre 02 gas is sold in every major city; liquid 02 is sold in only three locations in the U.S.
Evaluation:	02 gas is cheaper than liquid 02 02 gas is more available than liquid 02. (Therefore…)
Conclusions:	02 gas is more economical than liquid 02. 02 gas is more practical than liquid 02. (Therefore…)
Recommendation:	I recommend 02 gas

Concept in Action: 2

Change the standards (Objectives) and the outcome is often different!

Standard:	Compactness
Research Facts:	(as stated already)
(**Results**)	
Evaluation:	Liquid 02 is more compact than 02 gas, therefore…
Conclusion:	Liquid 02 is more practical than 02 gas, therefore…
Recommendation:	I recommend liquid oxygen

Unit 6: Audience Analysis

The Audience Analysis unit focuses on the different types of reader commonly encountered in the engineering workplace and addresses the specific expectations of each type so the writer may prepare for the Speech and write the Proposal, Progress Report, and Formal Report more effectively and persuasively for such constituents. This unit also shows the student how to build the Project Description context from which the audience profiles would come. The Audience Analysis unit has the following documents:

1. Audience Analysis Information
2. Example Project Description
3. Example Audience Profile

Audience Analysis Information

Think of readers of technical reports as stakeholders for you to persuade of your ideas. Therefore, we must identify general guidelines for typical types of workplace reader:

1. Technical reports are organized into separate compartments for engineers (experts), executives (managers) and technicians. Usually, readers will read only their segment.
2. No matter the training level of your reader, never talk down to him or her. Each person is a novice outside his or her area of expertise.
3. Provide background, definitions/analogies, theory, visual aids, and conclusions where each reader needs such information.
4. Know that understanding audience composition for a document is key to designing that document.
5. Don't underestimate reader intelligence, and don't overestimate reader knowledge.

Executives are decision-makers with lots of fiscal power but sometimes little understanding of a technical topic. They have little time to read, so offer background just to clarify difficult ideas, only enough theory so they can understand conclusions, and tables/graphs for visuals. They are most interested in how data is interpreted for the benefit of the organization. They favor fewer facts and explanations and more conclusions and recommendations.

Experts (engineers) do not need background because they know it, but they expect you to include and prove your conclusions by backing them up with complete data sets and complex visuals. Engineers want to know *how* and *why* (and sometimes *what* if the topic is new).

Technicians are often skilled at building and fixing but seldom like to read, so keep documents short, and use familiar visuals: line drawings, flow charts, simple diagrams unless the tech is college educated. If that is so, then adjust your visuals accordingly. Supply some background and definition/analogy but limited, simple theory and only a little background.

Lay readers are secondary readers in that they see a document only after it has been approved by readers in an organization. Their reading level can vary widely, but they read for practical interest. Therefore, documents for lay readers should offer simple background and visuals, little theory, and clear definitions and analogy to explain concepts.

Project Description

Organization working for:	Wally's Waste Disposal
Corporate Structure:	Headquarters in Newport Beach, Virginia
	Division Offices: three to oversee management of facilities
	Waste Management Facilities:
	Two: one in Manhattan, KS and one in Nashville, TN. Both facilities are licensed to operate an incinerator for hazardous waste disposal. The one in TN is very large and the most profitable.
Services:	Excavate, remove, and treat hazardous waste for client, offering particular focus on contaminated soil, water.
My role:	Process Engineer—work closely with clients to assess needs and select or design decontamination systems to best meet needs. Work with operators to ensure projects run as efficiently as planned.
I report to one expert:	Daniel Florsheim, Facility Manager (expert technician)
Who reads reports:	Excavation/Site Cleanup Chief; Facility Manager; District Manager.
Levels of readers:	Experts, Executives, Technicians
Criteria to judge solution:	How efficiently the proposed phytoremediation would meet client needs.
What I want from audience:	For them to realise phytoremediation could be a cost-effective, viable, eco-friendly alternative to incineration.
Topic Sentence:	Phytoremediation is an efficient and cost-effective method to remediate certain hazardous waste that can solve pollution problems with conventional incineration.

Audience Profile

Person:	Daniel Florsheim, expert technician on site clean-up
Rank in organization:	Excavation/Site Clean-up Crew Chief
Technical Specialty:	Operates specialized heavy equipment and leads team of 20 operators.
What he wants to see in report:	The new skills his crew would need to learn as well as additional time to phytoremediate sites. He would need to know government and any other rules, regulations.

Person:	Bob Quail, executive and boss over Florsheim
Rank in organization:	Facility Manager
Technical Specialty:	Directs all operations at the Nashville branch/
What he wants to see in report:	How would phytoremediation affect the daily running and productivity of the plant. He would be concerned about maintaining the good relationship with nearby community. He wants to know how phytoremediation could benefit him professionally. He would want to know drawbacks.
Person:	Tracey Somerville, executive and boss of both above
Rank in organization:	District Manager
Technical Specialty:	Supervises both plants and reports to board members
What she wants from report:	Her focus is on any ill effects of phytoremediation on plant productivity. She would want to know how to justify how long it takes for phytoremediation to work. She would need a benefit/cost analysis and governing regulations.

Unit 7: Proposal

The Proposal Assignment unit teaches students how to write an unsolicited, internal Proposal in response to a problem or need they perceive in the workplace. If the student has a real world, real time problem to solve (suggested by a current or former boss, perhaps), that is ideal because of the built-in audience accountability. If that option is unavailable, students may create their own, hypothetical context including a three person reader profile for the project based on their knowledge of the Audience Analysis unit. However, while the context and readers may be made up, the engineering facts that students research must be true, and how students interpret them must be logical and believable. The Proposal unit has the following documents:

1. Proposal Assignment including format
2. Proposal Theory and Reminders
3. Observations for students to consider for Proposals
4. Student A example Proposal—Problem-Solution
5. Student B example Proposal—Literature Review
6. Student C example Proposal—Problem Solution
7. Proposal Workshop Questions

PROPOSAL ASSIGNMENT

Please write an unsolicited, internal proposal to your Audience profile boss (an engineering expert) asking permission to research a Problem needing a solution, a Design opportunity, or a Literature Review need. This is to be a persuasive document; your goal is to get your boss to approve your request so you can research the topic further. You must go beyond merely informing your reader that you have a good research topic, so offer the following: A clear, directed **purpose** for the research; solid grasp of **audience** and his/her likely **needs** and expectations of your proposal; an authoritative, preliminary **understanding of the technical topic** you wish to pursue; a clear sense of **coherence** among the sections Problem/Need, Objectives, Product, and Method (one section's content must lead logically to the next); lots of convincing **evidence for each claim** you expect your readers to accept; logical and comprehensive **organization** of your proposal content (please use the Text **format**).

Prove that research on your topic is necessary for and beneficial to 'your' organization.

Proposal Assignment Checklist

Heading: Include names and ranks, date, and four-part subject line: name of document, name of topic, type of research, and purpose.

Format/Content: <u>Introduction</u>—Give background/context, ask for permission to research.

<u>Research Problem/Need/Opportunity</u>—define terms; offer extended explanations of research need with evidence/proofs like facts, figures, numbers, clearly stated claims, transitions, lists, sources correctly cited. **DO NOT discuss solution/design in this section**.

<u>Objectives</u>—clearly list stated goals/needs you want the research to fulfill. Think of these as types of info for Formal Report. <u>Nouns</u>

<u>Product</u>—state info the Formal Report will contain; defend product or service as valuable to your organization. Give research scope.

<u>Method</u>—logically list all the tasks you will do to complete objectives. List in parallel form; include a 'governing regulations' task. <u>Verbs</u>

<u>Conclusion</u>—offer a summary paragraph with technical conclusions about the nature and extent of the negative cost of leaving things the way they are: what readers stand to lose. Also, tell what readers stand to gain if research is approved. Include piece of *cited* evidence Request research approval (name your boss).

<u>References</u>—alphabetically list and correctly cite five sources that you also *use* (supply in-text citation for each) in the Proposal.

Proposal theory/reminders

1. Definition: A Proposal is an official written request for permission to research a topic.
2. Plan to write an Unsolicited (unasked for) Proposal, not a Solicited one, internal (originates in and affects only the company) not external.
3. Remember: Bosses grant time, resources, permission to researcher to complete the tasks outlined in the Proposal.
4. Do your preliminary research first, so your Proposal will be 'strong.'
5. A Proposal that only informs fails: You want Action, so persuade your reader by giving lots of proofs, facts to support your claims.
6. Don't 'give it all away;' instead, tell what you WILL do if given permission (Ie. Do not solve the problem or give the solution in the prop).
7. Persuade the reader a research need exists with claims and evidence.
8. A Proposal is a contract: both sides are bound by it to deliver on their respective obligations.
9. Keep in mind that with an unsolicited proposal, you are competing against other projects your boss has given you.
10. Your Formal Report goal (which your Proposal will work towards) is to get your boss to implement your major recommendation (Problem-solvers) or call for more research (Literature Reviewers)
11. Insert claims about the research need (these go in the PROBLEM or NEED section), and explain what is wrong with the current state of things. In the PRODUCT and CONCLUSION sections, you may mention benefits to the organization of your being allowed to do the research.
12. Have several examples of facts/evidence per paragraph to support claims. Draw from research about the problem and knowledge of company.
13. Include text (explanation) that shows clear knowledge of how your 'company' works: Eg."As you know, sales declined by 12% last quarter."
14. Use organizational patterns—cause/effect; comparison; definition; classification; object description; process description. This is because readers expect familiar packaging of certain kinds of information.
15. In conclusion, tell what company gains with research approval; tell what company loses if research is denied (forces reader to decide in your favor)
16. Limit your research scope—tell what research will and will not cover (avoids this problem: "I thought you'd build a prototype").
17. Create a task (in METHOD) to research governing specs/standards so project will pass inspection several years from now.

Some observations as you work on your Proposal

1. Do not mix discussion of Problem (or Need or Opportunity) with that of Solution (or Lit Review information or Design). Keep the sections separate.
2. Be sure you have plenty of EVIDENCE to back up your claims throughout the Proposal, but especially in the Problem (or Need or Opportunity) section. Look for numbers, all sorts of numbers, to insert, and be sure to interpret those numbers from the reader's point of view. This is a persuasive strategy. Lack of evidence is the single most compelling issue I see in the drafts at conference time.
3. Be sure your subject line contains the four parts: type of document, type of research, name of research topic, and purpose of research.
4. Do offer a very brief defense of each Objective and each task (Method).
5. In the Conclusion, you will need one last documented piece of compelling evidence, a projection of what likely will happen if the research is denied, the same if the research is approved, and the request that your boss approve your proposal.
6. You will need at least five individual source citations in your Proposal; the Problem (or Need or Opportunity) section likely will need sources although sources can be scattered elsewhere too, such as in the Objectives, Product, and Conclusion sections.

By_______
Proposal Final Draft
ENGL 415, Marcella Reekie

GE Engine Services, Inc.-Strother
P.O. Box 797
Strother Field
Arkansas City, KS 67005

TO:	________, Component Repair Team Leader
FROM:	________, Component Repair Process Engineer
DATE:	13 October, 2---
SUBJECT:	Proposal to research cost and feasibility of implementing lance peen operations for peening inside small diameter holes to keep additional repairs in-house.

INTRODUCTION:

GE Engine Services, Inc –Strother has set the standard as the premier engine repair facility in the world for decades. We have established ourselves as the primary location for repair development on the CFM56 and CF34 engine lines with our superior engineering, manufacturing, and problem-solving abilities. Many customers prefer to send their engines to our facility because of our proven security, quality, and speed of repair. To continue this tradition, improve profitability, and decrease engine turn time, GE must explore technologies that will allow us to perform more repairs on location rather than sending parts to vendors.

I request permission to research further technologies in the shot peen area—particularly in peening small interior surfaces—in order to bring a large volume of repairs in-house from outside vendors.

PROBLEM:

With the current tough economic climate, the Strother facility must quickly perform as many repairs as possible to retain customers. With the constant risk of work being outsourced to our biggest competitor in Celma, Brazil, Strother needs to advance its processes to remain competitive against a location with non-Union labor and few environmental regulations.

The first round of improvements should include adding repairs that are very similar to those already performed in-house. By making small updates to existing equipment, we can bring an astounding number of repairs online with minimal set-up cost and operator training time. Shot peen is one area where simple advances could have wide-spread economic benefit because four readily-solved problems exist:

1) Strother does not currently own any equipment to peen the inside of holes.

2) Current methods for developing saturation curves only apply to peening flat or large-radius surfaces.
3) The current practice is to send any part needing interior peening to a vendor.

4) By not repairing parts in-house, GE is increasing the turn-time of engines for customers.

Problem 1: Lack of Equipment to Peen Interior Surfaces

Shot peen is a proven method for improving fatigue strength and surface properties of flat surfaces, but traditional methods are ineffective when attempting to peen internal surfaces with small radii or unusual geometries **(Burney, 1969)**. Serious limitations include lack of space for a nozzle to reach the area, tight geometry causing the shot to ricochet against the walls, and difficulty attaining uniform coverage over a given area. Areas such as holes, dovetails, and fillets are stress concentration points where cracks tend to originate. Thus, these areas must be shot peened to improve fatigue life. In fact, GE's engine manuals require these areas to be shot peened, but our lack of equipment means that these repairs go to other shops.

Problem 2: Lack of Hole Curve Development Technologies

Shot peening is a highly effective process, but "the intensity of shot peening must be carefully controlled, because peening at intensities both above and below a critical range will not harden the component properly" **(Baiker, 2003, p. 3)**. Typically, this intensity is determined by performing the Almen strip test in which a thin hardened steel coupon is shot under a variety of conditions **(Smith, 1972)**. Strother operators already perform the Almen test on a daily basis, and the Component Repair process engineers analyze the information with computer software and then update the operators' Manufacturing Instructions manual regularly. However, the traditional Almen test for determining optimum blast duration is only effective for flat surfaces. To create accurate saturation curves, the operator will have to perform a new type of test. A new strip holding apparatus will have to be purchased, and the operator will need to mask the test strip, as only a small portion of the strip is peened **(Smith, 1972)**. After the operator's portion of the test is complete, the engineer will either need to relate the test results mathematically to the Almen scale or will need new computer software to develop saturation curves directly from the small radius test **(Smith, 1972)**.

Problem 3: Sending Out Simple Repairs

The largest percentage of repairs on an engine occurs on components in the fan and high pressure compressor sections of the engine because this is where the most foreign object damage (FOD) is seen. The numerous fan and compressor blades in these sections are connected to disks by dovetail slots that transfer all dynamic loads between these components. To maintain proper fatigue life, the dovetails on all of these parts are shot peened **(Bazdona, 2005)**. Being able to peen these dovetails in-house, as well holes in any other components, greatly increases our profit margin.

Additionally, the current economic conditions mean that fewer engines are coming into the shop. The operators represent a sunk cost because they must be paid whether they are fixing an engine or not. Bringing in new shot peen repairs will produce more work (that was previously going to vendors) to keep operators busy during their entire shift.

Problem 4: Extending Engine Turn Time

Sending parts to vendors for interior peen repairs has a number of economic implications as explained above, and also increases the turn-time of each individual engine. For customers, every day that an engine is off-wing for overhaul is money lost, so when they pay a shop several million dollars to repair an engine, they expect it to be returned quickly. As airlines have taken hard economic hits, they have changed from the practice of complete overhauls to IRAN's (Inspect and Repair As Needed). In a typical overhaul, every component is repaired but in an IRAN only the parts with critical damage are repaired. When a smaller number of parts are repaired, waiting for a single part to return from a vendor can hold up the delivery of an entire engine. This delay makes the repair more expensive and costs the customer time that the engine could have been in service.

OBJECTIVES:

My research will provide the following items in a final report:

1) A complete analysis of technological options to implement interior peening, as well as the required curve development equipment

2) A report describing necessary operator training

3) A detailed analysis of the cost of purchasing and installing the required new technology, and an estimate of how long the investment will take to pay for itself as required by Strother management for any equipment purchase request

4) A final recommendation on the best method of interior peening to implement for Strother's business goals and economic and personnel resources

PRODUCT:

My final report will contain the best option or combination of options for Strother to implement interior peening, specifically a method known as lance peening. I will include a summary of all possible technologies, and a detailed report on those that I believe need to be introduced to Strother facilities. Also included will be the changes to current equipment that will be required to install the new technologies, costs associated with new equipment, and training topics for operators. Finally, the report will include the necessary technical information for the Component Repair process engineers to make an informed decision that will yield adequate results, as well as general and financial information for the Plant Manager and his team as the executive decision-making team at Strother.

METHOD:

To complete my objectives, I will perform a number of tasks:

1) Contact equipment manufacturers and review available technologies for purchase

2) Request cost estimates from equipment manufacturers for purchase and installation of new technologies

3) Review operator training and any special safety requirements in equipment manufacturer’s product literature

CONCLUSION:

As **Luan, Jiang, Ji and Wang (2009)** explained, “Shot peening [is] an effective method used widely in industry, [and] can considerably improve fatigue strength and fatigue life of cyclically loaded components” (p. 2454). Shot peening and lance peening are proven technologies that are well within the capabilities of Strother facilities. As such, Strother is currently missing an opportunity to complete additional repairs in-house. Such repairs are imperative to the continued competitiveness of our facility. If we do not take advantage of these opportunities, we risk having much of our business outsourced to overseas facilities. I request approval of this proposal and authorization to complete additional research to further weigh the advantages and disadvantages of each method of lance peening. With this research, the best option for the Strother facility can be chosen to ensure our continued business success.

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Benjamin Williams
Proposal Final Draft
Marcella Reekie 11:30
14 October 2014

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TO:	Jason Sallies, Lead Process Engineer
FROM:	Ben Williams, Process Engineer
DATE:	1 October, 2014
SUBJECT:	Proposal to research best practices for standardizing steam condensate removal processes at the Chevron Phillips Chemical Company Orange Plant.

INTRODUCTION:

Chevron Phillips Chemical Company (CPChem) has established itself as a premier manufacturer in the petrochemicals industry. We are now among "the world's top producers of olefins and polyolefins and a leading supplier of aromatics, alpha olefins, styrenics, specialty chemicals, piping, and proprietary plastics (Chevron Phillips Chemical Co., 2014)." Two of CPChem's primary objectives are the safety of its employees and communities as well as reducing its energy usage in all plants. We pride ourselves on sending every employee home safely every day. Additionally, energy reduction is necessary to increase profit, but, more importantly, to reduce the company's carbon footprint. One of the greatest opportunities to improve the safety and reduce energy loss at the Orange Plant is through the steam condensate removal systems. Failure to repair and standardize these systems will cause a loss of energy through flash steam, damage to piping, and danger to employees, compromising the operational excellence standard for which CPChem has always been renowned.

Therefore, I request permission to research the best practices in steam condensate removal and recovery in order to standardize the approach CPChem takes to repair these systems.

NEED:

One of the greatest issues facing our society is energy conservation and discovering alternative methods for powering our lives. Efficient energy usage is vital in the manufacturing industry, because the company that manufactures a product at the cheapest cost will always be the leader in the industry. Steam is one of the most common energy sources in every industry, especially petrochemicals. Primarily used in shell-and-tube heat exchangers or heat tracing apparatuses, steam is cheap, emission-free, and has outstanding heat transfer properties. However, the production and transportation of steam is not a simple task. Condensation can form throughout these pipelines and cause a wide variety of issues. Nearly all plants in the petrochemical industry utilize condensation removal methods to address these issues. Unfortunately, insufficient research and failure to consult with experts on this subject have led to energy losses and inefficiencies as well as safety hazards. Incorrectly applying condensation removal technologies can have the following consequences:

1) Flash steam loss due to failed-open steam traps.

2) Water hammer throughout piping leading to unnecessary safety risks and compromising equipment integrity.

3) Back-pressure in condensate lines disallowing pumps to operate efficiently.

4) Pressure safety valve failures and rapid cycles leading to an increase in maintenance costs.

<u>Flash Steam</u>

Failed open steam traps lead to high costs by allowing steam otherwise used for energy to flow through along with the condensate. In fact, according to McCauley (1995), a failed open steam trap with a ½" orifice can waste 835,000 lbs of steam per month (p. 1). Costs of this nature were observed during the annual Spirax Sarco survey performed at the Orange Plant in May 2014. The survey stated that the plant was losing over $130,000/y in flash steam loss due to failed open steam traps. This is caused by the incorrect application of traps, incorrect sizing of traps, and incorrect installation of traps. As R N Kerr explains, "Responsible plant energy conservation must include an effective steam trap program including an overview of all traps, repair of defective traps, and regular maintenance to cut energy loss to a minimum." By standardizing the steam trap system throughout the entire plant, we can reduce these costs and benefit from our efficient energy transfer.

<u>Water Hammer</u>

This phenomenon can derail an entire plant by leading to safety hazards and the failure of piping (Barrera & Kemal, 2010). Both of these effects can lead to the shutdown of a unit or an entire plant, decreasing production to zero until repairs can be made. Water hammer occurs when failed closed steam traps allow condensate to increase in volume in a steam line to the point where it moves at the same velocity as the steam (20-30 fps) (Swagelok Energy Advisors, Inc., 2009). After an extended time at this velocity, piping integrity can be compromised. Again, a uniform overhaul of the steam trap system can minimize this risk.

<u>Back Pressure</u>

One of the most significant issues facing CPChem's Orange Plant is back pressure in the condensate header. This is caused by high pressure condensate mixing with a lower pressure condensate pipeline. Back pressure can cause pressure powered pumps to malfunction, and; consequently, a reduction in condensate removal. Problems such as these can be addressed by many methods which my research will show.

<u>PSV Failures</u>

Limiting the removal of condensate will lead to the failure of pressure safety valves at many locations. Because of the harmless nature of the fluid, no safety threat is posed; however, maintenance costs will increase to continuously repair these valves. CPChem has frequently observed this phenomenon upstream of failed pressure powered pumps. In addition to maintenance costs, PSV releases waste steam that can otherwise be utilized for valuable energy.

OBJECTIVES:

My research will provide the following information:

1) The correct applications, sizing methods, and installation instructions for each type of steam trap.

2) The proper design of a pressure powered pump system.

3) A detailed overview of new technologies emerging in condensate removal and a comparison to methods currently used.

4) A complete cost-benefit analysis of each method of condensate removal.

PRODUCT:

My final report will provide comprehensive information on the opportunities presented to CPChem to improve its condensate removal systems. I will provide information on how each technology works, and how it is beneficial to its specific application. From this report, CPChem will see the disadvantages the plant is at with its current technologies and the benefits they will gain by standardizing every condensate removal process. Finally, this report will provide information on how to implement these technologies.

METHOD:

To complete the aforementioned objectives, I will perform the following tasks.

1) Consult with experts on the subject who can provide non-biased recommendations for each technology.

2) Request additional information from CPChem regarding the current state of the condensate removal systems.

3) Investigate many avenues to purchase each technology to reduce cost.

CONCLUSION:

CPChem has a great opportunity to reduce energy costs by improving condensate removal systems. Current technologies allow for removal to be done effectively and sustainably. By standardizing this process, future process engineers throughout the company will now have a specific approach to each problem they face regarding condensate and will be able to solve each problem accordingly. Failing to accomplish these goals will lead to increased costs, safety concerns, and inefficient production. I request approval of this proposal and authorization to complete additional research to further analyze these best practices so CPChem will make the best decisions to ensure its success.

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Kendall Schmidt
Proposal Final Draft
ENGL 415 1:05
September 30, 2015

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TO:	Travis Fucich, Seminole Power Engineering Department Manager
FROM:	Kendall Schmidt, Seminole Power Assistant Mechanical Engineer
DATE:	September 30, 2015
SUBJECT:	Proposal to research opportunities that can enhance thermal and economic efficiency of the Seminole Unit 4 gas-turbine power generation system.

INTRODUCTION:

Oklahoma Gas & Electric Company is one of the foremost providers of electricity throughout Oklahoma and Western Arkansas and we continually strive to uphold our responsibilities to benefit our stakeholders and minimize harm to the environment. I have recently worked on a project for OG&E's Seminole Generating Station in Seminole, Oklahoma, and I believe it is necessary to make changes to the Unit 4 power generation system. This unit uses a simple Brayton power-generation cycle involving a single gas-turbine, and I am confident that we can make changes that will improve its thermal and economic efficiency. Our official company website directly states that, "we're proud of our reputation as an environmentally responsible company," so we must take steps to validate this statement and investigate methods that can reduce the environmental impact of Unit 4 and increase profits for our company (Our environmental position - OGE energy corp.2015). Therefore, I am requesting permission to conduct research with the purpose of finding an economical solution that could improve the low efficiencies exhibited by our Seminole Unit 4 power generation system.

PROBLEM:

According to the U.S. Department of Energy, "a simple cycle gas turbine can achieve energy conversion efficiencies ranging between 20 and 35 percent" (How gas turbine power plants work - energy.gov office of fossil energy.2015). Last March we invited a team of consulting engineers from Burns & McDonnell to perform a study on the Seminole Unit 4 simple cycle gas turbine power generation system and they determined that this unit is operating within this range at approximately 31% thermal efficiency. The efficiency of this cycle happens to be close to the upper limit of the range determined by the U.S. Department of Energy, but it is relatively low compared to the most efficient plants around the U.S. such as the Cape Canaveral Next Generation Clean Energy Center in Florida which demonstrated an efficiency of 60.75% in May 2011 (Ray, 2014).

As you know, thermodynamic efficiency (often denoted by η) essentially boils down to the following equation:

$$\eta = \frac{\text{amount of sellable energy generated } (\dot{W}_{net})}{\text{amount of energy input from burning fuel } (\dot{Q}_{in})}$$

In this equation, $\dot{W}_{net}$ is the rate of work done and $\dot{Q}_{in}$ is the rate of heat that is put into the cycle (these are both quantities that could expressed as values in Joules, horsepower, etc.). Maintaining a 31%

efficiency means that we are condoning 69% of the energy from purchased fuel being wasted instead of being used to do valuable work. The fraction on the right side of the efficiency equation points us to the three main problems facing our existing gas turbine. These problems go against our responsibilities to the environment and to our stakeholders:

1. Using a lot of fuel to generate electricity results in larger amounts of environmentally harmful emissions.

2. Our society has recognized the importance of cleaner power generation and is causing the U.S. government to pass legislation that penalizes power plants that release greenhouse gasses at high rates.

3. We are releasing a large amount of valuable energy to the atmosphere instead of capturing excess heat to generate more revenue.

Harmful Emissions

The simple-cycle gas turbine operating in Unit 4 exhibits an efficiency (approximately 31%) that is slightly lower than that of a typical coal plant, which operates at about 34% thermal efficiency (Zhang, Myhrvold, and Caldeira 2014). Despite having efficiencies higher than our gas-turbine power cycle, coal plants are slowly becoming obsolete in the United States because of their excess carbon dioxide emissions and low efficiencies. According to the official website of the White House, "The President put forth an initiative to end public financing for new coal-fired power plants overseas," a step which has been taken to influence other countries to follow our country's lead and stop constructing new coal-fired power plants (Climate change and president obama's action plan.2015). Fortunately, natural gas is often considered to be a 'bridge' fuel (a temporary fuel until transitioning to zero-emission technologies is possible), so reasonably, Unit 4 would have a less significant impact on the environment in comparison to a typical coal plant (Zhang et al 2014). However, I do not believe that our use of natural gas excuses the low efficiency exhibited by Unit 4 because there are many natural gas fired power plants around our country that demonstrate much better performance.

Government Legislation

Pressure on the federal government has been increasing as a result of growing fears related to global warming. This pressure has caused the U.S. government to take many steps to promote cleaner energy generation in the United States. President Obama's Clean Power Plan "sets achievable standards to reduce carbon dioxide emissions by 32 percent from 2005 levels by 2030" (Climate change and president obama's action plan.2015). The current regulatory laws affecting the energy industry in the U.S. can be costly to the owners of power plants that expel greenhouse gasses at high rates relative to their rate of power generation and I can almost guarantee that more legislation will be passed in the future to meet President Obama's goals by the year 2030. Most recently, the Environmental Protection Agency in the U.S. finalized the Clean Power Plan Rule to cut carbon pollution from existing power plants on August 3, 2015 (Climate change and president obama's action plan.2015). This shows why it is important that we strive to be progressive to ensure that OG&E successfully fulfils our societal responsibilities and avoids facing fines that will eat away at our profits.

Wasted Heat

Gas turbines are similar to many other industrial processes in that they create extremely hot exhaust gasses, typically in the range of 400-550˚C (Rahim, Amirabedin, Yilmazoglu, and Durmaz 2007). Rahim et al explain that, "if some of this heat loss can be recovered and converted to useful energy, the process efficiency can be increased with both economic and environmental benefits" (2007). The denominator in the previously stated efficiency equation (the amount of heat we buy to generate energy) is directly related to the amount of money we spend on fuel for Unit 4. Fuel translates to heat, and it doesn't make sense to purchase this heat and then release a large amount of it to the atmosphere instead of finding a way to capture this heat and sell it or utilize it to do useful work.

OBJECTIVES:

The following items will be the main focus of my research for my final report:

1. Provide proof that we can produce the same amount of power with less greenhouse gas emissions.

2. Identify all pertinent laws, regulations, and engineering standards that will affect Unit 4 if we choose to modify Unit 4 or if we decide to leave it in its current state.

3. Show that options are available for utilizing the wasted heat being expelled from Unit 4.

4. Describe the most cost-effective strategy for recovering wasted heat and how this strategy can be implemented to benefit our company financially.

PRODUCT:

My final report will focus on the best option available for improving the efficiency of the Seminole Unit 4 power generation cycle. I will include a complete description of how my solution works and the processes that would be involved in its implementation. This would also include the costs and benefits of the improvements as well as estimations regarding the amount of time that would be necessary to fully implement the solution. All relevant technical information regarding the science and technology involved in the final product will also be included.

METHOD:

I will fulfill the objectives above by following these steps:

1. Review scholarly articles for technical descriptions of possible solutions to this problem.

2. Contact knowledgeable professionals in the field of engineering with real-world experience on this topic.

3. Research regulations and engineering standards that apply to this topic.

4. Evaluate several options and choose the solution that most effectively solves the problem.

CONCLUSION:

An article on the website of GE Power Generation explains solutions available that allow a gas-turbine power plant to produce up to 50% more energy using the same amount of fuel (Combined cycle power plant - how it works - GE power generation.2015). To materialize the amount of money we are missing out on, a 100 megawatt simply cycle gas turbine could be generating upwards of $5000 more per hour (based on GE Power Generation's estimate of increased efficiency and the average cost of a kilowatt-hour from EIA.gov, the website for the U.S. Energy Information Administration). This adds up to an additional $3 million per month. Further investigation into the possibilities that are available for increasing the efficiency of Seminole Unit 4 will likely unveil many benefits for OG&E that will advance our company with regard to increased profits and enhanced environmental responsibility. If we don't take action are accepting our role in contributing excess amounts of environmentally harmful substances which is socially irresponsible and will become more expensive with the escalation of progressive environmental legislation. I am requesting approval to continue my research on methods for increasing thermal and economic efficiency of a simple cycle gas turbine power generation plant. I am confident that my efforts have the potential to benefit OG&E, its customers, and society in general.

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Proposal Workshop Questions

1. Briefly, explain the context (especially audience) of your proposal, and listen to your partner relate his/her context. Then exchange papers and read the draft carefully 'in character' as its main reader (as much as you can) and respond to the following issues by writing comments on the draft, identifying by number which question the comment 'belongs to.' Plan to return the draft and go home with your own, critiqued draft to revise.

2. Evaluate the persuasive appeal by addressing these questions:

a. What specifically is the problem, need, or opportunity addressed in the proposal? Identify the research goals (objectives) and evaluate them—are they complete? Are they logical?

b. How does the writer seek to convince you that the problem should be solved or the opportunity/need addressed now? How persuaded are you? (You may wish to comment on the distribution of persuasive concrete details in the Introduction and Problem Statement) Does the draft predict consequences of Proposal approval or denial? Does the draft make strong claims? Does compelling evidence support those claims?

c. How, specifically, is the writer proposing to solve the problem or fulfill the need or opportunity? What is the scope of the proposed project? (Ie. what will the research cover; what will it not cover?) How is it to be carried out (method, tasks)? What is the end result supposed to be (what is s/he hoping to be able to offer the reader)?

d. How pleased are you with the proposed Solution/Design/Literature Review information? What questions do you want answered before you can approve the Proposal?

e. Do you approve the Proposal as is, with conditions (name them), or not at all? Explain, please.

3. Discuss (from an objective point of view) how effectively the writer has used the informal report format.

4. Provide any additional stylistic and editing advice or praise that seems appropriate (of course, perfect copy was not required at this rough draft stage, but you might give some feedback on the writing anyway).

5. Please rate the Proposal's overall effectiveness on the scale:

(poor) **1 2 3 4 5 6 7 8 9 10** (excellent)

Unit 8: Visual Aids

The Visual Aids Assignment unit asks students to anticipate at least three visuals they will likely include in their Formal Report and either find or create them. The visuals may demonstrate aspects of the Problem or Need, show some aspect of a Solution, or illustrate information that would go into a Literature Review. Whatever the type, students will need to identify target reader for each visual (from their Audience Profiles), topic, and purpose for including each graphic in their Formal Report. Accordingly, the Visual Aids Assignment unit offers the following documents:

1. Visual Aids Assignment
2. Visual Aids information to guide selection/creation/usage of visuals and common visual types for engineers to consider
3. Features of good visuals
4. Distortion: How to avoid common types
5. Student example of Visual Aids Assignment

Visual Aids Assignment

Please construct or borrow (and document) **three** visuals that you anticipate you will need in the Formal Report. These visuals must all be different types (eg. You can't offer two bar graphs or two drawings). If you wish, you may include any type of visual not covered in class or in the text just as long as it is pertinent to your research. Abide by all the principles of construction and usage I have given you.

Preceding each visual, in a paragraph, address the following:

a) Purpose: Tell why the visual will need to be in the report; be specific!
b) Audience: Tell who (give names from your Reader Profile) will need it and why. Be specific and tell *how* they will use it: To understand? To decide? To complete a task?

Visual Aids

Can you answer the following questions? You should be able to at the end of this unit.

1. How do you choose between a line graph and a bar graph?
2. What's the difference between a diagram and a drawing?
3. In what way are photos limited visuals?
4. What ten functions do maps demonstrate?
5. How are visuals and text integrated?
6. What situations need a visual?

This true example of visual aid usage should clarify the need for you to consider audience very carefully. A farmer purchased a John Deere tractor in the late 70s. The manual said do not allow any passengers on the tractor; particularly, do not allow anyone to stand on the pto plate and hang on to the roll bar. This warning came with a cute cartoon depicting a grizzled old farmer driving his tractor, and hanging on to the roll bar was Sports Illustrated's swimsuit model of the year. The man who bought the tractor subsequently allowed his son to ride on the back hanging on to the roll bar. One day, the son jumped off and the farmer inadvertently backed over him, killing him. With the help of a good lawyer, the farmer sued and won. Why? The answer is that the text and cartoon did not complement each other, so for someone illiterate, the message was unclear.

What is the point? Visuals are inevitable for the engineer who is called on to write, and bad visuals can result in litigation at worst, and at best they can result in confusion and misunderstanding.

Here's how this unit is organized:

1. List of three considerations to govern decisions about visuals
2. Pool of common visual types, with emphasis on engineer/executive readers
3. Twelve features for every visual you present
4. How to avoid distortion in visuals
5. Visual aids assignment and student model

<u>Considerations that govern decisions about visuals</u>

You must learn to approach visuals in your work from the perspective of the reader interpreting them. To help you, here are three fundamental questions to ask yourself:

a) Is a visual ***necessary***?
b) If so, what type of visual would ***best*** show the main relationship or quality you want to demonstrate?
c) How can your selected visual be ***integrated*** into the text?

   a) A visual is necessary if you find yourself discussing what something looks like, how something relates to other components in an item, mechanism, or how something works. A visual is expected if you are dealing with lots of numbers or if you are trying to logically explain a setup or process. Visuals also save time and money and overcome language barriers.

   b) A **table** is best for showing large quantities of absolute values (i.e. numbers) and for mixing numbers and icons; a **line graph** is best for showing trend, cause-effect, change over time, and function; a **bar graph** is best for comparing discrete data when absolute values are secondary; a **pie chart** is best for showing ratio, percentage, and proportion (a pictogram is a layperson's preferred type of bar graph); a **diagram** is best for showing a process (or an item) that is highly technical or that is hypothesized, and it relies on symbols for interpretation of parts and process. A **drawing** is best for demonstrating to scale and proportion something that exists in the 3D realm; a **chart** is a variation of a diagram and focuses on simple process flow or organizational hierarchy; and a **photo** is an unaltered capture of a scene, thing, or event by mechanical means (camera).

c) Integrate your visual using the following means: Give it a complete title and figure (or table) number; locate it very close to the text it belongs with; and announce it before it appears.

Common visual types for executives and engineers

Tables	Graphs	Drawings	Diagrams	Charts	Photos
Formal	Bar graph	Cutaway	Blueprints	Flow	
Informal	Pictogram	External	Elevations	Organizational	
Budget Statement	Pie graph	Sectional	Schematics		
	Line graph	Exploded view	Maps		

Features of good visuals from Mickey Mouse concrete to abstract

1. Each visual must have a visual number: Number each consecutively in a report, and treat tables separately from figures. (See Table 1 or See Figure 22)

2. Give each visual a title: Use substantive nouns and words to designate essential relationships in one sentence.

3. Use callouts, legends, labels and keys: Callouts are the labels on photographs. Legends are the lists or columns below figures explaining numbers on parts clockwise. Place legends between the figure and the title below the figure. Labels go on 'x' and 'y' axes and lines/curves, for example, on line graphs. They also go on bar graphs and pie charts. Keys are explanations of symbols on a technical diagram.

4. Observe the conventions of construction. A pie chart starts at noon with the largest slice, unless some other logic prevails. Put time/distance on the horizontal axis; temperature and height go on the vertical axis.

5. If you construct visuals from several sources, indicate those sources in a footnote below the title. It's ok to borrow a visual, but acknowledge the source. If you changed a visual, say '…adapted from…' and say from where.

6. Integrate each visual into the text:
   a. Announce it in the text; eg. (see fig. 2) before the visual appears
   b. Place it on the same page as the text or the facing page
   c. Give an example of how to interpret each visual so reader can follow. E.g. on a bar graph: In 2003, 145 billion bananas were sold. Locate this on the visual.

7. Information and scale on a visual should be consistent. E.g. units cannot go from tens or tenths to hundreds or hundredths unless you are using a logarithmic scale. Remember this when comparing two or more visuals (you cannot compare apples and oranges; they are too unalike).

8. Relationships in a visual should be quickly understandable. Title should reflect relationships so reader doesn't have to struggle to understand: "Photograph showing damage caused by mold on apple trees." Choose the appropriate visual for the data. Simplify visuals to remove extraneous clutter, but be sure not to distort information.

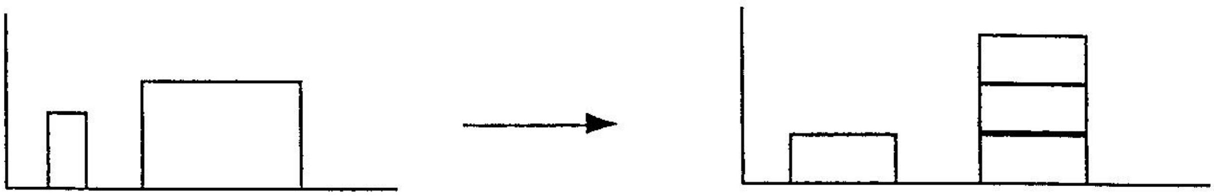
9. Adapt visuals to the level of the audience primarily concerned with the visual. Make sure you use and interpret symbols on diagrams.

10. Make the visual large enough, but not too large: a 2" by 4" diagram of a nuclear reactor is not acceptable!

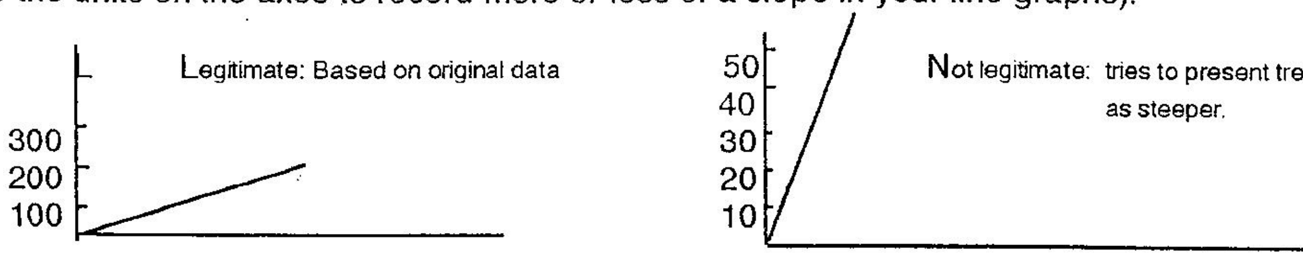
Distortion in Visual Aids

Permit no distortion: the message in the text should be the same as that in the Graphic Aid and vice versa. Here are some examples of distortions you would want to avoid:

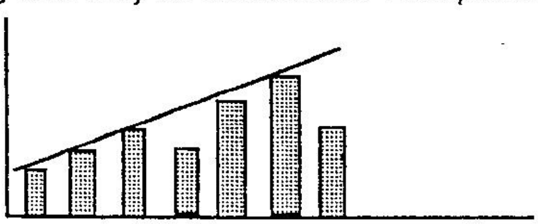
a. Surface Area Distortion: Remember to pile up like-sized boxes instead to show differentiation.



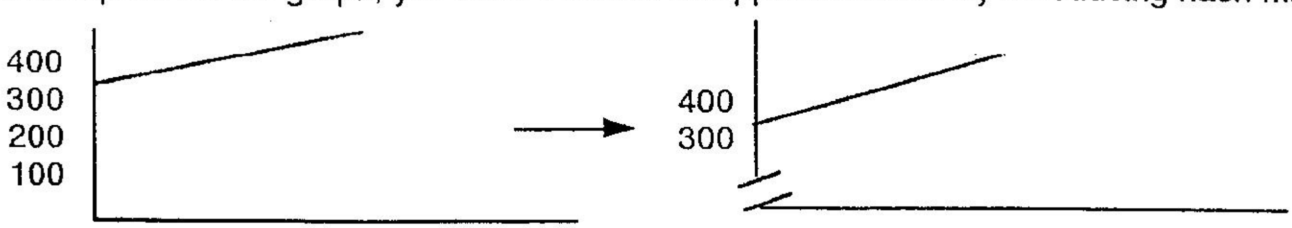
b. You may not manipulate the scale, or your original units, to your advantage (that is, you may not change the units on the axes to record more or less of a slope in your line graphs).



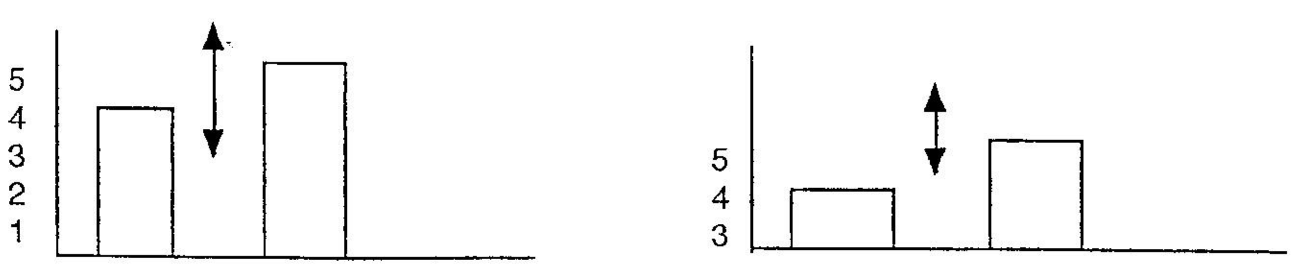
c. You may not present discrete data (as opposed to functional data) as if it is continuous. In other words, if you have cause-effect variables, and you want to show trend, use a line graph; you may not, however, take discrete, individual units of data and manipulate it into a line graph. Such usage is misleading and may be inaccurate. *Exception: Barr (data) for <u>all</u> units on the axis.*



d. If your data on a graph is only relevant high up on the axes, and you don't wish to represent extraneous space on the graph, you must indicate a suppresses zero by introducing hash marks.



e. Lastly, don't disguise true minimal differences between bars on a graph to appear either treater or smaller, according to your preference.



Matt Shobe
ENGL 415 TuTh 11:30
March 29, 2016

Visual Aids Assignment

I anticipate needing a few drawings or diagrams displaying how systems work that I will be researching. A diagram of the Wi-Charge system in its most basic form will help both engineers and product development executives quickly understand the general concept. Engineers will use this diagram to get an idea of how Wi-Charge could be a part of future products. Executives will use this diagram to decide if it would even be a practical alternative to the current short range induction chargers. I would likely include a more detailed version, if possible, in an appendix in the Formal Report.

Diagram of Wi-Charge System

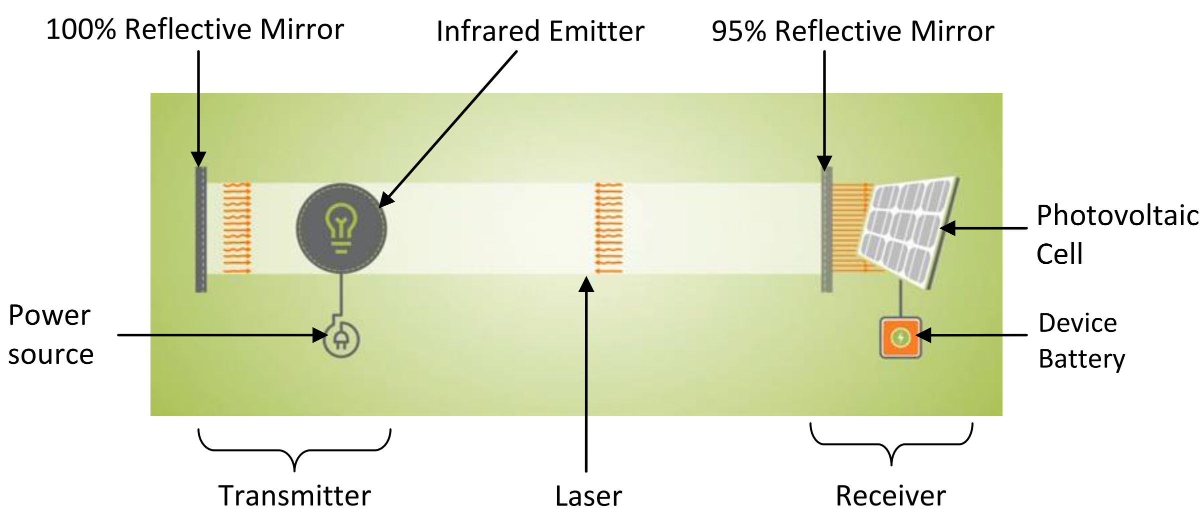


Figure 1: The powered transmitter and the receiver connected to the device, when uninterrupted, form a laser that charges the device via a photovoltaic cell similar to a solar panel.

Source: Wi-Charge. (n.d.). *How it works.* Retrieved from http://www.wi-charge.com/technology.php?ID=25

I will be analyzing several different companies and the products they are developing. The table provides a list of features for each of five non-induction wireless charging systems. This table will help executives to decide which systems might be good candidates for implementing in future battery powered products.

Table 1: Features of Various Wireless Charging Systems

Company	Devices At Once	Range	Form	Direction	Output
Wi-Charge	multiple	30 ft	infrared lasers	line-of-sight	10 W
Ossia Cota	multiple	30 ft	radio frequency	any	1 W
Powercast	multiple	10 - 50 ft	radio frequency	one	trickle charge
Energous WattUp	up to 12	15 ft	radio frequency	any	1-16 W
Power Beam	one	32 ft	laser	one	1.5 W

Sources:
Wi-Charge. (n.d.). *How it works.* Retrieved from http://www.wi-charge.com/technology.php?ID=25
Ossia (n.d.). *Home.* Retrieved from http://www.ossia.com/cota/
Powercast. (n.d.). *Powerharvester receivers.* Retrieved from http://www.powercastco.com/products/powerharvester-receivers/
Energous. (n.d.). *Product Overview.* Retrieved from http://www.energous.com/product-overview/
Takahashi, Dean (December 22, 2008). *PowerBeam steps closer to launch of wireless electricity*. Retrieved from http://venturebeat.com/2008/12/22/powerbeam-steps-closer-to-launch-of-wireless-electricity/

Powercast is a well-developed company that already has multiple products on the market with a variety of configurations allowing for better power and range. This line graph depicts the relationship between RF-DC conversion efficiency and input power. Design engineers will likely use this graph to understand how efficiency varies with input power for certain Powercast receivers that are set to either maximize distance or maximize power. The graph will also help the engineers know which Powercast products might be best suited for different applications.

RF-Conversion Efficiency of P2110 and P1110 Powercast Receivers

Figure 2: Line graph relating conversion efficiency for two different Powercast receivers to the input power.

Source: Powercast. (n.d.). *Powerharvester receivers.* Retrieved from http://www.powercastco.com/products/powerharvester-receivers/

Unit 9: Progress Report

The Progress Report Assignment unit teaches that students are accountable for reporting research findings in an informal memo at some point during the research in case target readers wish to make changes and for readers to understand that research is proceeding as expected and worthy of continuation. The Progress Report Assignment unit has the following documents:

1. Progress Report Assignment
2. Progress Report Background
3. Student A example Progress Report—Problem-Solution
4. Student B example Progress Report—Literature Review
5. Student C example Progress Report—Problem Solution
6. Progress Report Workshop Questions

Progress Report Assignment

1. Use the informal report format: To, From, Date, Subject, References, Attachments (Attachments must be attached; References need not be).

   Use **Introduction, Task Summary,** and **Conclusion** main headings**.**

2. Correctly use and reference any five sources not used in the Proposal (you may count any source in the Research Topic Review that you did not cite in the Proposal or that was only cited as Additional Reading in the Proposal).

3. In the <u>Introduction</u>, tell what you proposed to research. Also, tell the predicted benefits of the research and how you planned to achieve those benefits (Task list). Conclude by saying how much research is done. Tell your accomplishments in <u>words</u> rather than percentages.

4. In the <u>Task Summary</u>, address each research task in logical or chronological order;
   (1) Number each task.
   (2) Name each task.
   (3) Tell **what you did** (break down each task into components steps).
   (4) Tell **what you found** out, briefly.
   (5) Tell the **significance** of the results.
   (6) Tell what remains to do for each task (**task status**)
   These bolded materials need to be addressed in separate paragraphs/sections.

5. In the <u>Conclusion</u>, summarize the overall research status and tell why the research is still worth pursuing. Tell what remains to do, overall. End with a list of *technical* conclusions so far and two *standard* conclusions: (a) my research is on schedule and is 70% done (b) I will finish my research by (plug in the due date for the assignment).

   When you determine how much research has been done, consider that all tasks are not necessarily equal; task one may be weighted much more heavily than all the others, but if you are finished with it, you may have completed quite a bit of work.

Progress Report Background

Assignment: Write a P.R. to the main expert and main executive readers in your Audience Analysis profile. You should report the actual *research* progress you've made by the due date (70% of all the research completed).

General Orientation: One or more P.R. is required on nearly every project that takes longer than a month to complete. Every P.R. becomes an integral part of the work record on a project. Each P.R. fulfills part of the contract between the writer and the readers, serves as further definition of that contract, and creates the (legal) reality of what's happening with the project. The P.R. serves several purposes for both writer and reader(s).

For the writer, the P.R. permits the following:

1. Show that work is progressing on time (you were a good choice to do the project!).
2. Explain <u>why</u> the work is not progressing as scheduled (not just say it isn't).
3. Ask for, if needed, a renegotiation of due dates, costs, schedules to permit project to return to schedule.
4. Reflect on the project, get outside the actual work to be able to analyze and make changes: methods, personnel, work orders, etc.
5. Impress the readers with the quality of researching and writing.

For the reader, the P.R. permits the following:

1. Be reassured that the project is feasible and will be completed per schedule or know why not.
2. Know that the writer has the same understanding of the direction and scope of the project as does the reader.
3. Understand where the time and money are being spent.
4. Alter the direction and scope of the project, if needed.
5. Evaluate the writer as worker and communicator.

Goals: The writer should make as positive and professional an impression on the audience as possible and still be true to the facts of real progress. No matter what the progress is, the writer should convey professionalism in reporting. The reader should be able to tell exactly what has been done and if the project is truly on schedule.

Report Organization: Use the informal memo report format you used for the proposal.

By______________
Progress Report Final Draft
ENGL 415, Marcella Reekie

GE Engine Services, Inc.-Strother
P.O. Box 797
Strother Field
Arkansas City, KS 67005

TO:	_________, Component Repair Team Leader
	_________, Plant Manager
FROM:	_________, Component Repair Process Engineer
DATE:	10 November, 2___
SUBJECT:	Progress report on research of cost and feasibility of implementing lance peen operations for peening inside small diameter holes to keep additional repairs in-house.
REFERENCES:	Project Proposal, Approval of Project Proposal
ATTACHMENTS:	Attachment: Photograph of RLD-500 system

INTRODUCTION:

On October 13, 2009, I submitted a proposal to research the feasibility of implementing lance peen procedures to the Component Repair Team Leader. The proposal was approved October 20, 2__. This research stemmed from the dwindling amount of engines in the shop and a need for additional repairs to occupy employees' time. Additionally, given the current economic climate, Strother needs to perform more repairs in-house, improve the quality of work, and decrease engine turn-time to remain competitive against the non-union shop in Celma, Brazil. My research will enable Strother to add a large volume of repairs that are very similar to current in-house repairs, but are presently sent to outside vendors because of a lack of equipment.

Due to the new CF34 rotating part hi-metal repair requirements, a substantial increase in the number of parts requiring shot peen has occurred. This includes interior peening of holes that must be performed by vendors because of our lack of equipment. Lance peen, the shot peening of the interior of small-radius holes by means of an extended lance nozzle, is very similar to the shot peen operations that Strother employees currently perform. Therefore, I have proposed that the implementation of lance peen at Strother would be a simple, low-cost process with exceptional profit gains. I will complete the following tasks through the course of my research to provide Strother with an objective review of equipment options and a recommendation to transition in lance peen repairs:

1. Evaluate academic and industrial publications outlining the available technologies

2. Request cost estimates from equipment manufacturers for purchase and installation of new technologies

3. Review operator training and any special safety requirements in equipment manufacturer's product literature

This report provides the status of each of these tasks and summarizes the necessary work to complete each. I have identified the need for additional repairs, and that lance peen is an inexpensive and effective area to develop these repairs. I have evaluated the available equipment options and determined those I believe to be most appropriate for Strother. To complete my report, I will contact equipment manufacturers to obtain cost, installation, training, and safety information, and compile a recommendation for a plan of implementation.

TASK SUMMARY:

<u>Task 1:</u> Evaluate academic and industrial publications outlining the available technologies

To begin this project, I used library and internet resources to locate as much material as possible on peening small radius holes. I reviewed each of the articles and case studies for information to prove that Strother needs this technology. Additionally, I gathered background information on each of the available technologies. Finally, I reviewed information from several companies' websites that could provide the necessary equipment.

There are three substantial reasons for Strother to adopt an interior peening technology:

- ***Keep Repairs in-house.*** Current economic conditions and the constant risk of work being outsourced to Celma means that as many repairs as possible must be brought in-house. This will help keep operators busy and avoid layoffs. Engine turn-time can also be reduced by eliminating the waiting period while parts are shipped to a vendor.

- ***Utilize Existing Equipment.*** Each of the available technologies outlined below is not an entire new system, but rather an add-on to the existing shot peen equipment.

- ***Minimal Training Required for Operators.*** Along with using existing equipment, the technological add-on of lance peen to existing shot peen operations would require very minimal operator training because of the similarity of the old and new systems. My research suggests that this training could be completed in as little as half of a shift.

Four basic interior peening technologies exist:

- ***Quadrant Peening*** can be used for holes with a ratio of length to diameter (L/D) of less than two, and involves dividing the hole into four quadrants and aligning the pressure nozzle at a 45 degree angle to each quadrant for peening **(Barker)**. Quadrant peening is already in practice at Strother.

- ***Deflector Pin Peening*** makes use of standard shot peen equipment to peen small holes that are open at both ends. A small pin with a 45 degree conical tip is inserted into one end of the hole, while a pressure nozzle is aligned with the axis of the hole at the other end. As shot is blown into the hole, the pin is rotated, deflecting the shot uniformly onto the walls of the hole at the ideal 90 degree angle (Barker).

- ***Deflector Lance Peening*** improves on the flexibility of deflector pin peening by attaching a hollow lance to the pressure nozzle that can be used to peen holes with access from only one direction **(Bozdana, 2005)**. At the end of the lance is a 45 degree deflector that reflects the shot onto the walls at the ideal 90 degree angle. DLP is used to peen very long inner diameters such as those in fan and low pressure turbine shafts. In order to ensure uniform coverage, the part must be rotated because the lance does not rotate. However, fixturing that is already in place to rotate parts for external peening can be used to rotate them for DLP.

- ***Rotary Lance Peening*** is the most flexible of the interior peening methods (Bozdana, 2005). A deflector lance is fitted with a mechanism to rotate it about the lance's axis. RLP can peen holes or geometries in parts that are difficult to rotate because of their size or the location of the holes (not on the central axis). Additionally, RLP can be coupled with a CNC manipulator for complex geometries (Barker).

Strother currently sends all parts with holes needing interior peening to outside vendor shops. A number of viable options exist for integrating lance peen into existing shot peen systems. My research indicates that any of the above technologies (or any combination thereof) could be quickly implemented with current facilities, personnel, and equipment at relatively low cost, instantly bringing more repairs into the shop. However, the information I have gathered to this point indicates that a combination of DLP and RLP is likely the best option for Strother.

Task 1 is 100% complete

<u>Task 2:</u> Request cost estimates from equipment manufacturers for purchase and installation of new technologies

After using Task 1 to narrow the equipment choices, I searched several possible equipment suppliers first online, and then with direct personal communications. I searched for their location, available equipment, and costs. Two companies offer the most viable options:

- ***Progressive Technologies Inc,*** is located in Grand Rapids, Michigan. They offer the RLD-500 rotary lance drive. This device is an attachment that connects to the existing peening nozzle and orientation equipment in the shot peen booth. The RLD-500 propels the desired shot through a deflector lance at the part while being rotated axially by an internal rotation mechanism **(Rotary lance drive for shot peening)**. Progressive Technologies also offers a wide variety of deflector lances that could be used for DPP (Barker). Additionally, Progressive Technologies designs "custom automated process machinery for aerospace…industry applications" (Green, 2003, p.1). Please see Attachment for a photograph of the RLD-500 system.

- ***Abrasive Blast Systems, Inc.*** is located in Abilene, KS **(Custom designed systems).** Abrasive Blast Systems (ABS) "has made hundreds of custom designed machines…[and]

designs, manufactures and supports these machines." (Custom designed systems, p.1). ABS built the equipment that is in use at Strother and is willing to design and build a custom lance peen system to meet Strother's needs **(Personal Communication, _____, October 27, 2009)**.

These findings illustrate that there are several options available for customizing the equipment that is in use. In addition to evaluations of the products, the location of the companies and the distance technicians would travel to install and service the new equipment can be taken into consideration. Although these companies have not yet made cost estimates available, the cost of purchasing this supplemental equipment will be much cheaper than purchasing entire new systems to bring other repairs into the shop.

Task 2 is approximately 70% complete

<u>Task 3:</u> Review operator training and any special safety requirements in equipment manufacturer's product literature

To ensure operator safety, I attempted to gather information about any additional safety requirements associated with the available equipment options by reviewing product literature. I also researched training aspects and requirements to make sure that the quality standards on Strother products are met.

My efforts thus far to research safety information have yielded limited results. So far I have not located any safety requirements for the proposed equipment outside of those already in place for traditional shot peening.

My efforts to locate operator training requirements indicate that there are two major areas in which operators will need training:

- ***Interior Peening Almen Testing.*** The traditional Almen test for determining optimum blast duration is only effective for flat surfaces. In order to create accurate saturation curves, the operator will have to perform a new type of test. A new strip holding apparatus will have to be purchased, and the operator will need to mask the test strip, as only a small portion of the strip is peened **(Smith, 1972)**.

- ***Changing Machines Between Traditional and Lance-Style Shot Peening.*** The proposed supplemental equipment is relatively small, and can be installed or removed rather quickly from the shot peen machine **(News releases from progressive technologies)**.

This information illustrates that the training for Strother operators will be simple and should be completed within a matter of hours. However, further research consideration still needs to be given to safety requirements, specifics of equipment installation, and potential ergonomic issues for operators.

Task 3 is approximately 75% complete

CONCLUSION:

My investigation into comparing available technologies for interior peening and their implementation at Strother is progressing on schedule. I have completed approximately 80% of the research necessary to identify the best option for Strother and make an appropriate recommendation. At this point, I need to communicate further with Progressive Technologies, Inc. and Abrasive Blast Systems, Inc. to clarify specifics of their available systems, obtain cost estimates, identify safety concerns, and determine how much and what type of training the operators will need. After obtaining all of this information, I will construct a detailed comparison of the options that are currently available for Strother. Upon completion of all of these tasks, I will present my information and make a recommendation for implementation of interior peening in a formal report.

Technical Conclusions

Task 1: Strother currently uses quadrant peening, but there are few applications for this method. Three other options for interior peening that can be easily added on to Strother's existing equipment are available.

Task 2: Two companies offer the type of standard or custom system we need.

Task 3: The new system should be very safe, effective, and easy for the operator to learn to operate.

Standard Conclusions

1. My investigation into lance peening equipment is progressing on schedule.

2. My final report will contain the additional cost information, comparison of technology and equipment providers, and a final recommendation of implementation and training. I will submit this report on December 1, 2___.

References

Barker, Bill. *Shot Peening Small Holes*. Grand Rapids, MI: Progressive Technologies. Retrieved September 8, 2009, from <http://www.ptihome.com/casestudy.php?id1>

Bozdana, A. Tolga (2005). On the mechanical surface enhancement techniques in aerospace industry—a review of technology. *Aircraft Engineering and Aerospace Technology: An International Journal*, 77(4), 259-292. doi: 10.1108/00022660510606349

Custom designed systems. In *Abrasive Blast Systems*. Retrieved October 29, 2009, from <http://www.abrasiveblastsystemsinc.com/CDS.htm>

Green, Will (2003). CNC Rotary Lance Manipulation versus Semi-Automatic, *Metal Finishing News*, 4(1). Retrieved September 12, 2009, from <http://www.mfn.li/article/?id=125>

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Rotary lance drive for shot peening. In *Aerospace Applications*. Retrieved October 7, 2009, from <http://www.ptihome.com/aerospace.php>

Smith, Glean D. (1972). *U.S. Patent No. 3,695,091*. Washington D.C.: U.S. Patent and Trademark Office

Benjamin Williams
Progress Report Final Draft
Marcella Reekie 11:30
11 November 2014

5309 Farm to Market road 1006
Orange, TX 77630
(409) 882-6224

TO:	Jason Sallies, Lead Process Engineer Rick Kinder, Plant Manager
FROM:	Ben Williams, Process Engineer
DATE:	11 November, 2014
SUBJECT:	Progress Report on researching best practices for standardizing steam condensate removal processes at the Chevron Phillips Chemical Company Orange Plant.
REFERENCES:	Project Proposal, Approval of Project Proposal

INTRODUCTION:

On October 14, 2014, I submitted a proposal to research the best practices for standardizing steam condensate removal processes to Jason Sallies, Lead Process Engineer. This proposal was approved October 21, 2014. My research is derived from the safety, equipment reliability, and energy conservation concerns related to flawed design of these systems in the Orange Plant. Following the conclusion of this research and submittal of my formal report, Chevron Phillips Chemical Co. (CPChem) can standardize condensate removal processes company-wide. Future process engineers can now quickly analyze the problem and design a solution that will save the company time and money.

I was to complete the following tasks to provide CPChem with an analysis of solutions to fit the specific condensate removal needs at the Orange Plant:

1) Consult with experts on the subject who can provide non-biased recommendations for each technology.

2) Request additional information from CPChem regarding the current state of the condensate removal systems.

3) Investigate many avenues to purchase each technology to reduce cost.

4) Review any possible environmental or safety regulations from government agencies such as OSHA and EPA.

The status of each of these tasks and the remaining work required for each of these tasks is outlined in this report. I have determined the best and most cost-effective designs and solutions for steam trap and pressure-powered pump applications. I have analyzed the specific needs of the Orange Plant and can provide solutions for each. To complete my report, I plan to explore additional opportunities to decrease cost for each system.

TASK SUMMARY:

<u>Task 1:</u> Consult with subject experts who can provide non-biased recommendations for each technology.

My first task of this research project was to gather information from library and internet resources on many condensate removal systems. I then studied the information to determine different applications of condensate removal and the compatible solution to each application. Next, I gathered information on ideal installation and maintenance strategies. Finally, I researched new technologies to compare the new ideas to conventional methods.

CPChem has four main applications in which condensate removal systems are required:

Process Equipment (Primarily Heat Exchangers)
For applications in which the rate of heat transfer is high, a steam trap that continuously discharges condensate is required. Float and thermostatic steam traps are generally the primary selection for these situations. These traps also contain an air vent, which is advantageous during start-up of large equipment (Chikezie, 2008).

Steam Mains and Supply Lines
Flow rates on main steam headers can reach 20,000-50,000 SCFH and can hundreds of yards in length, requiring many steam traps along the pipe. For this application, a cheap, rugged solution is required. Thermodynamic steam traps have a simple design with one moving part making them a cheap solution that is resistant to both water hammer and freezing (Watson McDaniel Company, 2010).

High Pressure and Superheated Steam Sources
Some processes in the petrochemical industry can reach pressures greater than or equal to 500 psig. For condensate removal at this pressure, an inverted bucket trap is required. While they do have poor air handling capabilities they are rugged, resistant to water hammer, and resistant to any impurities present in the condensate.

Condensate Recovery to a Pressurized Header
To remove and recover condensate to a high pressure (or higher elevation) condensate header, a pump is required. Pressure-powered pumps utilize steam as a motive force to create a positive pressure gradient for the removed condensate. These pumps are necessary when recovering large quantities of removed condensate to be reboiled.

My research indicates that the above technologies are the best practices in the industry for their respective applications. More information about installation, maintenance and cost will be provided in the formal report.

Task 1 is 100% complete.

Task 2: Request additional information from CPChem regarding the current state of the condensate removal systems.

After researching the general best practices for condensate removal in the industry, I needed information about the specific issues with condensate removal at the Orange Plant. According to a survey performed by Spirax Sarco in May of 2014, CPChem has the two following problems (Spirax Sarco, 2014):

- ***A large number of failed open steam traps*** are in need of repair. However, many of these failed open traps have failed multiple years in a row even after being replaced. From this data, we can draw the conclusion that these steam traps were in the incorrect application, installed improperly, or sized incorrectly. Any of the three problems can be fixed by the standardization principles that will be emphasized in the formal report.

- ***Multiple pressure-powered pumps have failed*** throughout the plant. This has caused the re-routing of condensate, the over-use of pressure relief devices, and the loss of condensate recovery. These specific pumps lack many characteristics of an ideal pressure-powered pump system. My formal report will include a detailed breakdown of all necessary components for each system.

This research has led to specific problems faced in the Orange Plant that are most likely faced throughout the company. In the formal report, I will be sure to address these specific problems as well as many others that CPChem may encounter.

Task 2 is 100% complete.

Task 3: Investigate many avenues to purchase each technology to reduce cost.

While condensate removal systems, if designed properly, can decrease cost to a plant by thousands of dollars per year, opportunities to reduce cost still exist. I have researched multiple vendors to determine which company provides the best overall value while not reducing quality. Additionally, I have researched opportunities to increase the efficiency of each system (to reduce the amount of steam traps or reduce the piping size, etc.). Finally, I will perform a comprehensive cost-benefit analysis of multiple condensate removal systems.

The following opportunities exist to create a more efficient condensate removal system:

- ***Insulate the steam system.*** The ideal method to decrease the amount of traps on a steam header is to reduce the amount of condensate that needs to be drained. This can be accomplished by insulating all of CPChem's steam systems. Reducing this heat transfer to the atmosphere will decrease the amount of condensate sent to each trap (TLV Euro Engineering, 2011).

- ***Vent air and flash steam from traps and pumps***. Air and flash steam can make pressure-powered pumps and float and thermostatic steam traps inefficient. Simply removing the vapor from the process can save a lot of power and money.

- ***Perform regular maintenance of steam trap systems.*** This simple task performed by one or two members of the equipment reliability group can have a payback period of around half a year (Einstein, Worrell, & Khrushch, 2001).

This information provides CPChem with different ideas for improving condensate removal systems before making expensive purchases. However, I still need to research multiple vendors to find the best value for the best quality, and finalize the cost-benefit analysis report.

Task 3 is approximately 50% complete.

Task 4: Review any possible environmental or safety regulations from government agencies such as OSHA and EPA.

For this task, I have researched literature from government agencies such as the Environmental Protection Agency and the Occupational Safety and Health Administration.

Because CPChem only involves steam derived from boiling water, any equipment malfunction and subsequent release of steam would be of no consequence to the environment or any employees near the location. Therefore, no environmental regulations exist involving the use of steam.

This information provides the reassurance that upon a release of steam, no environmental impact will occur preventing lawsuits and/or fines from government agencies.

Task 4 is 100% complete

CONCLUSION:

My research of condensate removal best practices is on schedule with approximately 80% completed. I must still communicate with companies such as Spirax Sarco, Swagelok, and Armstrong to determine pricing for different condensate removal systems and create a comprehensive cost-benefit analysis for each. After this is complete, I will make a recommendation of the standard procedures for condensate removal at CPChem.

Technical Conclusions

Task 1: Many applications exist for condensate removal systems in the petrochemical industry. Researched has proved the ideal solution for each of these applications.

Task 2: Multiple condensate removal issues exist at CPChem Orange Plant, and can be resolved using data gathered from Task 1.

Task 3: Many opportunities exist to increase the efficiency of current condensate removal system to reduce future purchases. Many potential problems can be avoided by correct maintenance and testing procedures.

Task 4: No government regulations restrict the use of steam or steam equipment in the petrochemical industry.

Standard Conclusions

1. My research of steam condensate removal best practices is progressing on schedule and is 80% complete.

2. My final report will include a comprehensive review of each technology, its application, and its cost benefit analysis. I will submit this report on December 4, 2014.

References

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Kendall Schmidt
Progress Report Final Draft
ENGL 415, TU 1:05
7 November, 2015

Oklahoma Gas & Electric Energy Corp.
321 N. Harvey Ave.
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TO:	Travis Fucich, Seminole Power Engineering Department Manager Doug Riedel, Eastern Oklahoma Regional Manager
FROM:	Kendall Schmidt, Seminole Power Assistant Mechanical Engineer
DATE:	November 7, 2015
SUBJECT:	Progress report on research for opportunities that can enhance thermal and economic efficiency of the Seminole Unit 4 gas-turbine power generation system.
REFERENCES:	Project Proposal, Approval of Project Proposal

INTRODUCTION:

Last month I submitted a proposal to research potential options for improving the thermal and economic efficiencies exhibited by Seminole power plant's Unit 4 in Konawa, Oklahoma. I submitted this proposal to Seminole Power Engineering Department Manager Travis Fucich on October 13, 2015, and he approved my request on October 16, 2015. Unit 4 consists of a simple gas-fired turbine that can produce power at a rate of 170 megawatts with an efficiency of approximately 31%. It is important that we address the poor efficiency of this section of the Seminole power plant because our current facilities are wasting valuable energy and contributing high amounts of harmful pollutants per kilowatt-hour of energy produced.

The research that I am conducting will accomplish the following tasks as I search for a solution that will allow us to increase our profits and strengthen our company's environmental responsibility:

1. Review scholarly articles to learn about possible solutions for this problem, and decide which solution would most effectively improve the efficiency of Unit 4.

2. Read technical articles related to the method chosen in task 1, and learn about the process and components involved in the chosen method as well as the benefits it can provide.

3. Research regulations and engineering standards that apply when a company modifies an existing power plant.

4. Contact knowledgeable professionals with experience modifying gas-turbine power plants to obtain information including estimates of the amounts of time and money required to complete a modification project.

The status of each of these tasks is outlined in this report along with a summary of the remaining work to be completed. I have determined which technology I believe to be the best option for improving

Seminole Unit 4, and I have learned how this solution works. I have also evaluated some cost and benefit information and researched federal legislation pertinent to the chosen solution. To finish my report, I will continue researching the relevant laws and regulations and I will obtain more details about the costs and benefits associated with the chosen solution.

TASK SUMMARY:

Task 1: Review scholarly articles to learn about possible solutions for this problem and decide which solution would most effectively improve the efficiency of Unit 4.

The first step in my research was to discover different methods for modifying a simple-cycle gas turbine power plant to improve plant efficiency. I read through several scholarly articles, and I found that the three most common methods for improving efficiency are conversion to a combined cycle power plant, utilization of cogeneration technologies, and addition of inlet air cooling equipment. Each of these methods of improvement are briefly described below:

- ***A combined cycle power plant*** uses hot exhaust gasses from a gas-fired turbine to turn water into steam. In addition to the power produced by the gas turbine, power is also produced by an additional turbine as this pressurized steam expands across it. The heat energy used to generate steam in a combined cycle would otherwise be released to the atmosphere, so this process reduces wasted energy and increases power production capacity. Efficiency is improved because the net power produced is increased while the amount of fuel burned remains the same. According to Rahim, Amirabedin, Yilmazoglu, and Durmaz, “any plans to increase the efficiency of power plants beyond 50% would result in binary (geothermal based) and combined cycles” (Rahim, Amirabedin, Yilmazoglu, & Durmaz, 2007).

- ***Cogeneration power plants*** are similar to combined cycle plants because they also utilize energy from hot exhaust gasses. Kanoglu and Dincer explain that “cogeneration systems often capture otherwise wasted thermal energy, usually from an electricity producing device like a gas-turbine, and use it for space and water heating, industrial process heating, or as a thermal energy source for another system component” (Kanoglu & Dincer, 2009). Kanoglu et al. then go on to analyze gas-turbine cogeneration systems, and they determine that these systems often have an energy efficiency around 47% (Kanoglu et al., 2009).

- ***Inlet air cooling*** is a technique used to boost the efficiency of a gas-fired turbine by increasing the mass flow rate of air through the turbine and decreasing the amount of work required from the air compressor. As the name of this method suggests, this technique involves lowering the temperature of the air entering the compressor of a simple cycle gas-turbine power plant. When ambient air temperatures are relatively high, a gas turbine power plan can experience power loss of more than 20% compared to standard conditions (Kakaras, 2004). One of the most common methods for lowering the temperature is through a technique called evaporative cooling, but this method only improves efficiency by about 0.44% and increases power output by about 6.8% (Kakaras, 2004).

I have determined that the most beneficial modification to Seminole Unit 4 would be conversion to a combined cycle power plant. My research indicates that combined cycle power plants exhibit efficiencies that are higher than those shown by cogeneration systems and turbines with inlet air cooling. Additionally, our options for utilization of cogeneration technologies are limited because Seminole Unit 4 is isolated from any other buildings, so space and water heating are not a feasible benefits.

Task 1 is 100% complete.

<u>Task 2:</u> Read technical articles related to the method chosen in task 1, and learn about the process and components involved in the chosen method as well as the benefits it can provide.

With the successful completion of task 1, I began to research combined cycle power plants to learn how this power generation process works. I learned that higher efficiencies are achieved when combining a Brayton cycle with bottoming Ranking cycle because this takes advantage of the fact that a Brayton cycle involves extremely high temperatures, while a Rankine cycle operates at relatively low temperatures (Rahim et al., 2007). As a result, the benefits of a combined cycles include the potential for a gas-turbine power plant to produce up to 50% more energy using the same amount of fuel (Combined cycle power plant - how it works - GE power generation. 2015).

Converting a gas turbine power plant to a combined cycle power plant involves adding a heat recovery steam generator (or HRSG). The simplest HRSG configuration available is referred to as a once-through heat recovery steam generator, and this is attached to the outlet of a gas-fired turbine. The hot flue gasses from natural gas combustion within the turbine enter the HRSG and flow through various heat exchangers. The heat from the gasses is transferred to water, and this water is turned into steam by the time the gasses exit the HRSG through the stack. Finally, the hot pressurized steam expands across another turbine and produces power in addition to that produced by the gas turbine (Combined cycle plant for power generation: Introduction. 2015).

The preceding paragraphs provide a brief overview explaining the results of my research over the process involved in a once-through heat recovery steam generator. The information I have found helps me understand specific details of combined cycle power plants, and it reinforces my belief that we have access to the resources necessary for implementing this process to improve Seminole Unit 4. To finish this task, I will continue to seek out additional benefits that combined cycle power plants provide.

Task 2 is 90% complete.

<u>Task 3:</u> Research regulations and engineering standards that apply when a company modifies an existing power plant.

Government entities at the federal and state level have enacted laws and regulations that power plants in the United States must follow. It is important that I find out what these regulations are to ensure that our company avoids costly fines and upholds its ethical and legal responsibilities. In recent news, the Environmental Protection Agency released a new set of rules on August 3, 2015 called the Clean Power Plan, and this legislation primarily focuses on reducing carbon emissions from power plants. Seminole Unit 4 is a natural gas fired plant, and the Clean Power Plan encourages utility companies to use natural gas instead of coal for fuel, so modifying this unit will not conflict heavily with this set of laws (Andracsek, 2015). However, this plan does include a set of standards for reconstructed natural gas power plants, so we must adhere to the rules outlined in this legislation (EPA Fact Sheet: Carbon Pollution Standards. 2015). The federal government also set goals for every state regarding the amount of CO_2 released by power plants within that state, so Oklahoma Gas & Electric must recognize these goals and do everything in our power to ensure they are met (Clean Power Plan: State at a Glance, Oklahoma. 2015).

I will continue to conduct research to find additional federal and state legislation that would affect a combined cycle conversion project. I will also research the engineering standards that may apply to a project of this type. It is important that I investigate these rules and regulations so our company can guarantee that our employees are safe and our environment is preserved.

Task 3 is 50% complete.

Task 4: Contact knowledgeable professionals with experience modifying gas-turbine power plants to obtain information including estimates of the amounts of time and money required to complete a modification project.

To complete my final task, I contacted professional engineers from Burns & McDonnell, an engineering consulting company in Kansas City, Missouri. The employees of engineering consulting firms like Burns & McDonnell often have an immense amount of valuable experience working on power plants, and the two engineers I contacted are currently working on a project which involves a combined cycle power plant in Riverton, Kansas. I had a phone conversation with engineer in training Derek Damas on November 2, 2015. He explained to me that the process of converting a gas-fired turbine to a combined cycle power plant takes approximately three years. This includes the time it takes for the bidding, design, and construction processes. Fortunately, the gas-turbine often is able to continue normal operation until the final stages of construction where the HRSG is attached to the outlet of the turbine. This is possible if the stack on the existing gas turbine is tall enough to avoid safety issues, and this means we would likely be able to minimize costly down-time. Finally, Derek informed me that the average cost of a project like this will cost between $165 million and $175 million (D. Damas, personal communication, November 2, 2015).

The information that Derek has provided so far is very helpful to my understanding of the amounts of time and money that are required for a project of this nature. I have emailed additional questions to Senior Mechanical Engineer Jonas Cafferty, and this task will be completed when I receive and review his response.

Task 4 is 70% complete.

CONCLUSION:

Technical Conclusions

Task 1: The best option for improving the efficiency of Seminole Unit 4 is to convert this unit to a combined cycle power plant.

Task 2: Constructing and attaching a once-through heat recovery steam generator would be a feasible solution to the problems exhibited by Seminole Unit 4.

Task 3: Federal legislation, state legislation, and engineering standards must all be considered when a company converts a gas-fired turbine to a combined cycle power plant.

Task 4: We should consider utilizing an engineering consulting firm to help us modify Seminole Unit 4. With the help of a company like Burns & McDonnell, we could strive to complete this modification within three years with a budget of approximately $175 million.

Standard Conclusions

1. My research on improving the efficiency of Seminole Unit 4 is progressing on time and is 80% complete.

2. My final report will include an analysis of each possible solution, and it will provide information about the costs, benefits, and implementation of the best solution. I will submit this report on December 3, 2015.

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Rahim, M. A., Amirabedin, E., Yilmazoglu, M. Z., & Durmaz, A. (2007). Analysis of heat recovery steam generators in combined cycle power plants. *The Second International Conference on Nuclear and Renewable Energy Resources,* Ankara, Turkey.

Progress Report Workshop

1. Briefly explain the major purpose of the report you're evaluating, and say what audience the document is aimed at. Please read the Progress Report carefully "in character," and respond to the following.

2. Evaluate the persuasive appeal of the progress report by addressing these issues:
    a. What, specifically, is the problem or opportunity addressed in the report?
    b. How does the writer seek to convince you that the problem is getting solved efficiently and cost-effectively? How persuaded are you that the writer is a conscientious employee and a good engineer? Concentrate on Tasks here.
    c. What, exactly, has been accomplished to date, and how strongly are you persuaded that the project will indeed be finished and the tasks completed?
    d. Are you convinced that the writer has spent research time between the Proposal and the Progress Report wisely? Explain. (Assess how much has been done in the time allotted)
    e. How comfortable do you feel about having the writer finish the project? At this stage, does it still look profitable? Has the writer balanced his/her time and the organisation's money effectively? Based on the quality of the document (content, tech writing skills, thoroughness, and tone), how confident do you feel about the writer's ability to do the project well? Explain your responses with specific references to the draft before you.
    f. As you read through the Introduction and the Task Summary, take note of any considerations you feel a discriminating reader would want explanation about. Now look closely at the Task Summary: Are those considerations explained and defended in this section? (Or does the report end with unaddressed questions and expectations?) Be extremely nit-picky here to help your colleague know where to improve the Task Summary.
    g. Can you approve the Progress Report as it stands? Or do you have to insist on conditions? Explain.
    h. Finally, please identify technical writing style and format pros and cons.

Unit 10: Formal Report

The Formal Report Assignment represents the culmination of the students' research and writing skillset and officially presents the completed research results and interpretations of those results in a professional document. This document will contain the technical body of information with prefatory elements at the front and Appendices (if warranted) and References at the back.

The assignment should demonstrate that the completed project offers the potential for 'measurable benefit' to the target readers, and that benefit should be quantified as return on investment, benefit/cost ratio, or by some other Engineering Economics mechanism if at all possible.

Moreover, the report should fully and correctly use the best format for the topic, whether Problem-Solution (often a Feasibility Study comparing options to elicit the best one), Design/Redesign, or Literature Review. With these goals in mind, the Formal Report Assignment unit contains the following documents:

1. Elements of the Formal Report Assignment
2. Principles of good communication: Reminder
3. Discussion, Introduction to Discussion, and Executive Summary components
4. Problem-Solution: Empirical Research Report?
5. Problem-Solution: Feasibility Study?
6. Formal Report Grading Criteria
7. Elements of the Formal Report broken down by constituent parts
8. Formal Report Workshop Questions

Elements of the Formal Report

Prefatory Elements

1. **Title Page**: Offer complete title (Type of research, topic, purpose), say to whom and by whom; don't forget the date. The title page is your reader's introduction to your report: its functions are to dignify the report and to orientate the reader to the contents.

2. **Letter of Transmittal**: The letter acts to signal the forthcoming Formal Report. It is a letter, so please sign and date it! In paragraph 1, intro the title of the research and state research is complete & submitted. Also, emphasize the **purpose** of the research. In the heart of the letter, go into depth about what the report *does*, *found out*, and the *value* of the findings. Give major conclusions/recs, and, giving page numbers, hit highlights of Discussion. Next, pinpoint the next step in the process, acknowledge helpful people/facilities, and then close the letter.

3. **Table of Contents**: The Table of Contents indicates the page where disc topics begin, it displays the nature and content of the topics you cover, and it acts as a preliminary outline for you. Include & label every heading and sub-heading. Use lower case roman numerals for the prefatory pages, and use Arabic numbers for all pages subsequent to and including the Executive Summary. You should write the Table of Contents last and give the page a heading.

4. **Illustrations**: This page catalogues the visuals, and you must separate, number, and title each figure; do the same for each table. Present first the one list and then the other in the order in which the visuals appear in the paper. Make sure each title IDs the type of visual, the topic, and the purpose. Use a heading: Illustrations.

5. **Glossary**: alphabetically define each term (5+) not known to most readers using the formula: Item (being defined) = category (it belongs in) + distinguishing traits. Offer a Glossary for five or more terms. Otherwise, define the terms in the report the first time you use each with a parenthetical definition. Italicize each term you are defining once, the first time you use it to alert the reader. Don't forget the heading: Glossary.

Body of Report

Please see the additional information I have posted on KSOL about each of the following documents, and keep in mind that each begins a new page.

1. **Executive Summary**: In separate paragraphs, do the following: give the context for research; state the extent of the problem or need making clear the research **purpose**; offer incentives for executive readers to act. Next, insert lots of evidence throughout; end with lists of Conclusions and then Recommendations (except Lit. Reviewers). Note: This is a one page <u>condensation</u> of the Introduction to Discussion and the Discussion, so it cannot be written first.

2. **Introduction to Discussion**: develop 3-4 paragraph section *proving research need* and stating **purpose** for expert reader (this is where you <u>detail</u> the problem, so pull from

your Proposal for this information if you did a good job); give paragraph on *effects* of problem/need; tell main findings the Formal Report offers; in separate paragraphs, state your research method and preview main headings that appear in the Discussion.

3. **Discussion**: This section is less prescriptive because each student will have his or her own topic that will dictate how to organize the Discussion to some degree; however, the following requirements apply to all: have text below every heading (except Discussion); state your Research Objectives somewhere; organize your materials logically and according to expected patterns/conventions; provide a strong benefit/cost or ROI section toward the end (Lit. Reviewers need only list simple costs, e.g. purchase, installation); interpret/defend all your findings here. Note: no need to revisit discussion of problem; it's in the Introduction to Discussion. Address any rules or regulations governing your topic; address counterarguments. Be sure your Benefits and Drawbacks sections are clear and have headings.

4. **Appendix/-ices**: letter and title each appendix in a separate cover sheet; list individual contents on the cover sheet.

5. **References**: Using APA format, list 10 (or more) in-text citations with appropriate Reference page entries.

Miscellaneous

1. Number all pages except the Title page.
2. Insert visuals for any of the situations outlined in the textbook chapter.
3. Use Empirical Research or Feasibility Study format where appropriate.
4. Use color on visuals. Make sure they look sharp and are labeled legibly.
5. Double-space between paragraphs and headings. Bold face headings, indent and underline to signal topic shift and importance.
6. Use lots of evidence, proof, numbers for each claim (aim for several per paragraph).
7. Have Conclusions (and Recs) listed, numbered at end of Exec. Summary AND Discus.
8. Lit. Reviewers: Include only Recs for more research; no technical Recs allowed!
9. Use persuasive strategies liberally in the Discussion (e.g. Lots of 'For example,')
10. Neutralize or at least acknowledge all major counterarguments.
11. Designers: locate the Design in the report as Appendix materials; in the Discussion, justify and explain your design platform/decisions.
12. In your report (except where inappropriate), organize ideas from most to least important.
13. Type on ONE side of the page only.
14. Turn in one copy of Formal Report, stapled or bound with a binder clip
15. Begin your Formal Report by WRITING THE DISCUSSION FIRST!
16. Start a new page only if you are starting one of the documents listed (i.e. items **bolded**)
17. Use the part by part pattern whenever you compare items

Written Communications Principles

As we assess student Formal Reports, keep in mind the discussion is about principles of good communication, not about trying to teach you one scripted way to produce a Formal Report. The reports I share show one format; you will encounter others in the workplace. Be willing to adapt to your future bosses' and readers' needs. Workplace communication needs and formats change; good communication principles do not. Never lose sight of the main principles:

1) Select information and write information for a *target reader*
2) Select information for a clearly focused *purpose*
3) Use persuasive writing strategies when building an argument (base the argument on a debatable proposition)
4) Organize your information to meet reader expectations (use traditional organizational patterns). Also, consider readers' preferred media: E.g. Snow day citizen complaints to the City of Overland Park are addressed on the City's fb page)
5) Write clearly, correctly, concisely; interpret the information when you can: E.g. One barge filled with fuel for a distribution point equals 15 trucks. This fact was part of an argument to repair/replace locks on US riverways—Andrew Walmsley, American Farm Bureau Transportation Specialist. Or, how much snow did the City of OP move this winter? Enough to fill a football field 30ft high.

The Discussion component of your Formal Report offers the following:

1. An extended explanation of your research Solution (for Problem solvers), or of your Literature Review Information (for Lit. Reviewers), or of your Design Platform (for Designers or Re-Designers) for the expert reader primarily
2. Focus on the technical aspects of the research Solution or Information Need or Design (pick whichever applies to you)
3. Listed defense of the Research Objectives from the Proposal
4. Listed Conclusions (and Recommendations if applicable)
5. Cost information on the topic as return on investment or benefit/cost ratio

The Introduction to the Discussion offers the following:

1. Extended discussion of the research need or problem
2. Information for the Expert reader, primarily
3. Focus on the technical aspects of the research problem, need, or design opportunity
4. No information on the Solution, Design, etc. (that's for the Discussion)
5. List of tasks for the Research Method
6. A paragraph or list giving the main Discussion headings

7. The Executive Summary offers the following:

1. Information condensed from the Discussion
2. Explanations for the Executive reader, primarily
3. Decision-making information, not heavily technical info.
4. A brief paragraph on Research Need/Purpose
5. A list of Conclusions (and Recs. if applicable)

Problem/Solution Formal Report: Empirical Research Report Discussion

If you decide your Formal Report is largely an Empirical Research Report, a report that solves a problem with data you have derived or collected rather than merely read about, then include the following in your Discussion:

1. Your research Objectives, listed and defended early in the Discussion. What is the point? To demonstrate your ultimate findings and data are rooted in sound judgments.
2. Explanation of the test/survey/experiment(s) you ran—materials, time allotted, steps, questions asked, equipment, protocol involved, in short everything necessary to ensure for the reader that your results are largely reproducible. What is the point? To prove your Method was sound.
3. The results themselves, probably as Appendix materials if they are too many or too complex to put in the Discussion. In the Discussion, then, you would interpret your results (conclude and address significance of your findings) in a dedicated section. What is the point? To persuade the reader the data led to sound conclusions the company can trust.

Problem/Solution Formal Report: Feasibility Study Discussion

If you decide your Formal Report is a Feasibility Study it will be because you recognize you are comparing alternatives with a view to determining the better or best one. In that case, you must employ the part by part comparison pattern, and your Discussion will therefore benefit from the following sections, among others:

1. Comparison Criteria: determine and then rank order from most to least important the benchmark criteria you and your company would expect the chosen solution to have.
2. Overview of Alternatives: tell your readers what options you are going to compare after first whittling down all the possible alternatives to the top 2, 3, or 4. In a brief paragraph, you may readily dismiss forever those options that common sense dictates could never stand up to a rigorous comparison.
3. Set up the part by part evaluation whereby you compare each retained option to each of the criteria in turn:

   <u>Criterion #1</u>

   Option A (how does it measure up to the benchmark criterion?)
   Option B (ditto)
   Option C (ditto)

   <u>Criterion #2</u>

   Option A (how does it measure up...?etc.)

   Keep up the pattern until you have compared all the options against
   All the criteria your readers would expect you to consider.

4. Offer a Conclusion containing a comparison table and paragraphs summing up which option clearly 'wins.'

Formal Report Criteria

A. Content (60 points)

1. Report contains sufficient Claims, Evidence, and Reasoning
2. Report offers clear statement of Need for research in Letter, Executive Summary & Introduction to Discussion
3. Report makes good use of Persuasive Strategies.
4. Report uses complete, accurate, documented (where applicable) visuals in color for any situation that calls for one
5. Report correctly uses 10+ sources after the APA style, 6^{th} edition
6. Report persuasively addresses major counterarguments
7. The Executive Summary meets the executive's needs
8. The Introduction to Discussion and Discussion meet the expert's needs
9. Report covers Research Method (Intro to Disc) & Research Objectives (Disc)
10. Report makes reasonable attempt to cover cost to implement/design main product or idea (applies to Designers and Problem-Solvers only)
11. Report clearly lists and explains Benefits and Drawbacks in labelled sections
12. Report contains no major omissions from the list in the Text
13. Report addresses any government/governing rules/regulations applying to the topic

B. Organization (35 points)

1. Every heading except the Discussion heading has text below it
2. Report uses Persuasive Organization Strategies effectively and sufficiently
3. Report *lists* Conclusions and Recommendations at the end of the Exec. Summary and Discussion. NOTE: Literature Review contains no technical recommendations
4. Report content follows organization (headings) in the Table of Contents
5. Report judiciously uses Format Options (headings, underlining, indenting, etc.)
6. Appendices have complete cover sheets
7. Report demonstrates logical progression of ideas and offers coherence/transitions
8. Report offers a short paragraph at the beginning of each section to guide the reader as to how to process the upcoming information
9. Designers only: The Design is in (an) Appendix/Appendices
10. Report uses Most to Least Important organization except where not appropriate

C. Grammar and Punctuation (sections C, D, and E worth 55 points total)

Report has very few and only minor grammar or punctuation faults

D. Technical Writing Style

1. Report favors the Active Voice over the Passive
2. Report is mostly devoid of Expletive Openers and hidden verbs
3. Report has very few redundant/wordy phrases

E. Miscellaneous

1. Report is stapled or bound with binder clip
2. Letter is signed and contains contact information (email address, phone number)
3. Page numbering follows prescribed system (roman numerals, arabic numbers)

FR workshop

1. Trade your 10+ pages with someone
2. Read the draft sections carefully
3. Ask questions verbally about content, organization, t.w. style, etc. Now, it doesn't matter that you may not have adequate context to fully understand the material. Your goal is to ask questions to stimulate the *writer's* sense of responsibility to his/her readers. Writers: Pay close attention to the questions you are asked, and address the relevant ones in your final copy of the F. Report.
4. Focus on each section of the draft separately; don't try to assume continuity necessarily among the different pages. If you run out of ideas, here are some:

   a. Are all necessary visuals supplied for each section?
   b. Do the visuals meet the rules of good construction and usage?
   c. Is the organization of ideas and relationships of topics and sub-topics clear with titles, sub-headings, indentation, double spacing, etc.
   d. Does *each* sub-topic have its own sub-heading?
   e. Are the ideas clearly written; can you understand them on ONE reading?
   f. Point out areas where the writer hasn't supplied enough information to properly explain, where the reasoning is simplistic, incorrect, or confused.
   g. Do the sections and ideas within the sections have an overall sense of integrity (wholeness) and progression, or does the writer present a sequence of topics seemingly unrelated to one another?
   h. If the writer has brought Executive Summary materials, has s/he included all the necessary components for each section? Are all sections complete yet brief enough to meet the needs of the executive decision-maker?
   i. If Results, Conclusions and Recommendations are included, are they all listed, numbered and properly separated?
   j. Does the writer show clear understanding of the differences between Conclusions and Results (research facts)?
   k. Has the writer made good use of "I" plus action verb when discussing research procedure, methods and discoveries, or is the draft peppered with passives or 'it is' phrases? Locate and underline such errors.
   l. Does the writer supply adequate transitions between sentences and between sections to clarify relationships among ideas? Identify any omissions.
   m. Locate and bracket any ideas in two or more sentences that could/should be combined for faster reading pace and more direct understanding by the reader.
   n. Does the writer use the glossary technique properly (if applicable)?

Unit 11: Speech

The Speech Assignment offers a taste of the Formal Report contents to the members of the organization (expanded from the three persons who would have read the internal Proposal and Progress Report memos to a broader group in the organization). Attendees would expect to exit the speech with a copy of the Formal Report. To make and support two main claims, the Speech Assignment should rely heavily on useful visuals based on Michael Alley's Assertion-Evidence approach from his Craft of Scientific Presentations. The Speech Assignment, accordingly, contains the following documents:

1. Speech Assignment
2. Miscellaneous information about the Speech
3. Additional Speech Assignment Information
4. Speech Visuals information
5. Speech Outline example
6. Speech Evaluation Sheet for grading
7. Sample Student Speech Power Point Materials

Speech Assignment

Don't be late, and don't be absent!!

Compose a persuasive, 12 minute extemporaneous speech to your Audience Profile members to introduce them to the Formal Report. Do not try to condense the Formal Report in to your speech; instead pick only TWO main points to develop and prove. Think of the speech points as the 'appetizers' for the main course, the Formal Report. Note: Literature Reviewers: you want to persuade listeners to want more research; Problem Solvers/Designers: you want to persuade listeners to accept and implement your main Recommendation.

Do not let your speech run much over 12 minutes to avoid penalty (we are constrained by time limits after all). Do not let your speech run under 10 minutes to avoid a serious penalty. After all, this is to be a persuasive endeavor, and time is a persuasive resource!

Plan for a two to three minute question/answer session following your speech where class members should plan to ask one intelligent question about the topic. This time is *not* part of the 12 minutes you should allocate for your speech. Remember to give to me your Speech Outline just before you introduce your speech. Ask a classmate to signal your time as you speak.

Plan to show at least three of your visuals in a power point presentation; remember, an outline or list does not constitute a legitimate graphic!

You may use 3x5 note-cards, but beware; they can cause you to look down instead of at us, which could jeopardize your goal of 80% eye contact.

Format

<u>Beginning</u>:
a) Tell who you are, name your topic, clarify your ***purpose*** (this last must be very clear to avoid a penalty). Purpose should reveal what you WANT of your readers at the beginning of the speech: "Today, I would like to persuade you to…."
b) Forecast the two main points you will develop in your speech.

<u>Middle:</u>
a) Put transitions between speech segments (points) and after the intro and before the conclusion.
b) Using key words develop each of your main points.

<u>End:</u>
a) Conclude by restating the speech purpose and summarizing your two main ***speech*** points (as opposed to research findings). Give the major recommendations (literature reviewers give the main conclusions).

b) Close your speech purposefully and invite questions that you will then answer.

Miscellaneous information about the Speech

Industry is moving away from using the traditional bullet point power point template because this method is boring and not particularly memorable or persuasive. Instead, presenters favor the Assertion/Evidence approach by Michael Alley at Penn State University.

Consult Michael Alley's (The Craft of Scientific Presentations) short videos on scientific presentations, slide design, and delivery malley@engr.psu.edu:

Scientific Presentations: https://vimeo.com/88991194. This focuses on the Assertion-Evidence strategy as better focused and understood by the audience than the traditional step through many bullet points approach.

Slide Design: https://vimeo.com/81809530. This says to choose slides to support the content. It also shows slides being layered with information.

Delivery: http://vimeo.com/86342823. This says be energetic; make eye contact; own your content (ie. Speak it don't read it); refer to graphics but don't read them to us; enjoy giving the speech; move about to convey content dynamically; and use pauses and vocal variation.

Student speech models: http://writing.engr.psu.edu/models.html.

Additional Speech Assignment Information

1. Please note that the speech should run 12 minutes.
2. If you know you are running out of **time**, budget some secondary information into the speech that you can drop at a moment's notice without compromising the two main ideas. Likewise, if you notice you are running out of **material**, budget some secondary information you can import into either of your speech main points.
3. Remember the differences among Memorized, Impromptu, and Extemporaneous methods of speech-giving: Memorized has the drawback of disconnecting speaker from listener as speaker focuses on his/her own internal monitor to recall words; Impromptu has the drawback of being off the cuff and so therefore disorganized and somewhat rough around the edges; meanwhile, Extemporaneous combines the advantages of both the other types. It has a memorized Intro, Conclusion, key words, and transition statements, and yet the development of the main points is presented as if from knowledge, not from memory. Please use the **Extemporaneous** method for your speech.

Speech Visuals

1. We need visuals in speeches for three reasons: to help the audience to understand; to help maintain the audience's interest; to help the audience remember.

2. Here are seven guidelines for visual aid selection/creation:
   a. they should be visible
   b. they should be clear and simple
   c. they should be controllable
   d. they should be accurate
   e. they should be appropriate
   f. they should be necessary
   g. they should be well done

3. Rules of Usage
   a. Place the visual so all can see it
   b. Face the audience not the visual as you speak about it
   c. Use a pointer to point to specifics on the visual
   d. Keep the visual out of sight until we need to see it
   e. Be in control of the aid/equipment
   f. Make the visual fit the correlating speech section
   g. Make sure the visual is a stand-alone component of the speech
   h. Apply all the criteria of good TW to your visuals (see text chapter)
   i. Don't read the visual to us; interpret its value instead

4. Types of Visual Aid
   a. Powerpoint slides: allow no clutter; allow only necessary ones; have more graphics than outline materials or lists; number visuals consecutively; use software features consistently to show slide parts; use color according to the text; allow no redundant details; reveal points visual one at a time.
   b. Overheads: plan on these in case technology fails. They are easy to carry and versatile (you can write on them, overlay transparencies, and re-use).
   c. Be sure to use legible font size (22 point).

5. Let visuals/outlines clarify goals of presentation, and/or mission statement
   a. of the company. For ex: Give the mission statement and tell how your research promotes it.
   b. Actual objects/written handouts. These can be very useful, but hand them
   c. out at the end only so as not to create distractions and inattention to speech.
   d. Chalkboard. Great for a short equation or a quick, simple visual, but be wary breaking eye contact and be wary of the effect of poor artwork.

Speech Outline

Abstract:

The current market for aviation companies is in crisis. With fewer people flying, airplanes are being grounded and the economic implications filter from the airlines to the manufacturers and to repairs shops like Strother. To continue earning a profit and avoid lay-offs, Strother needs to find ways to bring new repairs into the shop. I researched adding lance peen to the existing shot peen system. This will add a large number of repairs while requiring little investment or employee training.

Introduction:

"Good morning. My name is ________ and I am a Process Engineer in the Component Repair Department. After noticing the decrease of engine volume coming into the shop, I decided to investigate ways to bring new repairs into our shop. Today, I would like to persuade you that adding lance peening processes…

I. Process and Equipment Options

"After I identified the need for new repairs, I considered the types of repairs that would be simple, yet highly effective to implement…"

A. Quadrant Peening **"Partitioned Hole", "Shallow Hole"**

B. Deflector Pin Peening **"Deep Hole"**

C. Deflector Lance Peening **"LPT Shaft", "Deflector Lance"**

D. Rotary Lance Peening **"Cut-Away Diagram", "Rotary Lance Drive"**

II. Suppliers

"Once I had identified the type of system that would be best for Strother, I began researching companies who could provide the necessary products and services…"

A. Progressive Technologies, Inc. **"RLD-500"**

B. Abrasive Blast Systems, Inc. **"ID Blaster"**

Conclusion

"In conclusion, the low investment cost and high return of number of repairs…"

A. High demand

B. Variety of technologies

C. Best Suppliers

D. Proven Benefits

Questions?

Speech Evaluation Sheet

STUDENT NAME____

Content/Format (31 points)

1. Did the speaker introduce him/herself and the research topic? (2)
2. Did the speaker forecast the main speech parts at the beginning (or go straight to topic discussion)? (2)
3. Did the speaker clarify point of view (purpose: what s/he *wants*) at the beginning? (3)
4. Did the speaker use key technical words/phrases to identify important ideas? (2)
5. Did the speaker capably develop each main idea, offering clear definitions, descriptions and solid explanations (or merely mention main ideas offering only a superficial treatment of them)? (6)
6. Did the speech parts flow smoothly and logically from one another, helped by clear transitions, building persuasively to main findings/recommendations (or did they seem disjointed, unrelated to each other, devoid of connecting transitions)? (6)
7. Was the information clear, sufficient, convincing? Is listener persuaded not just informed? (6)
8. Did speaker recap the main parts of the speech and end with a final push of the main point? (2)
9. Did the speaker ably answer questions? (2)

Delivery (14 points)

1. Did gestures, movement, posture, suggest confidence and relaxation? (2)
2. Did the speaker make eye contact with us at least 80% of the time? (2)
3. Did the speaker avoid over-reliance on notes? (2)
4. Did the voice sound enthusiastic, loud enough, clear enough and interesting? (4)
5. Did the speaker use all the time available--no more, no less? (2)
6. Did the speaker avoid all verbally or physically distracting mannerisms? (2)

Visuals (10 points)

1. Did the speaker use enough visuals, too many, too few? (2)
2. Were the visuals well-constructed, controlled, properly used, integrated? (8)

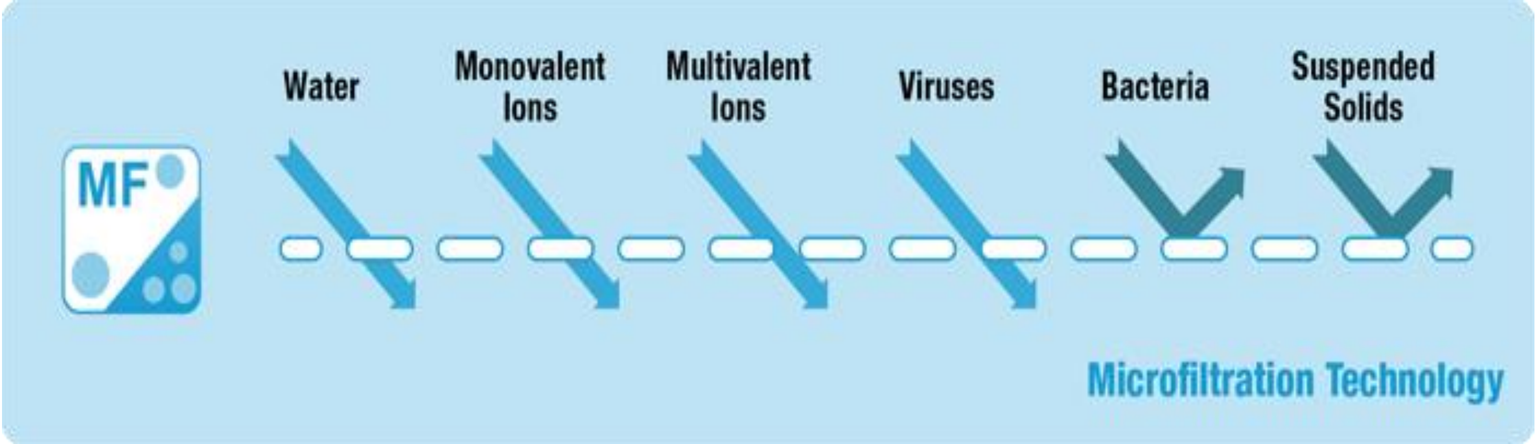
Outline (5 points)

1. Did the outline contain a speech abstract, hierarchy of only 2 topics, transitions, visuals? (4)

Written Evaluation and Grade:

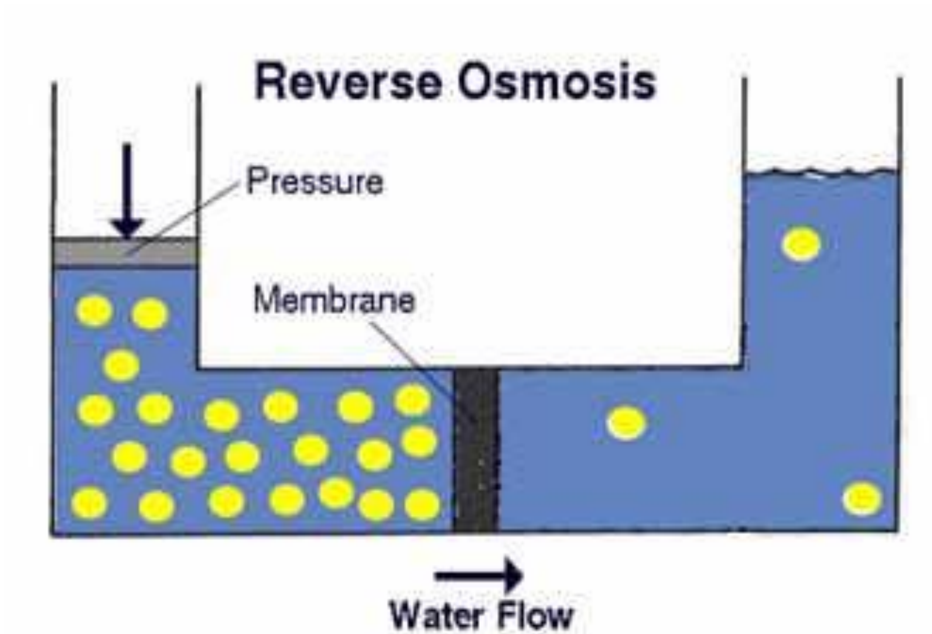
DIRECT POTABLE REUSE: A SUSTAINABLE WATER DISTRIBUTION ALTERNATIVE

Microfiltration purifies water by channelizing the flow to pass through a special membrane.



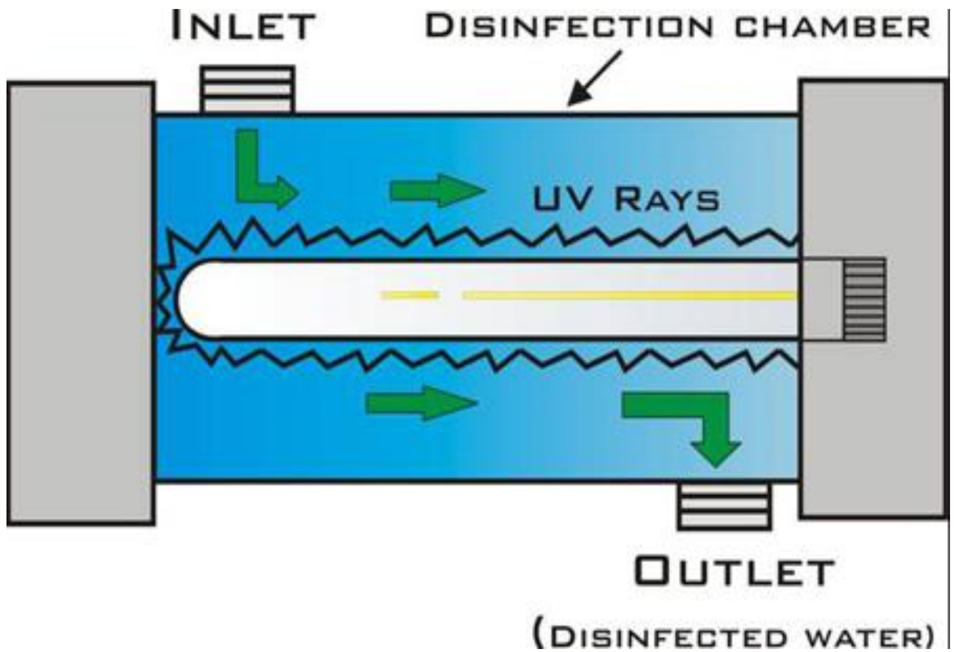
Source: < http://www.kochmembrane.com/Learning-Center/Technologies/What-is-Microfiltration.aspx>

Reverse Osmosis relies on pressure and temperature to separate total dissolved solids from water



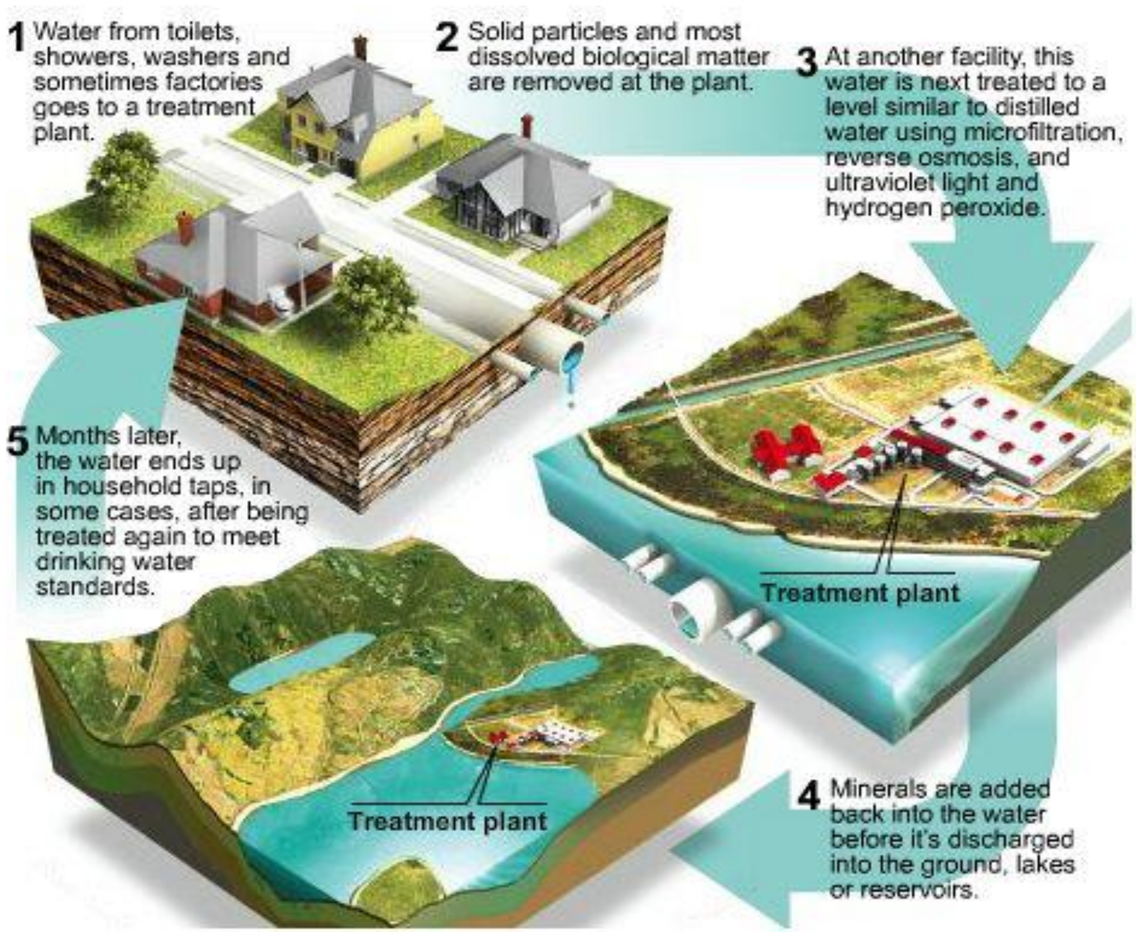
Source: < http://www.pure-pro.com/reverse_osmosis_q.htm>

Ultraviolet Disinfection transfers the electromagnetic energy emitted from a mercury arc lamp to an organism's DNA and RNA.



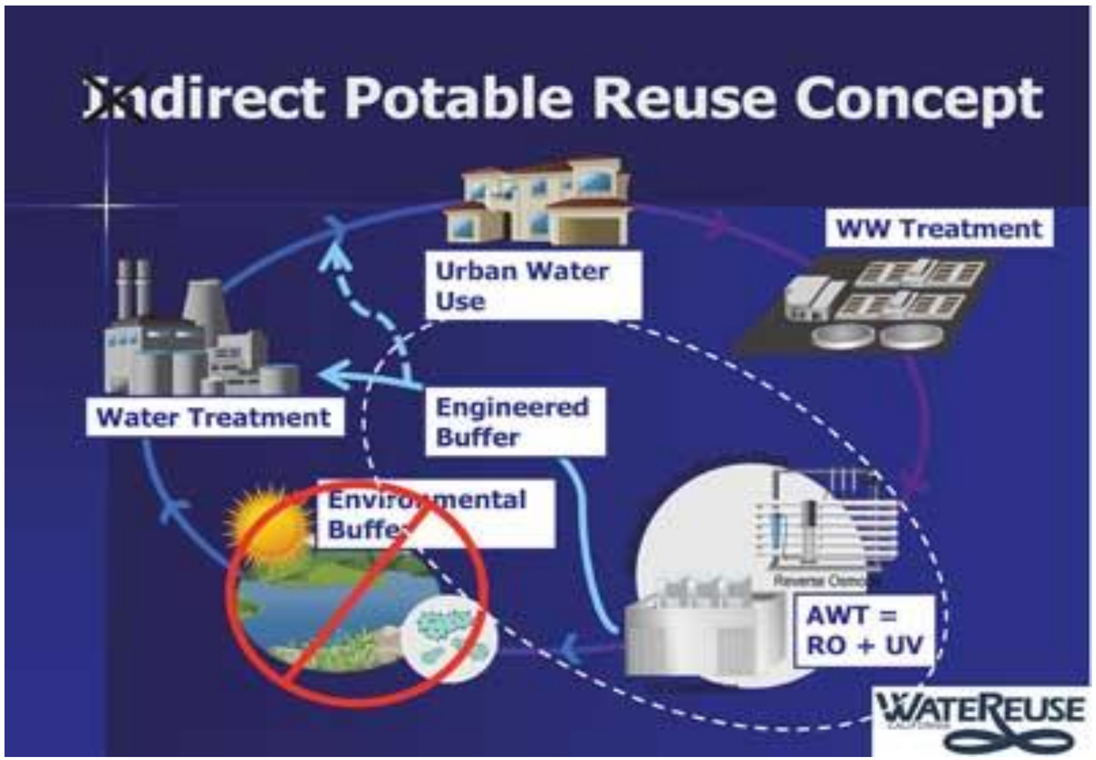
Source: < http://www.synergyboreholes.co.uk/water_boreholes/index/uv/>

Indirect Potable Reuse is the most common distribution scheme in the United States.



Source: < http://usatoday30.usatoday.com/money/industries/environment/2011-03-03-1Apurewater03_CV_N.htm>

Direct Potable Reuse is the newest and least common distribution system.



Source: < http://www.waterworld.com/content/dam/ww/print-articles/2013/09/potable-wastewater-environ-buffer-1309ww.jpg>

Conclusions

- The technology to incorporate DPR already exists.
- DPR could cut down energy bills relating to water discharge and water transportation.
- Sub-par wastewater treatment plants and drought-stricken regions could benefit from the sustainability that DPR systems provide.

Recommendations

- Burns & McDonnell should invest more time and money into further research of implementing direct potable reuse as a sustainable water treatment plant.

- Burns & McDonnell should research the feasibility of creating a combined water treatment plant—one that has wastewater treatment and water purification all in the same location.

Unit 12: Honor/Integrity, Plagiarism Quiz, and Documentation Quiz

The Honor and Integrity unit address Kansas State University expectations of students using the resources of others and includes the Engineering Code of Ethics as well as a quiz on Plagiarism issues and one on Documentation issues. Thus, the Honor and Integrity unit has the following documents:

1. Kansas State University Honor and Integrity website home page
2. Engineering Ethics/Code of Ethics of Engineers
3. Plagiarism Quiz
4. Documentation Quiz

Search web, people, directories
Browse A-Z Sign in

K-State home » Honor System

Honor and Integrity System

- Home
- Honor and Integrity System Basics
- Honor Council
- Faculty Tips
- Student Tips
- Development and Integrity Course
- Violation Report Form

K-State Honor & Integrity System
Kansas State University
215 Fairchild Hall
Manhattan, KS 66506

785-532-2595
785-532-5944 fax
honor@k-state.edu

Dr. Steve Starrett - Director
steveks@k-state.edu

Dr. Camilla Roberts - Associate Director
cjroberts@k-state.edu

A Community of Integrity and Trust

Imagine this......a campus community where instructors clarify their expectations for academic work and students respect those parameters. It is happening here at K-State, with the help of all involved. Education, consultation, mediation, adjudication: We do it all with student and faculty development in mind!

Beginning in the fall 1999 semester, Kansas State University initiated the Honor and Integrity System based on personal integrity, which is presumed to be a sufficient assurance that, in academic matters, one's work is performed honestly and without unauthorized assistance.

Undergraduate and graduate students, when they register, acknowledge the jurisdiction of the K-State Honor and Integrity System. The policies and procedures of the Honor and Integrity System apply to all full and part-time students enrolled in undergraduate and graduate courses on-campus, off-campus, as well as on-line. A component vital to the Honor System is the inclusion of the Honor Pledge, which applies to all assignments, examinations, and other course work undertaken by students.

"On my honor, as a student, I have neither given nor received unauthorized aid on this academic work."

Contact us Emergency Statements and disclosures

Kansas State University Manhattan, KS 66506 785-532-6011 Updated: 10/31/12

Code of Ethics of Engineers

Honor and integrity are fundamental in Tau Beta Pi, the Engineering Honor Society. Fully worthy character is a basic membership requirement of the Society. The character and reputation of Tau Beta Pi members must be above challenge. The slightest suggestion of anything untoward in their actions or speech seriously reflects upon themselves, Tau Beta Pi, and their profession.

The honor and integrity of engineers comprise two elements: First, conformity to all the requirements of honesty and responsibility, which are expected of the best citizens, regardless of occupation; second, meeting the requirements of the special ethics of their profession.

Every profession has established a code or standard to govern the conduct of its member in matter that pertain to the profession and that do not concern lay citizens. Many of the important national engineering societies have adopted their own codes.

The Fundamental Principles

Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

I. Using their knowledge and skill for the enhancement of human welfare;
II. Being honest and impartial, and serving with fidelity the public, their employers and clients;
III. Striving to increase the competence and prestige of the engineering profession; and
IV. Supporting the professional and technical societies of their disciplines.

The Fundamental Canons

I. Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.
II. Engineers shall perform services only in the areas of their competence.
III. Engineers shall issue public statements only in an objective and truthful manner.
IV. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
V. Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
VI. Engineers shall act in such a manner as to uphold and enhance the honor, integrity and dignity of the profession.
VII. Engineers shall continue their professional development throughout their careers and shall provide opportunities for the professional development of those engineers under their supervision.

Plagiarism Quiz

T F 1. If you make an honest attempt to avoid plagiarizing when you borrow a source, yet fail to apply the rules of conduct properly, you are not guilty of plagiarizing.

T F 2. When you paraphrase material, you may use a phrase or two from the original without quotes.

T F 3. Once you cite a source once, you do not need another in-text citation if you reuse it.

4. The correct way to avoid plagiarism is to do the following: (circle correct response)

   a) Introduce the author of the source you're using in a paragraph.

   b) Provide a Reference entry for every source you use.

   c) Acknowledge all quoted materials with quote marks.

   d) Use in-text citation for each source.

   e) Paraphrase borrowed ideas entirely in your own words.

   f) All of the above

   g) b), c), d), and e)

T F 5. In a court of law, another's ideas and words are considered property.

T F 6. Plagiarism is wrong because it violates the standards of honor, fair play, and trust.

7. Proof reading by a friend is not the same thing as plagiarism. Discuss

8. KSU punishes proven plagiarism by doing the following:

   a) Publishing guilt on the student's record

   b) Keeping records on file for authorized parties to consult

   c) Failing the paper or exam

   d) Failing the student in the course

   e) Suspending the student

   f) Dismissing the student

   g) Levying any or all of the above

9. According to the Engineering Code of Ethics, your highest loyalty is to your business interests.

10. Name three specific types of plagiarism.

Documentation Quiz: APA style (https://owl.english.purdue.edu)

1. What are the differences between quoting, paraphrasing, and summarizing?
2. What functions does documenting your sources serve?
3. What three kinds of material should always be documented?
4. True or False: When you document sources, readers expect you to use a style guide.
5. You are to use the APA style guide for English 415. What two basic elements does APA say you must include to document a source properly?
6. True or False: You do not have to document unpublished sources.
7. What are the rules for citing multiple authors using the APA style?
8. What are the APA rules for citing multiple authors?
9. In APA, each in-text citation requires two elements; what are they?
10. In general, where does each in-text citation go?
11. What is your primary goal in deciding how to place in-text citations?
12. Where do you place a citation that refers to material in several sentences?
13. Does an in-text citation go inside or outside the sentence punctuation?
14. If your source has an unknown author, what should the in-text citation include?
15. Regarding the References (or Works Cited) page, how the entries organized?
16. On a References page, is giving the publishing information optional or required?
17. What sources come under the heading Personal Communication?
18. How should you space lines within and between entries on a References page?
19. How should you indent sources on a References page?

Unit 13: Appendix A: Student Problem-Solution Formal Report

FEASIBILITY STUDY OF IMPLEMENTATION OF LANCE PEEN PROCEDURES AT GE AVIATION—STROTHER

SUBMITTED TO:

____
Component Repair Team Leader
GE Aviation—Strother

SUBMITTED BY:

Process Engineer

1 DECEMBER 2___

imagination at work

Denison Ave
Manhattan, KS 66502
@ksu.edu
30 November, 2___

___________, Plant Manager
GE Engine Services, Inc.—Strother
P.O. Box 797
Strother Field
Arkansas City, Kansas 67005

Mr.______:

I am pleased to submit my completed formal report, “Feasibility Study of Implementation of Lance Peen Procedures at GE Aviation—Strother,” that was approved by the Component Repair Team Leader on October 20, 2009. This report outlines the results of my research and compares the varying technologies available for lance peen procedures.

I decided to conduct this research to help bring more repairs into the shop. This report explores implementing lance peen because it is a simple and inexpensive addition to our shot peen operations. The report is divided into six parts: background information on shot and lance peen (p.4), the benefits and drawbacks of implementing lance peen (p.5), a part-by-part comparison of available lance peen technologies (p.6), an overview of the systems suppliers can offer Strother (p.11), a review of operator training requirements (p.12), and a summary of governing regulations (p.13). I conclude the report with my recommendations and a list of steps to implement lance peen (p.15).

This report provides Strother with the necessary information to make an expedient investment in lance peen technology. My research has proven that lance peen is a simple, yet customizable, addition to existing shot peen operations that will bring a large volume of repairs in-house to occupy operators and increase profit margins. At this point, an executive decision on purchasing equipment can be made, and we can move to contacting the equipment manufacturer to arrange for purchase and installation. After installation is complete, operator training can begin as outlined in this report, and the system can be used immediately because of the similarity between the existing shot peen system and the proposed lance peen system.

I appreciate the opportunity to investigate this technology and provide a recommendation for equipment purchase and implementation. I would like to thank Mr. _____ and Mr. _____ for helping identify the need and supporting this research to completion.

Please contact me with any additional questions or comments regarding the information in this report.

With regards,

____

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Title Page Photo Borrowed from:

DefenceIndustryDaily.com. “Re-engining the E-8 JSTARS.” August 6, 2009. Accessed on November 2, 2009 from <http://www.defenseindustrydaily.com/Re-engining-the-E-E-JSTARS-04891/>

EXECUTIVE SUMMARY

GE Engine Services, Inc –Strother has set the standard as the premier engine repair facility in the world for decades. We have established ourselves as the primary location for repair development on the CFM56 and CF34 engine lines with our superior engineering, manufacturing, and problem-solving abilities. However, the recessed economic conditions coupled with the aftermath of 9/11 have hit the aviation industry hard. The airlines have suffered, cancelling flights and grounding airplanes. This means that fewer engines are being overhauled in our shop. Strother needs to perform more repairs in-house, improve the quality of our work, and decrease engine turn-time to remain competitive against the non-union shop in Celma, Brazil. My research will enable Strother to add a large volume of repairs that are very similar to current in-house repairs, but are presently sent to outside vendors because of a lack of equipment.

On October 13, 2009, I submitted a proposal contending that the purchase of lance peen equipment to supplement current shot peen operations will bring a large number of repairs in-house from outside vendors and will result in a significant profit increase for the Component Repair department. Lance peen is a variation on the traditional shot peen process in which tiny metal or ceramic beads are shot at a part. The effect of this process is to improve the number of times an engine can be run before a part will need to be replaced.

Four basic methods for lance peening the inside of a hole in a component exist. I have exhaustively compared all four and have drawn conclusions as to which methods will be the most applicable and cost-effective for Strother's needs. Two companies provide the type of equipment Strother will need. Progressive Technologies of Grand Rapids, MI offers a standard attachment that will perform the desired functions, and Abrasive Technologies of Abilene, KS offers a custom designed system that is tailored to Strother's needs and exactly matches the existing shot peen equipment.

When I began my investigation into lance peen, I outlined three steps: (1) evaluate academic and industrial publications outlining the available technologies; (2) request cost estimates from equipment manufacturers for purchase and installation of new technologies; and, (3) review operator training and any special safety requirements in equipment manufacturers' literature. The Component Repair Team Leader approved the project on October 20, 2009. I have completed each of these tasks and compiled an effective report on the actions Strother should take.

Conclusions

1) Lance peen is a simple addition to an existing shot peen operation.

2) The varying lance peen technologies mean it can be customized to fit Strother's needs exactly.

3) Minimal operator training makes lance peen a cheap investment that will begin to return productivity and profit gains immediately.

4) Strother will not need to address any new government, company, or customer regulations to use lance peen and therefore can begin using it immediately.

Recommendations

I strongly recommend that Strother purchase and install lance peen technologies as quickly as possible. The low investment cost and high return of number of repairs performed in-house make it an invaluable process. Strother should purchase Almen test masking and fixturing equipment from Progressive Technologies, Inc. Then, we should consult Abrasive Blast Systems and begin customizing the automatic peening booth to perform Deflector Lance Peening on LPT, HPT, and Fan Shafts. The shaft repairs are the most pressing concern at present. After these repairs have been instituted, communication with ABS should continue to design a Rotary Lance Peen system to peen any holes that are not accessible by DLP. Upon completion, these additions to the shot peen department will give Strother a much broader capability range, ability to perform a large number of vendored repairs in-house, and perhaps even the chance to act as a vendor shop for other companies.

INTRODUCTION TO THE DISCUSSION

GE Engine Services, Inc –Strother has set the standard as the premier engine repair facility in the world for decades. We have established ourselves as the primary location for repair development on the CFM56 and CF34 engine lines with our superior engineering, manufacturing, and problem-solving abilities. Many customers prefer to send their engines to our facility because of our proven security, quality, and speed of repair.

However, the recessed economic conditions coupled with the aftermath of 9/11 have hit the aviation industry hard. Many people are either afraid to fly or can't afford it, and as a result the airlines have suffered. Flights have been cancelled, and airplanes remain grounded. Fewer airplanes flying mean that fewer engines are being overhauled in our shop. Strother needs to perform more repairs in-house, improve the quality of our work, and decrease engine turn-time to remain competitive against the non-union shop in Celma, Brazil. My research will enable Strother to add a large volume of repairs that are very similar to current in-house repairs, but are presently sent to outside vendors because of a lack of equipment.

On October 13, 2009, I submitted a proposal contending that the purchase of lance peen equipment to supplement current shot peen operations will bring a large number of repairs in-house from outside vendors thus resulting in a significant profit increase for the Component Repair department. My method for investigating lance peen included three steps: (1) evaluate academic and industrial publications outlining the available technologies; (2) request cost estimates from equipment manufacturers for purchase and installation of new technologies; and, (3) review operator training and any special safety requirements in equipment manufacturers' literature. The Component Repair Team Leader approved the project on October 20, 2009.

This report represents the culmination of my research. The report begins with a basic outline of the characteristics of shot and lance peen. Next, I address the benefits and drawbacks of purchasing and integrating a lance peen system into existing shot peen operations. Then, I present an exhaustive comparison of the available lance peen methods, followed by a comparison of the options available from two equipment manufacturers. Next, I address necessary operator training and governing regulations. Then, I review the research objectives outlined in my proposal. Finally, I present my conclusions and recommendations and provide a plan for implementing lance peen at Strother.

My investigation into lance peen as a method to shot peen the inner surfaces of small holes shows that each of the available options has advantages and disadvantages. Although each of the methods presented incurs an initial start-up cost, all of them provide an increased profit margin that far outweighs the cost. Therefore, I recommend that Strother switch from sending out all lance peen repairs to purchasing the supplemental equipment to complete these repairs in-house.

DISCUSSION

Characteristics of Shot Peen

Turbine jet engine parts are subjected to extreme cyclic conditions throughout their lifespan that can cause serious detriment and premature failure. These fluctuating stresses are most prevalent at the surface of a part **(3)**. Thus, a primary goal for component manufacturers is to surface treat these expensive parts in order to increase the number of cycles an engine can stay on-wing before they must be replaced. One of the most common surface treatment methods is shot peen. As Luan, Jiang, Ji and Wang explained, "Shot peening [is] an effective method used widely in industry, [and] can considerably improve fatigue strength and fatigue life of cyclically loaded components" **(10:2454)**. GE Engine manuals require that components be shot peened whenever the integrity of the surface of a critical part has been compromised. Additionally, new CF34 manual regulations require that all rotating parts undergo shot peen after any surface repair.

Shot and Lance Peen Outcomes

During shot peening, a nozzle uses air at a specified pressure to shoot tiny metal or ceramic beads toward the surface of a part. Each impact converts the kinetic energy of the shot into plastic deformation on the work piece surface (**9**). The combination of all the impacts creates a uniform layer of permanently deformed material at the surface of the work piece. This deformation results in residual compressive stresses that are much higher than the ultimate strength of the material. Because cracks propagate through a material by means of tensile forces, the residual compressive stress pushes cracked material back together, effectively stopping the crack from forming or expanding **(4)**.

While shot peen is a proven method for improving fatigue strength and surface properties of flat surfaces, traditional methods are ineffective when attempting to peen internal surfaces with small radii or unusual geometries **(5)**. Serious limitations include lack of space for a nozzle to reach the area, tight geometry causing the shot to ricochet against the walls, and difficulty attaining uniform coverage over a given area. Areas such as holes, dovetails, and fillets are stress concentration points where cracks tend to originate. Thus, these areas must be shot peened to improve fatigue life. Lance peen is a nearly identical process to shot peen, but it changes the geometry of the process to account for these limitations.

Traditional Almen Test

Shot peening is a highly effective process, but "the intensity of shot peening must be carefully controlled, because peening at intensities both above and below a critical range will not harden the component properly" **(1:3)**. Typically, this intensity is determined by performing the Almen strip test in which a thin hardened steel coupon approximately 3 by ¾ inches is shot under a variety of conditions where the process parameters are changed **(15)**. These process parameters include shot flow rate, shot velocity, shot size, and impact angle **(9)**. After the series of coupons is shot, the curvature, or bow in each strip is measured. Then, the Strother process engineers use computer software to relate the coupon data to a saturation curve. The saturation curve determines the optimum pressure, duration, and angle of peening. Strother operators already perform the Almen test on a daily basis, and the Component Repair process engineers analyze the information and update the operators' Manufacturing Instructions manual regularly. However, the traditional Almen test for determining optimum blast duration is only effective for flat surfaces. To create accurate saturation curves, the operator needs to perform a new type of test. The details of the new Almen test are addressed later in this report in the Operator Training section beginning on page 12.

Consequences of Implementing Lance Peen

Lance peen is a well-established technology with many manufacturers and repair shops already utilizing the technology. Lance peen is not a completely new system, but rather an addition to the shot peen system that already exists. This technology has many benefits, and a few drawbacks that are described below:

Benefits

The benefits of implementing lance peen processes are simple and obvious. All of the benefits are based on the concept of making a small change in the shop that will create a significant monetary gain for Strother. The benefits can be divided into three main categories:

- **Keep Repairs In-House.** The largest percentage of repairs on an engine occurs on components in the fan and high pressure compressor sections of the engine. The fan and compressor blades in these sections are connected to disks by dovetail slots that transfer all dynamic loads between these components. To maintain proper fatigue life, the dovetails on all of these parts are shot peened **(3)**. Also, due to the new CF34 rotating part hi-metal repair requirements, a substantial increase in the number of parts requiring shot peen occurred. This includes interior peening of holes that must be performed by vendors because of our lack of equipment. Being able to peen these dovetails and rotating parts, as well holes in any other components, in-house increases the profit margin and keeps operators busy. Additionally, engine turn times can be reduced if the engine is not waiting for parts to return from other repair shops.

- **Utilize Existing Equipment.** Several options exist for controlling lance peen operations. Each method takes advantage of the existing orientation equipment in the peening booth to position the blast nozzles for peening specific areas of a part. Also, for many parts, the fixturing that already exists for exterior shot peening can also be used for interior lance peening. All of the air and shot supply equipment is used for both shot and lance peening as well.

- **Minimal Training Required for Operators.** Two options are available for controlling RLP operations: CNC and semi-automatic **(8)**. A CNC-Robotic system controls a single nozzle and lance in four axes (horizontal, vertical, pitch, and yaw) to control peening of highly complex parts. Pre-installed computer programs handle a variety of geometries and can peen multiple areas of a single part with no operator input following initial set-up. A semi-automatic system controls rotation and vertical motion of the lance, while an operator intervenes to set up each individual peening cycle **(8)**. Operators at Strother are already trained to set up peening runs on a wide variety of parts at any position because no two parts come in with identical damage needing repair. Training for these operators would simply include changing the machine from traditional pressure blast to lance peen mode and how to run test curves for small diameter repairs. This training could likely be completed in less than half of a shift. Specifics of this training are addressed in the Operator Training section on beginning on page 12.

Drawbacks

The main arguments against implementing lance peen at Strother are based on the initial cost of purchase and installation. However, instituting any new repair is costly at first, but most pay for themselves quickly. The two fundamental drawbacks to lance peen are as follows:

- **The Traditional Almen Test cannot be Used.** The traditional Almen test for determining optimum blast duration is only effective for flat surfaces. To create accurate saturation curves, the operator must perform a new type of test. A new strip holding apparatus needs to be purchased, and the operator masks the test strip, as only a small portion of the strip is peened **(15)**. After the operator's portion of the test is complete, the engineer has two options. Either he or she will mathematically relate the test results to the Almen scale, or he or she will need to purchase new computer software to develop saturation curves directly from the small radius test **(15)**.

- **New Control Devices for Lance Peen are Required.** No CNC robots currently exist in the shot peen area at Strother, so all apparatus for controlling and rotating a lance need to be purchased. If a CNC system is chosen and a new booth is required to install it, the current shop configuration has no space for an additional booth. Furthermore, pressurized air supply and shot sources must be diverted to the new booth, both at a very high cost. However, as explained in the Benefits section, a semi-automatic system is the more reasonable choice for Strother, and does not incur these costs.

Lance Peen Methods

Holes in components are divided into two groups: shallow holes and deep holes. A shallow hole has a ratio of length to diameter of less than two. Similarly, a deep hole has an L/D ratio of two or greater. Of the four types of lance peening, Quadrant Peening can be used for shallow holes, while Deflector Pin Peening, Deflector Lance Peening, and Rotary Lance Peening are used for deep holes **(2)**. These four methods of lance peening are compared below by three primary shot peen variables:

Ensure Uniform Coverage: Rotation

Ensuring that uniform coverage of the treated surface is achieved to create a homogeneous layer of compressive residual stresses (**9**) that arrest crack development **(3)** is a key element in the success of shot peening. One of the most effective methods of ensuring consistent coverage over the interior surface of a hole is rotation. Each method of lance peen uses different types of rotation.

- **Quadrant Peening.** QP does not use continuous rotation. Instead, the circumference of the hole is partitioned into four sections as in Figure 1. Then, shot is directed into the hole at a 45 degree angle as shown in Figure 2. Each section, or quadrant, is peened, and then the part is rotated to align the nozzle with the next quadrant **(2)**.

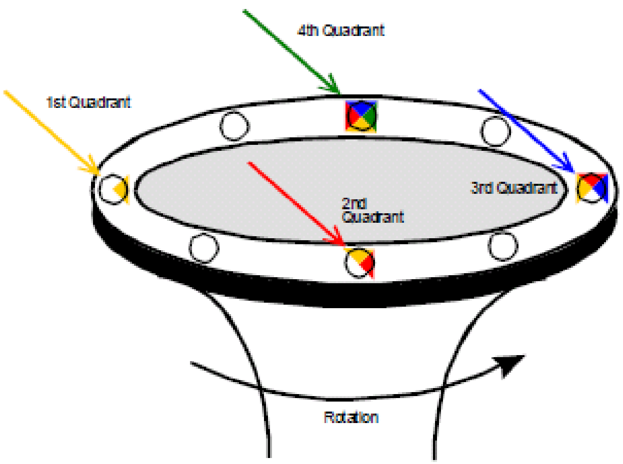

Figure 1—Diagram showing a hole partitioned into quadrants. **(2)**

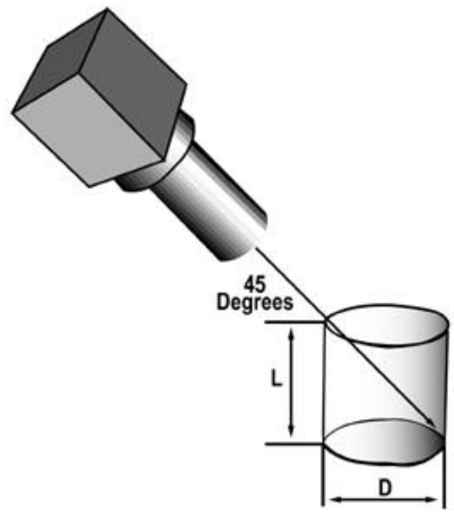

Figure 2—Diagram of a shallow hole undergoing Quadrant Peening. (**2)**

- **Deflector Pin Peening.** If a hole is open at both ends, a typical shot peen pressure nozzle can be used to perform DPP. As shown in Figure 3 on the following page, the pressure nozzle is aligned with the axis of the hole, and shot is directed longitudinally down the hole. A deflector pin that has a conical tip with a 45 degree angle is inserted into the hole from the opposite end, and as the shot hits the pin it is reflected against the walls of the hole at the optimum 90 degree angle **(2)**. To account for any deformation in the tip of the deflector pin and ensure uniform shot coverage, the deflector pin is rotated during DPP.

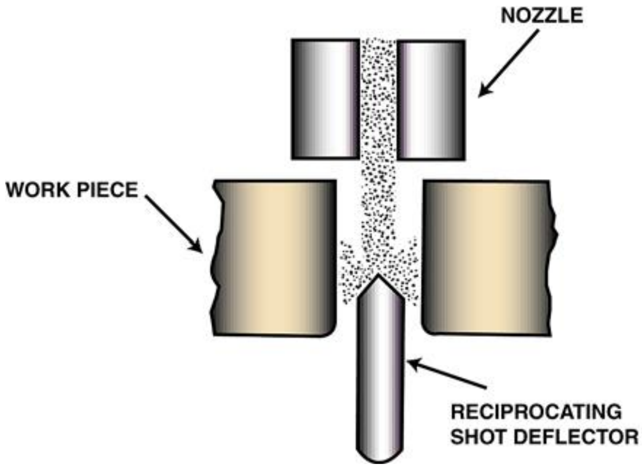

Figure 3—Diagram of a deep hole undergoing Deflector Pin Peening. **(2)**

- **Deflector Lance Peening.** DLP improves on the versatility of DPP by allowing holes with access from only one end to be peened. DLP consists of a deflector lance that is aligned with the longitudinal axis of a hole. Then, the part is rotated axially around the deflector lance while shot is blasted through the lance and reflected onto the walls of the part **(2)**. DLP can be aligned either vertically or horizontally in the shot peen booth. Figure 4 shows a photograph of a low pressure turbine shaft, which is likely one of the first parts that would be integrated into a new lance peen system at Strother, undergoing DLP.

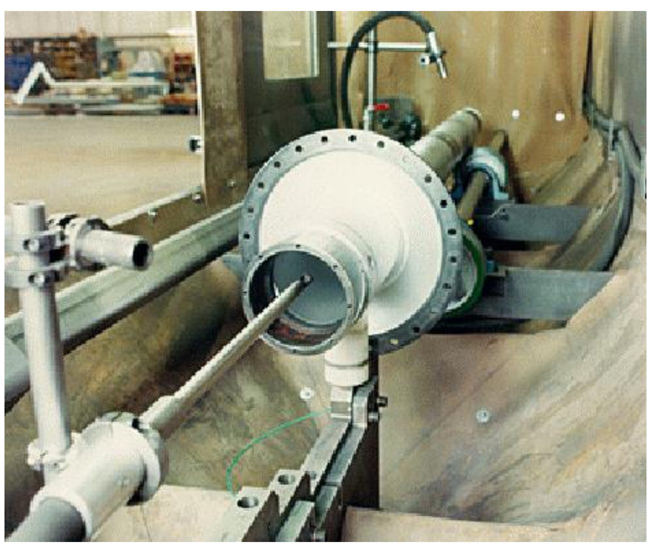
Figure 4—Photograph of LPT shaft undergoing DLP **(2)**

- **Rotary Lance Peening.** RLP increases the versatility of lance peening by rotating the deflector lance rather than the part. This allows parts with holes that are not aligned on the central axis to be peened as well as large or unusually shaped parts that are difficult to rotate **(2)**.

Blast Nozzle Type

The second variable is the type of nozzle used to deliver the shot to the work surface. Each method uses different types of nozzles in a variety of configurations.

- **Quadrant Peening.** QP uses a typical shot peen pressure nozzle that is directed into the hole at a 45 degree angle **(3)**. Strother already regularly uses this method to peen parts.

- **Deflector Pin Peening.** In DPP, a typical shot peen pressure nozzle is aligned vertically along the longitudinal axis of the hole. When shot is blown down the hole, it reflects off the 45 degree conical tip of a deflector pin at a 90 degree angle against the walls of the hole **(2)**.

- **Deflector Lance Peening.** DPP attaches a deflector lance, a long hollow tube with a 45 degree angle and small opening at the tip as shown in Figure 5, to the shot and air supplies. This lance is then inserted into the hole to be peened, reaching deep, blind holes that are inaccessible by either QP or DPP **(2)**.

Figure 5—Photograph of a Deflector Lance **(2)**

- **Rotary Lance Peening.** RLP attaches a deflector lance like the type used for DLP to the shot and air supplies. The deflector lance is also attached to a rotary drive mechanism that rotates the lance within the hole. Unlike DLP, RLP can be used on holes that are not on the central axis of the part **(2)**.

Fixturing

Nearly every component that undergoes shot peening is secured within the booth by some type of fixturing. Some fixtures serve only as masking, some hold a part in a specific orientation, and others rotate a part during peening.

- **Quadrant Peening.** Parts undergoing QP must be oriented with the nozzle at a 45 degree angle to each quadrant of the hole. For most parts this can be accomplished by placing the component in the peening booth and orienting the nozzle appropriately. Some parts may require fixtures to hold them in an appropriate position, but most of these fixtures likely already exist for peening exterior surfaces of the part. These fixtures do not need to rotate the part.

- **Deflector Pin Peening.** DPP requires a fixture for each part to position it with the longitudinal axis of the hole vertical. Another fixture is required to align the deflector pin with the longitudinal axis of the hole and rotate it. While a single fixture for the deflector pin could probably be used for all deflector pin operations, none of the required fixtures exist for this method of peening. Producing fixtures for every part is likely too cost prohibitive to make DPP a practical option.

- **Deflector Lance Peening.** DLP uses a fixture to rotate the part about its central axis. No fixtures are required for the nozzle. Some appropriate fixtures may already exist for peening the exteriors of parts such as fan and turbine shafts. For shorter parts, a turntable may serve as a viable fixture for a number of components.

- **Rotary Lance Peening.** While RLP requires a special drive mechanism to rotate the lance, most parts shouldn't need any fixturing. Some parts may need a fixture to hold them in a workable orientation, but like QP, most of these fixtures probably already exist for peening exterior surfaces of these parts.

Summary of Lance Peen Methods

After considering each of the four methods within each criterion, I chose a combination of DLP and RLP as the best option for Strother. Quadrant Peening is the cheapest option, but it has very limited applications and will not resolve the need for an interior peening method for deep holes. Deflector Pin Peening is also impractical because of the extremely large volume of fixtures required. Additionally, DPP can only be used on holes that can be accessed from both ends, thereby limiting the number of applications. Deflector Lance Peening only requires the purchase of deflector lances and construction of some part fixtures. It can easily peen the LPT and Fan Shafts that most urgently need this technology. Rotary Lance Peen requires the purchase of a lance drive system, but few new fixtures. RLP covers any applications where DLP is impractical. Between DLP and RLP, any possible part configuration can undergo interior peening.

Comparison of Equipment Manufacturer's Options

My research of shot peen equipment manufacturers led me to select two companies for consideration to provide the new equipment. Progressive Technologies, Inc. and Abrasive Blast Systems, Inc. both offer feasible products and are recognized industry leaders in shot peen equipment for aerospace application. I compared the two companies with three criteria:

System Offered

I contacted both PTI and ABS by phone and e-mail and reviewed the systems each had to offer. The companies offer slightly different systems, each with its own unique advantages and disadvantages.

- **Progressive Technologies, Inc.** My e-mail communication with Jim Whalen, VP of Sales and Marketing for PTI, resulted in the conclusion that PTI's RLD-500 system is the best option for Strother from PTI **(16)**. The RLD-500 is a motor-driven system to drive a rotary deflector lance controlled by servos **(13)**. Figure 6 depicts the RLD-500. It is lightweight and compact, weighing less than 15 lbs **(14)**, and can quickly be installed or removed from the shot peen booth. Also, the system has a speed sensor directly on the RLD output to help ensure the work piece is being peened at the correct intensity **(13)**. Also, PTI offers a wide variety of deflector lances that can be replaced separately from the rest of the system to help reduce replacement cost **(13)**. Finally, PTI provides a full line of "Almen tooling alternatives from shaded strips…to externally mounted full Almen strip fixtures" for performing modified Almen tests **(13:3)**.

Figure 6—Photograph of RLD-500 system **(14)**

- **Abrasive Blast Systems, Inc.** Abrasive Blast Systems (ABS) "has made hundreds of custom designed machines…[and] manufactures and supports these machines." **(6:1)**. In fact, the shot peen and plastic media blast cabinets in use at Strother were custom built and installed by ABS. I spoke to Steve Whalen, Sales and Service Contracting Administrator, about ABS's options. ABS will custom-design a lance peen system that perfectly matches the existing booth, and makes use of the current orientation equipment in the booth. The custom system can incorporate any single or combination of lance peen methods that Strother chooses. Replacement equipment is also readily available from ABS. ABS provided me with drawings and specifications for a pre-designed Rotary Lance

Drive system that probably meets Strother's needs **(17)**. However, ABS requested that I not include the drawings for proprietary reasons. The information is available to Strother upon request.

Purchase and Installation Cost

The cost of purchasing the supplemental lance peen equipment, having it installed, and having technicians perform any necessary training is one of the most important factors in choosing one option over another. Cost estimates are as follows:

- **Progressive Technologies, Inc.** PTI declined to provide me with any price estimations because I am not a customer.

- **Abrasive Blast Systems, Inc.** Steve Whalen explained that ABS cannot provide a cost estimate at this time because they need more information on the machine's scope of use. If provided with the size and geometry of parts, as well as the type of peening to be performed on them, ABS can provide an estimate for the design and retrofit of a custom system for Strother **(17)**.

Location

A final difference between the two companies to deliberate is their location. Location is important when considering how much time it will take for a technician to arrive to install this system, perform training, or make a repair, as well as how much it will cost to bring the technician to Strother.

- **Progressive Technologies, Inc.** is located in Grand Rapids, Michigan **(13)**.

- **Abrasive Blast Systems, Inc.** is located in Abilene, Kansas **(6)**.

Summary of Equipment Manufacturer Comparison

While both companies offer acceptable alternatives, Abrasive Blast Systems emerged as the more practical equipment provider. Progressive Technology's RLD-500 system is likely cheaper than any option from ABS, but the information I gathered on it is vague as to the coupling method to connect it to the existing shot peen machine. ABS has an option very similar to the RLD-500, and can guarantee that it will match up with the existing system perfectly. Additionally, ABS's close proximity to Strother makes it much more practical for delivery, installation, and service of purchased equipment.

Operator Training

According to the Code of Federal Regulations Title 14, Section 43.3, only authorized personnel may "rebuild or alter any…aircraft engine" **(12)**. Additionally, Title 14, Part 145 requires all repair stations to maintain FAA-approved training programs **(7)**. All Strother employees undergo extensive training that includes continuing education after initial training is complete.

An important aspect of implementing any new repair is proper training for employees to ensure that federal and internal quality and safety standards are met. FAA-approved training can include classroom, on-line, and on-the-job training **(7)**. Below, I outline necessary on-the-job training for operators before performing lance peen operations.

Interior Peening Almen Test

In his test strip holder patent, Erwin Baiker explains that "the intensity of shot peening must be carefully controlled, because peening at intensities both above and below a critical range will not harden the component properly" **(1:3)**. Fortunately for Strother, the GE engine manuals specify the intensity that each component must be peened to after repair to achieve appropriate surface effects. However, when these peening intensities are established using the Almen test, the assumption is made that the resulting bow in the test strip is due only to direct hits from the nozzle and not from ricochet. Interior peening intensity curves are developed by performing the traditional Almen test as well as a similar test with a portion of the test strips masked to simulate the diameter of the hole. The results of these tests are then mathematically related **(2)**. The results are commonly tested by peening test strips inside a special hole simulation fixture. Detailed instructions for performing the mathematical relations are included in Appendices A and C. Operators need to be instructed how to mask the test strips to perform the second set of tests for correlation. Otherwise, the saturation curve development process will remain unchanged for the operators.

Change Machine Between Shot and Lance Peen

All product literature suggests that the small attachments necessary for performing lance peen can be installed or removed from shot peen systems in a matter of minutes **(11)**. Technicians from the equipment provider need to conduct training on installing and removing the devices when the system is delivered and initially installed. This training should be completed within half a shift.

Safety Considerations

I have not found any safety requirements unique to lance peen that are not already covered by shot peen training.

<u>Governing Regulations/Restrictions</u>

To protect citizens' lives, the Federal Aviation Administration, U.S. Department of Transportation, and General Electric all set forth governing regulations to ensure that shops are held to the highest quality and safety standards.

Government Agencies

Extensive research has shown that the only applicable government regulations are that Strother is a certified repair shop (FAA audits already routinely check this), and that we have an FAA-approved training program. Both requirements are already fulfilled by current practices, and implementing lance peen will not require any changes.

GE Engine Manuals

GE manuals specify the shot type and intensity for each part that undergoes a shot or lance peen repair. So long as the modified Almen test is performed correctly, the regulations for lance peen are the same as for the current shot peen procedure.

Review of Research Objectives

When I proposed this research project in October, I planned three objectives to ensure that I found all the necessary information to make an informed recommendation to Strother. I completed all of my objectives and addressed them throughout this report. My objectives are recapped below:

1) Evaluate academic and industrial publications outlining the available technologies

2) Request cost estimates from equipment manufacturers for purchase and installation of new technologies

3) Review operator training and any special safety requirements in equipment manufacturers' product literature

Conclusions

This report comprises the culmination of four months of research into available lance peen technologies. The report examines the physical process of shot and lance peening, exhaustively compares the available lance peen technologies, presents two company's offerings, and investigates operator training and government regulations. The conclusions I have drawn from this research are as follows:

1) Lance peen is a simple addition to an existing shot peen operation.

2) The varying lance peen technologies mean it can be customized to fit Strother's needs exactly.

3) Minimal operator training makes lance peen a cheap investment that will begin to return productivity and profit gains immediately.

4) Strother will not need to address any new government, company, or customer regulations to use lance peen and therefore can begin using it immediately.

Recommendations

I strongly recommend that Strother purchase and install lance peen technologies as quickly as possible. The low investment cost and high return of number of repairs performed in-house make it an invaluable process. Strother should purchase Almen test masking and fixturing equipment from Progressive Technologies, Inc. (see Appendix B for additional details). We should consult Abrasive Blast Systems and begin customizing the automatic peening booth to perform Deflector Lance Peening on LPT, HPT, and Fan Shafts. The shaft repairs are the most pressing concern at present. After these repairs have been instituted, we should continue communicating with ABS to design a Rotary Lance Peen system to peen any holes that are not accessible by DLP. Upon completion, these additions to the shot peen department will give Strother a much broader capability range, ability to perform a large number of vendored repairs in-house, and perhaps even the chance to act as a vendor shop for other companies.

Steps to Implement Lance Peen at Strother

A basic plan to purchase and implement Lance Peen is as follows:

1) Contact Abrasive Blast Systems, Inc. to design a Deflector Lance Peen System

2) Contact Progressive Technologies, Inc. to supply Almen test masks, hole simulators, and fixtures. Request consultation services for developing a procedure for curve correlation.

3) Request that ABS technicians perform initial installation of DLP system and train operators to install and remove equipment.

4) Update MI introduction section to include instructions for equipment installation and modified Almen Test. Add MI pages for each new lance peen repair. Update all routers to reflect an in-house repair with an MI page rather than a vendor repair.

5) Repeat steps 1-4 for an RLP system.

APPENDIX A: ALMEN TEST CORRELATION INSTRUCTIONS

Material Selected from: *Shot Peening Small Holes* by Bill Barker (Reference #2)

Subject ... Page

Intensity Verification for Small Holes ... 17

Procedure for Correlating Almen Strip Readings for Small Holes ... 17

Masking Shaded Strips ... 18

Full to Shaded Strip Correlation ... 18

SAE AMS-2432B specifications ... 20

Example Correlation ... 20

Intensity Verification For Small Holes

Once you have determined the best method to peen a hole or slot, the next step is setting up and verifying your process parameters. **Figure 22** below shows a good example of a small hole peening application where use of a full strip is not feasible.

Figure 22 – Peening a turbine shaft oil hole (0.140" diameter)

In this example, the hole to be shot peened is about 0.140" (3.7 mm) in diameter. The peening requirement is to shot peen the hole ID to an intensity of 0.011"- 0.013" N. In this case we chose to use a small rotary lance with an outer diameter of 0.087" (2.2 mm) and used AWC14 cut wire shot.

Before we could establish the process parameters needed to peen the hole with the lance, we first needed to develop correlation data between full Almen strip readings and Almen strips that were only peened for 0.140" of width corresponding to the hole diameter. To do this, we performed the following:

Procedure for Correlating Almen Strip Readings for Small Holes

1. Set up a standard Almen block with the appropriate size Almen strip mounted. Using a standard direct pressure nozzle mounted to an automatic manipulator, develop a saturation curve for the lower end of the specified intensity range. We will use the lower range for the turbine shaft oil hole of 0.011" N (11 N) for this example.

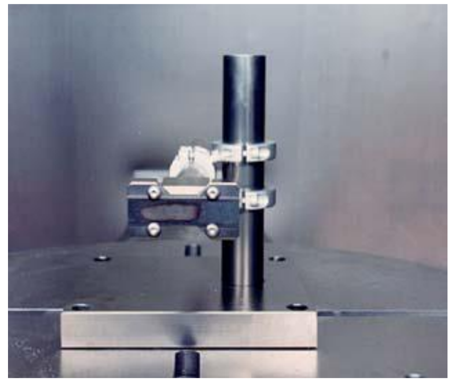

Figure 23 – Mount N strip to Almen Block

Using *PROGRESSIVE's* new computerized saturation curve solver we entered our arc height data and produced a calculated intensity T1. Normally multiple sets of data are used to get more repeatable results. We next verify our calculated intensity by using the corresponding T1 feedrate and peening an Almen strip.

When the calculated intensity is confirmed by your actual arc height reading at the T1 feedrate, proceed to step 2.

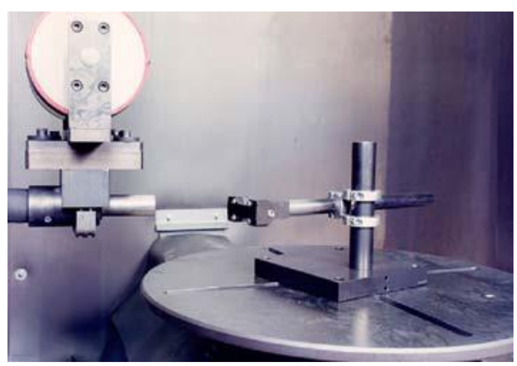

Figure 24 – Shoot full N strips with standard nozzle.

2. Now mask off an N strip so that only the center of the strip is exposed, with the exposed surface width equal to the ID of the hole to be peened. See **Figures 25 & 26**. Masking can be accomplished with vinyl masking tape or with fixed masks. Precision hole masks from *PROGRESSIVE* are shown.

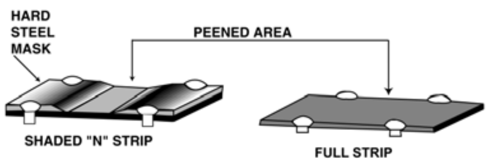

Figure 25 – Masking of portions of the Almen strip creates a shaded strip. The exposed surface represents the diameter of the hole to be peened.

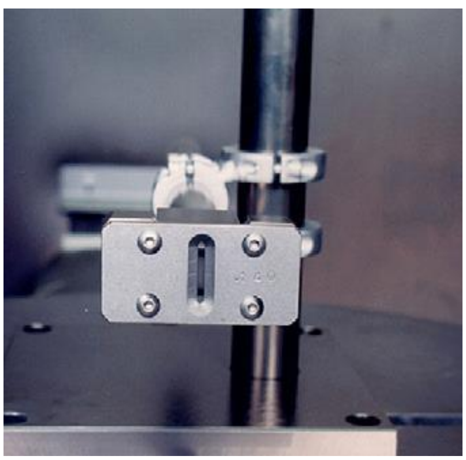

Figure 26 – Almen Block with hardened steel mask. Opening simulates the hole diameter.

3. Using the masked off Almen strip fixture, peen using the 11N intensity parameters determined in step 1. Measure the shaded Almen strip arc height. Your "shaded strip" arc height reading for the 11N-T1 parameters is your corrected N strip reading for the lower range of your specification.

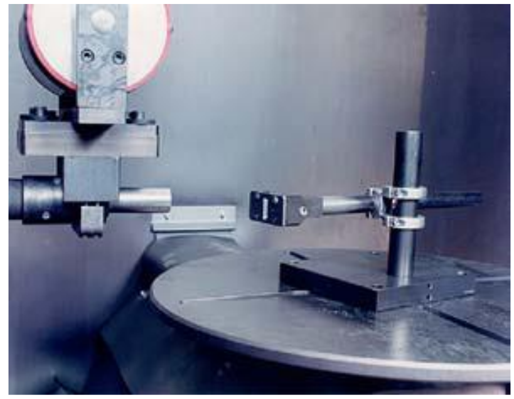

Figure 27 – Peen masked strip with 11N process parameters developed earlier.

This reading will be less than 11N since only a small portion of the test strip was peened and therefore the strip will have less deflection. Record this corrected N strip or "shaded strip" reading. This will be your target reading for the lower end of the specified range when peening with your rotary lance.

4. Now perform steps 1 & 2 again for the upper endof the specified range 0.013" N (13N).

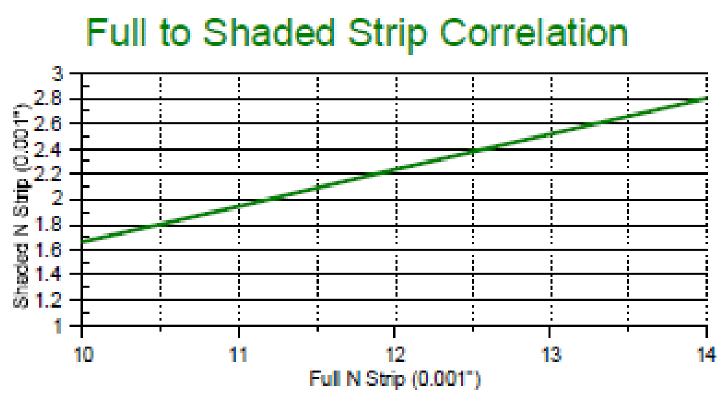

Figure 28 – Chart showing correlation between full N Strip readings for shaded N strips.

5. When complete you should be able to generate a chart like **Figure 28** showing a plot of full strip arc height versus shaded strip correlated values. This chart tells us that to peen the hole to 11-13N intensity, we

need to have a shaded strip reading of between roughly 2.0 N to 2.5N.

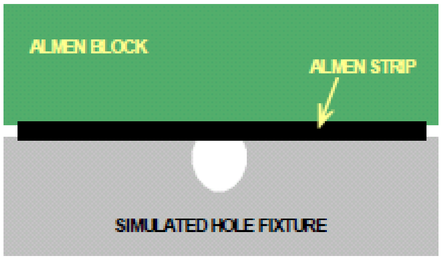

Figure 29 – Simulated hole fixture used for validating intensity for small holes.

6. Once you have determined the correlated intensities for the lower and upper range of the specification, you then must develop the process parameters to duplicate these readings using a rotary lance and simulated hole fixture. The simulated hole or slot fixture (**Figure 29**) should resemble your actual part configuration and take into account ricochet that may occur during peening.

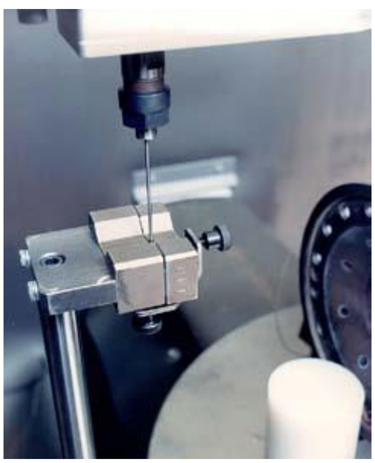

Figure 30 – *PROGRESSIVE's* small hole Almen tooling. A range of hole sizes are available.

7. Select an appropriate sized lance for your hole. In this case we selected a 0.087" diameter lance for a 0.140" diameter hole.

Mount an N strip in the Almen block and attach the hole simulation block to the fixture so that only the hole diameter will be exposed to the shot stream by the lance (**Figure 30**).

Figure 31 – Mask plate for 0.14" hole, simulated hole fixture, peened strip and small rotary lance.

8. Using the rotary lance and automated machinery, develop and record process parameters that will produce an arc height centered between the lower and upper correlated arc heights for the specified range found in step 5. Again, make sure that you have adequate coverage when visually inspected with 10x magnification.

Please note the procedure outlined above is just one of a number of methods used to determine intensity for surfaces which cannot easily accommodate a full Almen strip. Other methods include peening a full strip with a lance which effectively paints the entire strip surface over a number of passes, and also using miniature strips.

It should also be noted that the author could not find any specification which clearly defines how areas smaller than a standard Almen strip width shall be checked for intensity. Given this fact, it is *PROGRESSIVE's* recommendation that the SAE Aerospace Materials Engineering

Committee clarify this issue with a written specification or addendum to an existing specification defining how small areas should be checked for intensity.

Anyone familiar with shot peening also knows that you can get all sorts of Almen gage readings on brand new un-peened Almen strips. When setting up a new peening process it is sometimes helpful to use a correction technique to account for the pre-bow condition of new strips.

If shot peening in accordance with SAE AMS-2432B for computer monitored shot peening, you may find it advantages to compensate for the initial pre-bow or out-of-flatness condition of your Almen strips (reference SAE AMS-2432B, para 3.2.4).

This AMS specification requires Almen strips to have a flatness tolerance of ± 0.0005" (± 0.013 mm). Although this specification does not outline a particular method for compensating Almen strips, a generally accepted method for performing this technique is as follows:

1. Measure both sides of an Almen strip to ensure within ± 0.0005" (± 0.013 mm) flatness. Don't use if either side exceeds this specification. If either side of a strip measures 0.0000", write a "0" on the side measured and make sure that this side is mounted face down in the Almen block. Otherwise, find the side of the strip with the lowest absolute reading, and write down the reading on that side of the strip.

For example, if my strip has one side reading +0.0002" and the other side reading -0.0001", use the -0.0001" side and write down "-1" on that side of the strip with an ink marker pen. The number is always assumed to be in 1/10,000ths.

2. Mount the Almen strip in your Almen block with the measured side down, away from the peening source. After peening the Almen strip, measure your arc height and then subtract the value found on the back of the strip from the gage reading to find your corrected Almen strip reading.

Example: Let's use our pre-bow reading from above of "-1" and say that after peening we get an
Almen strip reading of 0.0114". We then look on the back of the strip and find that we originally had a correction of "-1" representing an initial reading of -0.0001". Subtracting our pre-bow reading from our current gage reading gives us a corrected Almen strip reading of:

0.0114"
-(- 0.0001")
0.0115"

A modification of this procedure is to only use Almen strips with initial pre-bow readings that are positive, so that the convex side of the Almen strip is peened. Then the pre-bow reading is subtracted from the peened Almen strip measurement.

APPENDIX B: PTI RLD-500 BROCHURE

Material Selected from: *Rotary Lance Peen: RLD-500* (Reference #13)

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PROGRESSIVE TECHNOLOGIES

ROTARY LANCE PEENING

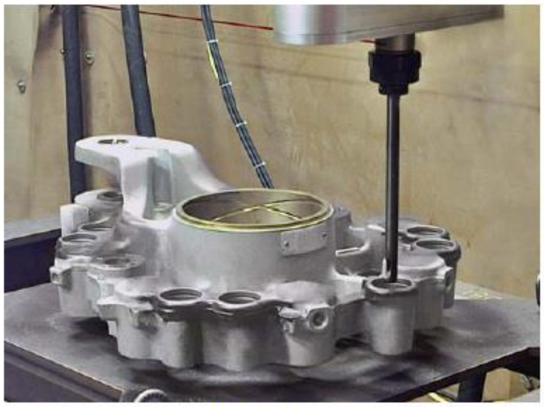
Model RLD500

Progressive Quality and
Rugged Design for your
Demanding Application Needs

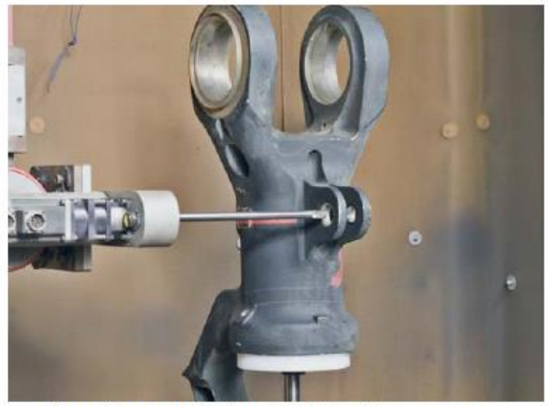
From helical dovetail slot peening to peening of small diameter oil drain holes, *PROGRESSIVE* understands the needs of rotary lance peening.

APPLICATIONS

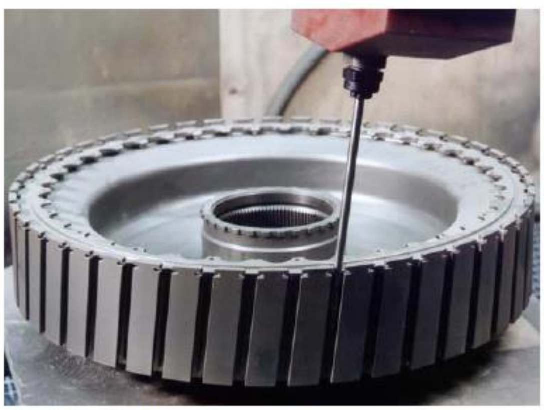
The *PROGRESSIVE* rotary lance drive (RLD) has been coupled with 5 or 6 axis robots or even single axis manipulators. This allows peening of a wide variety of components, from aircraft engine fan disk dovetail slots, to structural airframe components, to small bolt holes in aircraft wheels. Rotary lance peening is the only reliable direct method for peening these non-line-of-site features.



Deep Holes In Aircraft Braking Components

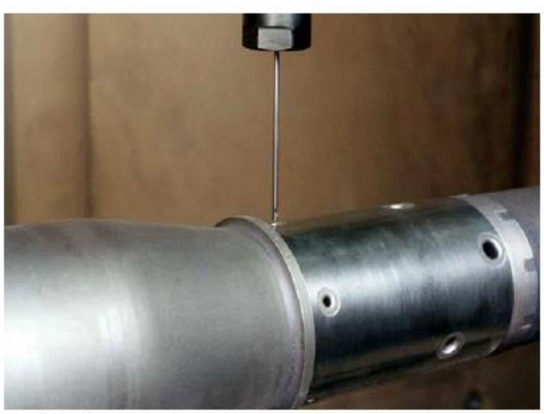


Lugs Bores In Helicoptor Rotor Components

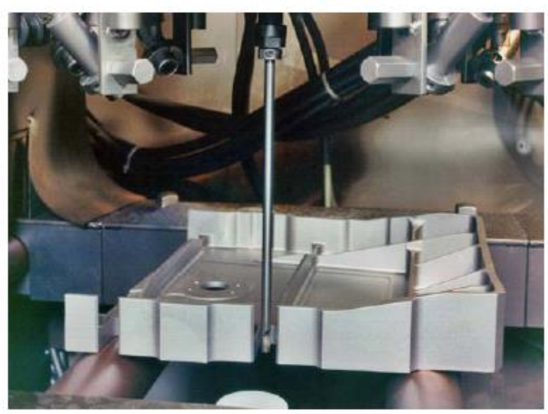


Dovetail Slots In Aircraft Engine Fan Rotors

Flow Path Surfaces of Bladed Rotors



Oil Drain Holes (.125" dia) In Aircraft Engine Shafts



Deep Slots and Features In Airframe Components

FEATURES

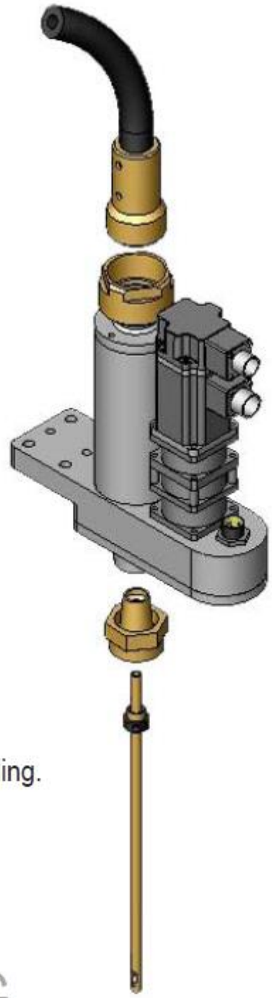
High rotational speed capability 15 to 150 rpm.

Process control shut downs.

Light weight/compact.

Straight through flow path for media.

Long life, high speed air slip coupling.



Accurate, repeatable, quick change attachment point.

Servo motor driven.

Speed sensor directly on RLD output.

Stand alone control module or integral installation capability.

ALMEN TOOLING

PROGRESSIVE also offers a wide variety of Almen tooling alternatives from shaded strips representing various diameter holes to externally mounted full Almen strip fixtures.

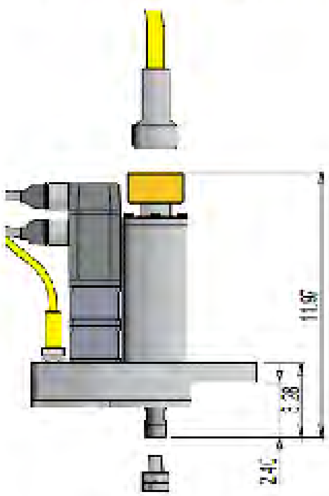


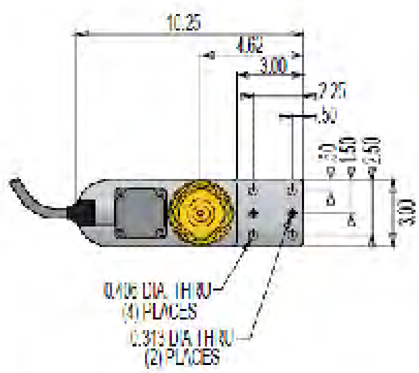
NOZZLE TECHNOLOGY

An integral part of rotary lance peening is the nozzle. *PROGRESSIVE* has developed the best lances found with the following advantages

- 100% tungsten carbide construction for superior life.
- Optimized deflector tip to minimize energy loss.
- Precision collet holds nozzle for optimum concentricity.
- Separate lance and collet design for lower replacement costs.
- Size Range from 0.100" (2.5mm) to 0.625" (16mm)

SPECIFICATIONS





Remote Control Panel

- Variable speed range 15 to 150 RPM
- Overall weight of RLD 15 lb (6.8 kg)
- Rotational speed sensor directly on lance output shaft.
- Available remote control panel (120 vac).
- Rotary lance kit also includes, carrying case, hand tools, cables, and one lance/collet set

www.ptihome.com

PROGRESSIVE TECHNOLOGIES

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APPENDIX C: METHOD OF MEASURING INTENSITY OF PEENING IN SMALL DIAMETER HOLES

Material Selected from: *U.S. Patent No. 3,695,091* by Glean D. Smith (Reference #15)

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Abstract 27

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Example 28

[54] **METHOD OF AND APPARATUS FOR MEASURING INTENSITY OF PEENING IN SMALL DIAMETER HOLES**

[72] Inventor: **Glean D. Smith**, Enfield, Conn.
[73] Assignee: Metal Improvement Company, Inc.
[22] Filed: **Sept. 28,1970**
[21] Appl. No.: **76,063**

[52] **US. Cl.** ....**73/11**, 73/88 R
[51] **Int. Cl.** **G01n 3/34**
[58] **Field of Search** 73/11, 12, 104, 88; 72/53

[56] **References Cited**
UNITED STATES PATENTS
2,607,213 8/1952 Barton 73/12
2,350,440 6/1944 Almen....................................... 73/12

Primary Examiner--Charles A. Ruehl
Attorney--Arthur Frederick and Victor D. Behn

[57] **ABSTRACT**

The method of measuring intensity of peening in the Almen scale of small diameter holes, such as 0.5 inch or less, consists of a first step of plotting an intensity curve on a reference graph, which intensity curve is proportional to but a fraction of the Almen scale. The intensity curve is plotted by peening, under a predetermined intensity, a number of Almen strips which have been masked to expose only portions of each of the strips so that each strip has an exposed portion differing in width from the others in equal increments of linear measurement and, then, measuring the curvature of each peered strip. Thereafter, peening a portion of an Almen strip which overlies at least one arcuate groove which has chordal dimension equal to the smallest unit width employed to produce the reference graph. After peening the Almen strip in which the same peering apparatus and technique used to peen the holes of the production pieces is utilized, the curvature of the strip is measured. The measurement is plotted on the reference graph to obtain an Almen scale measurement of the peering intensity. If the measurement is for a hole size outside of the intensity curve, the measurement is then extrapolated by using the reference graph to achieve an Almen scale measurement. This Almen value then can be compared with the Almen scale peening intensity called for to insure that the peening meets that requirement and continues to meet the Almen intensity during production peening.

METHOD OF AND APPARATUS FOR MEASURING INTENSITY OF PEENING IN SMALL DIAMETER HOLES

DISCLOSURE OF THE INVENTION

The invention relates to shot peening, and more particularly, to the method of and apparatus for measuring intensity of peening in the Almen scale of small, diameter holes and, hence, the monitoring of the peening equipment and its operation to insure peening of pieces to the proper degree.

BACKGROUND OF THE INVENTION

It is well known that white shot peening of a metal surface increases the fatigue strength of a treated part, subjecting the treated surface to that peening beyond "saturation" in other words overpeening, does not improve the treated surface. Accordingly, it is desirable to predetermine the peening technique required for a particular part so that the part can be exposed to proper velocity and size shot for a sufficient length of time to reach but not exceed the point of "saturation." This problem is not capable of a simple solution since intensity of shot peening depends on many variable factors, such as size of shot, material of the shot and the metal surface to be treated, striking velocity of shot which, in part at least, is dependent upon the angular velocity of the throwing wheel or velocity of the entraining air stream, as well as the length of exposure of the peened surface to the "rain" of shot. At present, no quantitive rules have been devised for assigning optimum peening effects.

One useful device for measuring peening intensity is the Almen strip test which, as more fully disclosed is an article by *H. F. Moore* entitled "*Shot Peering and the Fatigue of Metals"* published by American Foundry Equipment Co., consists of the use of a thin flat strip 3 inches long and three quarters of an inch wide and of a hard steel (as for example Rockwell C hardness of 44-50) which is subjected to shot peening for a specified time with the same combination of size of shot, material of the shot, and striking velocity of shot as is to be used in the peening of a structural or machine part. After exposure to the shot, the curvature of the strip is measured and this curvature resulting from the impaction of peening shot constitutes a measure of the intensity of the stresses set up by the peening in the surface of the strip and, hence, is a measure of peening intensity. The Almen test provides a means of measuring the results of a peening operation and, therefore, after several such tests and the recording of exposure times, serves as a basin for establishing the treatment time for a particular part.

While the above Almen test procedure has proven satisfactory for external surfaces of metal pieces to be peened, it is not useful for measuring peening intensity and monitoring the peening operations of the internal surface of small diameter holes, as for example, holes of about 0.5, or smaller.

Accordingly it is an object of this invention to provide a method and apparatus for measuring intensity of peening in the surface of small diameter holes in terms of the Almen scale.

The method of measuring intensity of peening in the Almen scale of small diameter holes of about 0.5 inches, or less, in diameter comprises the steps of first charter tire arc height (h) for various small widths using the conventional Almen test and equipment and shielding or masking each test strip of the A, C or N type, depending upon the intensity of peening desired, to expose each strip with an area of different width, each exposed width changing in size in equal increments, such as 0.10, 0.20, 0.30 inches, et cetera. Each strip is that shot peened at the exposed surfaces at a previously determined peening intensity, such as 3A or 5A Almen. The deformation of each strip is then measured and plotted on a reference graph having width increments *l* in tenths of an inch and arc heights *h* thousandths of an inch. Since the arc heights, as herein measured, are not the result of peening the entire strip, the arc heights are not representative of peening intensities as measured by the Almen scale. It, however, provides an intensity curve which is proportionate to an intensity curve as established by the Almen tests. A modified Almen holding block, according to the invention, is provided with at least one, but preferably a plurality of close, spaced, arcuate grooves each of which is of a chordal dimension corresponding to the smallest diametric increment, as in the example of 0.1 inch. A test strip of the type corresponding to the kind used to produce the reference graph (hereinafter referred to as a "modified strip") is secured over the grooves and, using the same peening apparatus and peening shot which is to be used to peen the holes in the production pieces, peen one or more of the surfaces of the modified strip overlying the grooves. The peening apparatus may be a miniaturized version of the type exemplified in the U.S. Pat. to Burney, No. 3,485,073. The deformation of curvature of the modified strip resulting from the peening is then measured. Since the resultant arc height is not the result of peening the entire modified strip, but only results from the peening of a portion of the strip length, the arc height is not a measure of peening intensity as identified by the Almen scale. It, therefore, is necessary to correlate this arc height to the Almen peening intensity scale. This is done by plotting the arc height on the reference graph for the hole size being peened and, if the point does not fall on the curve of the peening intensity desired, such as 3A or 5A Almen, adjustment of the peening apparatus and/or its operation must be made. In other words, if the arc height plotted point falls below the desired intensity curve increased peening is requited and, conversely, if the point falls above the curve, decreased peening is necessary. If the desired peening intensity in the Almen scale is desired for which no curve has been plotted, as for example, below 0.10 inch Almen intensity is determined, from the measured arc height, by extrapolation from the intensity curves on the reference graph by extending or projecting the graph intensity curves toward zero so that desired arc height it the Almen scale is determined. For example, if *l* is established by peening the surfaces of the modified strip overlying the three grooves of 0.10 inches in diameter, *l* then is 0.3. If, after peening the curvature *h* of the modified strip measures 0.006 inches, which measurement does not represent intensity of peening as measured by the standard Almen scale because the curvature was produced by peening only 0.3 of the total 3 inch length of the strip. However, to correlate this arc height, the intensity curve which is selected as the desired intensity to be employed in the peening operation, as for example a 5A Almen curve, is extended to intersect the abscissa line computed from the following formula:

$$l/k = h/x$$

in which

- *l* is the peened length of the modified strip.
- *h* is the arc height
- k is the constant 3 inch standard length of Almen strip.
- x is the unknown abscissa line.

In substituting the aforementioned values in the formula, x equals 0.06 as follows:

$$0.3/3 = 0.006/x$$
$$0.3x = 0.018$$
$$x = 0.06$$

By examining the reference graph, it can be seen that the intersection of the abscissa 0.06 and the extension of intensity curve (see dotted line) is close to the ordinate 0.004 or 4 on the Almen scale (see x on graph). Thus, if holes are to be peened to an Almen intensity of 4, the foregoing method and apparatus for measuring the intensity provides the means for monitoring such treatment by peening a modified strip according to this invention and measuring its arc height *h* and if, as in the example, the height measures 0.006 the peening apparatus is operating to produce, as required, an Almen intensity of 4.

In the alternative, a cross plot for *l* of 0.30 of an inch constant can be constructed on a graph where the coordinates are arc height in thousandths of an inch and Almen intensities. This *l* curve extends from the zero-zero point through the intersections of the intensity curves, as for example 3A and 5A, and the abscissa line .3 of the reference graph. In the abovementioned example where the measured arc height is 0.006 inch, the Almen equivalent from the cross plot would be 4 Almen.

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Unit 14: Appendix B: Student Literature Review Formal Report

INDUSTRY BEST PRACTICES OF CONDENSATE REMOVAL SYSTEMS: A LITERATURE REVIEW

Submitted To:

Rick Kinder
Plant Manager
Chevron Phillips Chemical Company | Orange Plant

Submitted By:

Ben Williams
Process Engineer
December 4, 2014

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4 December 2014

Mr. Rick Kinder, Plant Manager
Chevron Phillips Chemical Co. | Orange Plant
5309 Farm to Market Road
Orange, TX 77630

Mr. Kinder,

I am pleased to submit my completed formal report, "Industry Best Practices of Condensate Removal Systems: A Literature Review," that was approved by Lead Process Engineer Jason Sallies on October 21, 2014. This report outlines the results of my research and describes the different applications for condensate removal and their respective industry best practices.

This report is designed as the first step to the standardization of condensate removal systems at Chevron Phillips. The report is divided into five parts: the characteristics of steam and condensate removal systems (p.4), condensate removal applications and the industry best practice (p.6), maintenance requirements (p.14), cost analysis (p.15), and an overview of governing regulations (p.16). The research shows that standardizing these processes will simplify future repairs and increase profitability of the plant.

My report provides CPChem with the necessary information to standardize the condensate removal systems at the Orange Plant. The next step in the process is to perform a plant-wide condensate removal survey to determine which systems meet the standards. Failed traps and pumps can now be replaced with the ideal solution for each application. Additionally, CPChem can begin gathering additional information to establish a strict inspection regiment and effective training program. Informed and motivated employees will maintain the discipline required by the inspection and training programs to improve condensate removal systems to their highest potential.

I appreciate the opportunity to investigate condensate removal systems and ensure future plant profitability. I would like to thank Mr. Jason Sallies for supporting this research to completion.

Please contact me with any additional questions or comments regarding the information in this report.

Sincerely,

Ben D. Williams

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DRF Trusted Property Solutions. (2014). *Steam Traps*. Retrieved from DRF Trusted Property Solutions: http://www.drftps.com/steam-traps.

EXECUTIVE SUMMARY

Chevron Phillips Chemical Company (CPChem) has established itself as a premier manufacturer in the petrochemicals industry. We are now among "the world's top producers of olefins and polyolefins and a leading supplier of aromatics, alpha olefins, styrenics, specialty chemicals, piping, and proprietary plastics **(Chevron Phillips Chemical Co., 2014)**." Two of CPChem's primary objectives are the safety of its employees and communities as well as reducing its energy usage in all plants. We pride ourselves on sending every employee home safely every day. Additionally, energy reduction is necessary to increase profit, but, more importantly, to reduce the company's carbon footprint. One of the greatest opportunities to improve the safety and reduce energy loss at the Orange Plant is through the steam condensate removal systems. Failure to repair and standardize these systems will cause a loss of energy through flash steam, damage to piping, and danger to employees, compromising the operational excellence standard for which CPChem has always been renowned.

On October 14, 2014, I submitted a proposal to research the best practices for standardizing steam condensate removal processes to Jason Sallies, Lead Process Engineer. The goal of this project is to provide information that will simplify future repairs and training for employees. The project was approved by Mr. Sallies one week later on October 21. Specifically, I was to complete the four tasks to provide CPChem with an analysis of solutions to fit the specific condensate removal needs at the Orange Plant. The following tasks are completed and information gathered from each is included in this report:

1) Consult with experts on the subject who can provide non-biased recommendations for each technology.

2) Request additional information from CPChem regarding the current state of the condensate removal systems.

3) Investigate many avenues to purchase each technology to reduce cost.

4) Review any possible environmental or safety regulations from government agencies such as OSHA and EPA.

Current condensate removal systems at the Orange Plant vary widely for similar applications. This report will demonstrate the return on investment gained by simply standardizing all applications to the industry best practice. According to Einstein, Worrell, and Khrushch, performing regular maintenance of steam trap systems has a payback period of around half a year while condensate return systems such as pressure-powered pumps can pay for themselves in just over one year while lasting for 20-30 years **(2001)**. With such a short payback period, condensate removal systems can save CPChem's Orange plant thousands of dollars per year if selected, installed and maintained correctly. As long as the plant maintains its inspection regiment and continuous training, these updated systems will significantly increase the profitability of the plant.

Conclusions

This report analyzes data presented by experts in the field of condensate removal to provide a general overview of the applications at CPChem's Orange Plant that can be improved with the standardization of their devices. This report examines each application and the industry best practice for each. It provides advantages, disadvantages, maintenance, and installation information for each solution. It concludes with the return that CPChem can gain from an investment in these solutions. The conclusions I have drawn from this research are as follows:

1. Float and thermostatic steam traps are the industry best practice for process equipment such as heat exchangers.

2. Thermodynamic steam traps are the industry best practice for steam mains and supply lines.

3. Inverted bucket steam traps are the industry best practice for intense process conditions such as high pressure, high load, and loads containing a large amount of dirt and scale.

4. Pressure-powered pumps powered by motive steam are the industry best practice for recovering condensate to a pressurized header.

5. Regular maintenance and correct installation of steam traps can have a payback period of 2-6 months. Pressure-powered pumps can have a payback period of around one year.

6. Pressure vessel regulations are the only governing regulations concerning condensate removal devices. No environmental regulations exist for steam.

7. Standardization of condensate removal systems to the industry best practices will reduce energy losses, provide a safer plant, provide a more efficient process operation, and simplify training and future selection of new condensate removal devices.

INTRODUCTION TO DISCUSSION

Chevron Phillips Chemical Company (CPChem) has established itself as a premier manufacturer in the petrochemicals industry. We are now among "the world's top producers of olefins and polyolefins and a leading supplier of aromatics, alpha olefins, styrenics, specialty chemicals, piping, and proprietary plastics (Chevron Phillips Chemical Co., 2014)." Two of CPChem's primary objectives are the safety of its employees and communities as well as reducing its energy usage in all plants. We pride ourselves on sending every employee home safely every day. Additionally, energy reduction is necessary to increase profit, but, more importantly, to reduce the company's carbon footprint. One of the greatest opportunities to improve the safety and reduce energy loss at the Orange Plant is through the steam condensate removal systems. Failure to repair and standardize these systems will cause a loss of energy through flash steam, damage to piping, and danger to employees, compromising the operational excellence standard for which CPChem has always been renowned.

One of the greatest issues facing our society is energy conservation and discovering clean, alternative methods for powering our lives. Efficient energy usage is vital in the manufacturing industry, because the company that manufactures a product at the cheapest cost will always be the leader in the industry. Steam is one of the most common energy sources in every industry, especially petrochemicals. Primarily used in shell-and-tube heat exchangers or heat tracing apparatuses, steam is cheap, emission-free, and has outstanding heat transfer properties. However, the production and transportation of steam is not a simple task. Condensation can form throughout these pipelines and cause a wide variety of issues. Nearly all plants in the petrochemical industry utilize condensation removal methods to address these issues.

On October 14, 2014, I submitted a proposal to research the best practices for standardizing steam condensate removal processes to simplify repairs and reduce the amount of consultation required from outside vendors. My method for this investigation included the following four steps: (1) Consult with experts on the subject who can provide non-biased recommendations for each technology; (2) Request additional information from CPChem regarding the current state of the condensate removal systems; (3) Investigate many avenues to purchase each technology to reduce cost; (4) Review any possible environmental or safety regulations from government agencies such as OSHA and EPA. Jason Sallies, Lead Process Engineer, approved the project on October 21, 2014.

This report is the product of my investigations and research. It begins with an introduction to the steam systems at the Orange Plant. Next, it analyzes the specific applications in these steam systems that require condensate removal and provides the correct method for each application. My report will provide analysis on the operation, installation, and maintenance required for each method. I will also include information on the expected return on investment for standardizing condensate removal systems. Concluding the report will be a summary of my findings.

DISCUSSION

Characteristics of Steam and Condensate Removal Systems Systems

In the petrochemical industry, heat transfer plays an enormous role in the majority of processes. Many methods exist to produce heat including electricity, the burning of coal, or the burning of natural gas. However, as the cost of energy rises and EPA regulations become steeper, cheaper and cleaner sources of energy are necessary to help petrochemical companies reach a profit in addition to meeting their quota of greenhouse gas emissions. Steam is a widely-used source of energy in all industries. With a heat capacity of 1 BTU/LB/^oF and a heat of vaporization of 970 BTU/LB, steam has outstanding heat transfer characteristics with a comparable price per BTU to that of natural gas and other petroleum-based compounds.

An Overview of Orange Plant Steam and Condensate Removal Systems

At CPChem's Orange Plant, steam is used in a variety of applications. Steam is transferred into the plant from a nearby boiler at both 425 psig and 225 psig in a 16" carbon steel pipe. It is then routed to a variety of heat exchangers including both extruders. The purpose of these extruders is to melt the polyethylene product and cut melted strands into pellets to be distributed to customers. For this to occur, temperatures much reach a range of 240^o – 275^oF depending on the product. An additional 15,000 LB/HR of steam is required for the ethylene re-heater which reheats incoming ethylene after its pressure is reduced from 1000 psig to 600 psig.

Due to the hundreds of feet of steam piping and dozens of heat exchangers requiring steam as a heating source, many opportunities exist for steam to condense. Because the condensate formed will cause inefficient heat transfer, it must be removed from the system. The Orange Plant has over 400 steam traps installed to do just that. For steam headers and process equipment, current steam traps include inverted bucket, float-and-thermostatic, and thermodynamic traps. Many of these traps release the condensate to grade or to the firewater pond. For large quantities of condensate to be recovered in a pressurized header, CPChem has installed pressure powered pumps powered by 125 psig motive steam.

According to a survey performed by Spirax Sarco, a condensate removal vendor, in May 2014, over 100 steam traps were failed open, failed closed, or failed by rapid-cycling **(Spirax Sarco, 2014).** Flash steam loss to the atmosphere was estimated to be costing the plant over $137,000. Pressure-powered pumps were failing leading to loss of condensate and the rapid-cycle of pressure relief valves. Further analysis by process engineers revealed inconsistencies in multiple aspects of the condensate removal system. Many types of steam traps were installed for the same type of application; Pressure-powered pump systems were designed differently and all were failing.

Obviously, some level of consistency is needed. While no single trap is suitable for all services, it is possible to establish standards for many applications so that just a few trap types are needed **(Garcia, 1986)**. The remainder of this discussion will focus on assigning one trap or one process design to each application of condensate removal and the benefits and drawbacks of doing so.

Benefits of Standardizing Condensate Removal Systems

Aside from the obvious benefit of less research needed from process engineers for every condensate removal failure, standardizing these systems has a variety of benefits for the plant. These benefits are not just economic in nature. Standardization will prevent many safety-related issues associated with the failure of condensate removal systems. Therefore, CPChem can uphold its safety standards that are second-to-none in the petrochemical industry. While many benefits exist, I will outline the following three:

1. Reduce energy losses due to flash steam leaks
2. Provide more efficient process operation
3. Provide a safer plant by reducing the effect of water hammer

Reduce Energy Losses

As previously mentioned, CPChem's Orange Plant loses over $100,000 per year to failed open steam traps. By selecting the correct traps and maintaining these traps, CPChem can drastically reduce money spent on steam. Decreasing the cost of production will increase the overall profitability of the plant.

Provide More Efficient Process Operation

A large temperature gradient is vital for maximum energy transfer. Increased condensate in the steam systems will reduce the temperature of the steam. Therefore, more steam will be required to achieve the same heat transfer, increasing cost. Additionally, recovered condensate can be re-boiled, reducing the overall amount of water required to maintain plant operations.

Provide a Safer Plant

The greatest fear regarding all steam systems is water hammer. This occurs in horizontal pipes with steam flowing turbulently over condensate creating ripples on the surface of the condensate. These ripples can grow to occupy the entire pipe, generating a slug that can be pushed at the same velocity of steam, typically 20-30 feet per second **(Barrera & Kemal, 2010)**. This is illustrated in the drawing in Figure 1. At this velocity, water can destroy piping, injure plant personnel, and shutdown a plant. Maintaining condensate removal systems throughout the plant is vital to preventing this phenomenon **(Swagelok Energy Advisors, Inc., 2009)**.

Drawbacks of Standardizing Condensate Removal Systems

The only drawback that can be derived from standardizing condensate removal systems is the danger of the lack of research performed after a failure in the system. Future process engineers may be tempted to just look at the standards and make recommendations and purchases based solely on the standards. While these standards will simplify the process, future process engineers must always double-check recommendations through further consultation and through their own calculations.

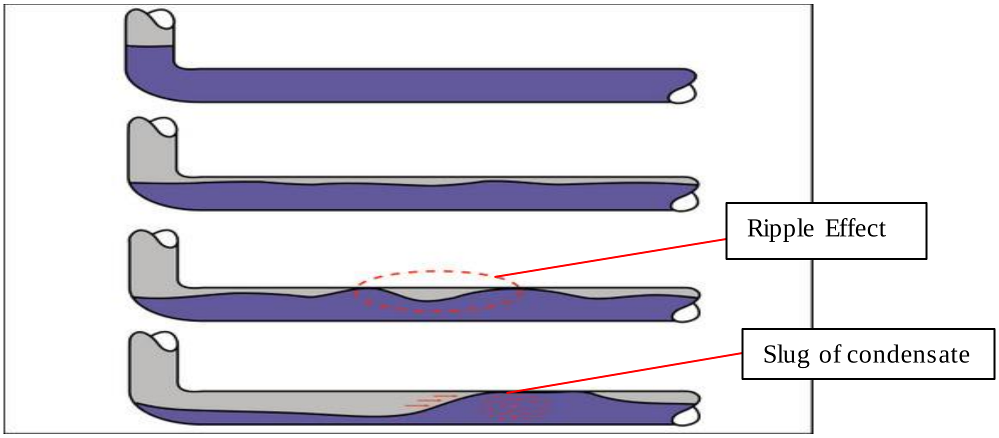

Figure 1: Drawing of Water Hammer Generation in a Horizontal Pipe
(Barrera & Kemal, 2010)

Condensate Removal Applications and the Industry Best Practice

Steam is used throughout all petrochemical plants. Everywhere steam exists, so should condensate removal apparatuses. While dozens of applications could be considered, we will consider the four main applications for condensate removal. Please note that each condensate removal apparatus listed for each application is a general best practice and may vary based on properties such as temperature, pressure, and condensate load. The four applications that will be discussed are as follows:

1. Process Equipment
2. Steam Mains and Supply Lines
3. High Pressure and Superheated Steam Sources
4. Condensate Recovery to a Pressurized Header

Process Equipment

Process equipment includes any equipment involved in the transfer of materials or heat. The primary example of process equipment that involves steam is the shell-and-tube heat exchanger. The substance needing to be cooled travels through the shell side of the heat exchanger while the high pressure steam travels through the tube side.

For these applications in which the rates of heat transfer and condensate production are high, a steam trap that continuously discharges condensate is required. Process equipment steam traps must also be designed to manage the start-up and shut-down of the equipment. Therefore, they must be able to handle a condensate load that varies widely between starting and running conditions in addition to air that can enter the system during start-up **(Chikezie, 2008).** Float and thermostatic steam traps are generally the primary selection for these situations **(Watson McDaniel Company, 2010)**.

How It Works

As described in the schematic in Figure 2, float and thermostatic traps use a float connected to the valve plug to discharge condensate from the system. In addition, these traps contain a thermostatic air vent to allow discharge of air upon start-up of the system (Watson McDaniel Company, 2010). Upon start-up, air and condensate enter the trap. While air is discharged, the rising condensate level lifts the float which opens the valve to allow the discharge of condensate. A level of condensate will shut the valve above the seating orifice to prevent loss of flash steam.

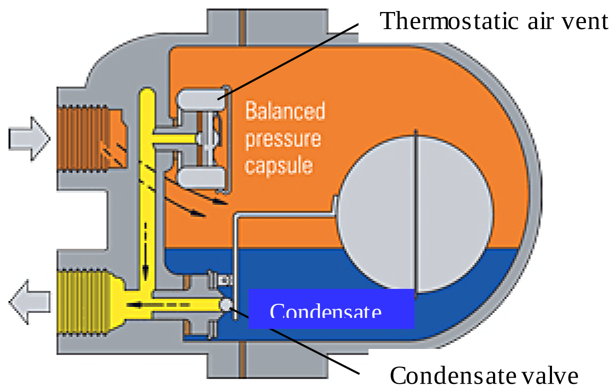

Figure 2: Schematic of Float and Thermostatic Steam Trap Operation (Spirax Sarco, Inc., 2014)

Advantages

A float and thermostatic steam trap used in a process equipment application to remove condensate has the following advantages:

- The trap continuously discharges condensate.
- It is able to handle heavy or light condensate loads equally well.
- The trap is able to discharge air freely.
- It is resistant to water hammer.

This type of steam trap meets all of the requirements of process equipment condensate removal and adds the benefit of being resistant to water hammer **(Spirax Sarco, Inc., 2014)**.

Disadvantages

While the trap meets all of the requirements for this application, no trap is perfect. The float and thermostatic trap can be damaged by severe freezing. Additionally, each trap is only designed for a limited range of pressures; pressures outside of the design can cause the trap to malfunction.

Installation and System Design

Selection and sizing of the steam trap is critical to its operation. Because design conditions vary based on vendor, process engineers must consult each vendor for trap specifications. These specifications must meet the process pressure, temperature, and condensate load. Additionally, safety load factors must also be taken into account. Safety factors of float and thermostatic trap are typically 1.5 to 2.5 times the rated load **(Mower, 1986)**. Finally, the orifice size must match the piping exiting the heat exchanger. A rapid increase or decrease has a significant effect on the fluid flow and can lead to a trap malfunction.

One trap should be installed upstream of the heat exchanger to ensure the best quality steam for heat transfer (Watson McDaniel Company, 2010). After the steam condenses in the heat exchanger, a second trap is needed. This steam trap must be designed to handle the full condensing load with the heat exchanger operating at 0 psig. Ideally, this trap should be installed as far below the heat exchanger as possible. However, the minimum distance should be 15" to provide a 0.5 psig pressure head (Mower, 1986). An isolation valve and strainer should be installed before any steam trap. The isolation valve simplifies maintenance of the trap and the strainer protects the trap from any dirt or debris in the line (Watson McDaniel Company, 2010).

Steam Mains and Supply Lines

Steam mains are the "energy grid" of steam systems in the plant. They transfer high-pressure steam from the boiler to all aspects of the plant, requiring hundreds of feet of piping. Steam mains have only a small percentage of their volume occupied by condensate relative to process equipment as the steam has just been boiled. Based on these characteristics, a small, cheap, and robust steam trap is the ideal choice for a supply line (Spirax Sarco, Inc., 2014). A thermodynamic steam trap is the primary choice for this application.

How It Works

Thermodynamic steam traps provide a very simple solution to remove condensate and prevent the discharge of flash steam. These traps operate via a single moving part, a small disc, and the Bernoulli's principle as seen in the schematic in Figure 3. High-pressure condensate raises the single disc allowing the discharge of the condensate. Steam approaches at high velocity and reduces the pressure below the disc while condensate flashes above the disc creating a high pressure region, lowering the disc to its seat. As the flash steam condenses at a lower pressure and high pressure condensate enters below the disc, the disc is raised, allowing the flow-through of condensate. In a working trap, the cycle is repeated every 20-40 seconds.

Advantages

Thermodynamic steam traps provide the following advantages in steam mains:

- They are cheap, compact, simple, and lightweight.
- Thermodynamic traps can be used on high pressure steam and are not affected by water hammer, freezing, or vibration.
- The disc is the only moving part; therefore, maintenance can be easily performed without removing the trap.
- The audible "click" that occurs as the trap cycles makes testing relatively simple (Spirax Sarco, Inc., 2014).

These traps meet all of the requirements for steam mains and provide a cheap, reliable solution for condensate removal.

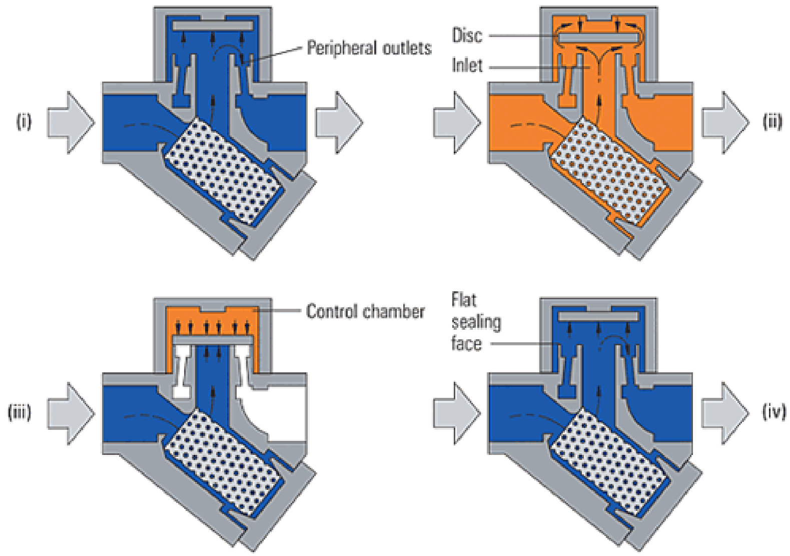

Figure 3: Schematic of Thermodynamic Steam Trap Operation
(Spirax Sarco, Inc., 2014)

Disadvantages

The following disadvantages exist by installing thermodynamic steam traps:

- The traps will not function on low differential pressures.
- Large amounts of air at high velocity can shut the trap just as steam can.
- Incorrectly sizing a thermodynamic trap by a small margin can cause trap failure more rapidly than for other steam traps (Watson McDaniel Company, 2010).

While these disadvantages exist, these traps are relatively cheap and can be replaced easier than larger traps.

Installation and System Design

Sizing plays a significant role in the life of a thermodynamic steam trap. A trap that is too small can fail open and allow condensate and flash steam to be discharged continuously. Sizing a trap too large can induce a rapid-cycle failure and wear the trap quicker than a properly functioning trap. Process conditions such as temperature, pressure, condensate load, and surrounding temperatures must be taken into account when sizing thermodynamic traps. Surrounding temperatures that are too cold can cause the trap to fail. Simply insulating the trap can solve this issue (Spirax Sarco, Inc., 2014).

Care must be taken by engineers and operators installing thermodynamic steam traps. Incorrect installation can lead to failures such as water hammer. Traps must be installed so that the disc is at the top. Additionally, traps must be installed facing the correct direction. According to process engineers, backwards traps have led to multiple failures at the Orange Plant. As with float and thermostatic steam traps, isolation valves and strainers must be installed with each thermodynamic steam trap. However, many thermodynamic traps have a strainer installed standard for convenience.

High Pressure and Superheated Steam Sources

The most rigorous process conditions involving steam include high pressure systems, superheated systems, large loads, and loads containing vast amounts of dirt and scale. For these situations, a rugged, efficient solution is required. Because of their tough design and simplicity, inverted bucket traps are the best choice for high intensity conditions.

How It Works

Inverted bucket traps consist of an inverted bucket connected by lever to the outlet valve in addition to a small air vent. As condensate fills the trap, the bucket hangs down, opening the outlet valve as shown in the first part of the schematic in Figure 4. The arrival of steam creates buoyancy in the bucket that shuts the valve preventing steam loss. The valve remains shut until the steam condenses or exits through the small vent at the top of the trap (Spirax Sarco, Inc., 2014).

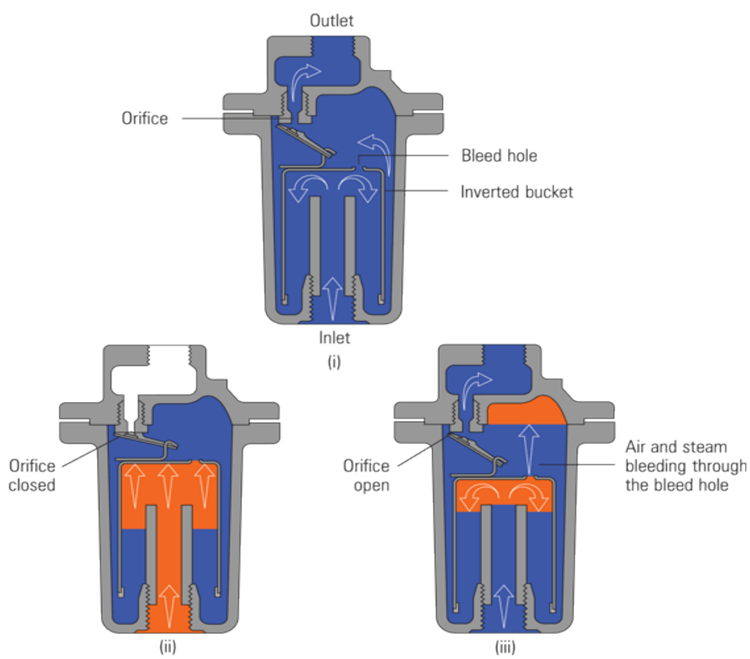

Figure 4: Schematic of Inverted Bucket Steam Trap
(Spirax Sarco, Inc., 2014)

Advantages

Inverted bucket traps contain the following advantages over other steam traps, making this trap an ideal solution for the most intense process conditions:

- This trap can withstand high pressures, superheated conditions, and large condensate loads.
- It has a good tolerance to water hammer conditions.
- Inverted bucket traps are resistant to dirt and scale that are present in the system.

These traps meet many requirements for conditions that many smaller traps cannot handle.

Disadvantages

Inverted bucket traps, however, come with many disadvantages. While they can be utilized in other applications such as steam mains, they should be a secondary choice to the more effective traps. The disadvantages are as follows:

- The air vent is small, allowing a minimal amount of vapor to discharge. While this prevents the loss of a large amount of steam, air cannot exit quickly, making this trap a poor choice for process equipment (Watson McDaniel Company, 2010).
- A sudden drop in pressure can cause condensate to flash to steam. This will sink the bucket and allow live steam to pass through the exit valve.
- Inverted bucket traps are susceptible to freezing. Therefore, these traps are a poor choice for cold conditions.

These traps should only be used in high pressure conditions with large condensate loads. Too many severe disadvantages exist to make the inverted bucket trap a primary choice in many condensate removal applications.

Installation and System Design

As with previous steam traps, all process conditions must be taken into account and process engineers must consult with vendors to ensure the product they purchase matches those conditions. Safety factors must also be accounted for as the possibilities for failure are higher at more intense conditions.

Pressure fluctuation and high temperature of superheated steam can cause the inverted bucket trap to lose its water seal, causing a back-flow of steam and condensate. Installing a check valve immediately upstream of the trap will eliminate this problem as it prevents flow in the opposite direction. Finally, operators must ensure that the trap is installed in the correct orientation as improperly installing an inverted bucket trap can lead to its failure. Similar to previously mentioned steam traps, an isolation valve and strainer must be installed upstream of the inverted bucket trap.

Condensate Recovery to a Pressurized Header

In many cases, steam pressure in the process equipment may not be sufficient to overcome the back pressure in the condensate return line. Traditional steam traps are not adequate for these situations as they either maintain or reduce the pressure of the condensate. Creating a positive pressure differential for the transfer of condensate requires a pump. The two primary choices for this type of pump are an electrically-powered centrifugal pump and steam-powered pumping traps (pressure-powered pumps). However, as I will prove in the following sections, pressure-powered pumps are the ideal solution for these applications.

How It Works

Pressure-powered pumps operate on a similar principle to float and thermostatic steam traps. Figure 5 shows liquid condensate enters through a check valve and raises a float. When this float reaches its maximum level, a valve is opened allowing high pressure (typically 125 psig) steam to provide the motive force for pumping the condensate **(CDB Engineering SPA, 2014).** Once backpressure is overcome, the outlet check valve is opened and condensate is released until the low level of the float closes the steam valve.

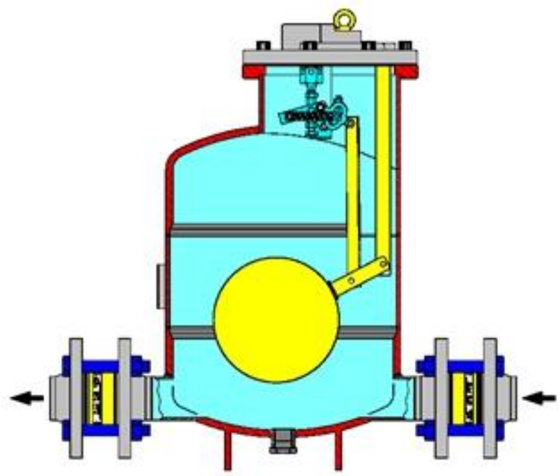

Figure 5: Schematic of Pressure-Powered Pump
(CDB Engineering SPA, 2014)

Advantages

Pressure-powered pumps have the following advantages over alternatives:

- These pumps have no danger of cavitation (See *Industry Alternative* below).
- Pressure-powered pumps are relatively unaffected by broad differences in back pressure (**TLV Euro Engineering, 2011**).
- They are well-suited for explosion-proof areas and remote locations because no electricity is required. Only access to a high pressure steam line is required.

These pumps are the simplest and most effective method for pumping condensate.

Disadvantages

Pressure-powered pumps come with a couple of disadvantages that process engineers should understand. First, the discharge pressure is limited by the motive steam pressure and condensate load. Although they are uncommon, high back-pressures over 100 psig will not be met by a standard pressure-powered pump. The second disadvantage is the forces generated by the snap-action of the pumping mechanism can cause failures in the pin joints and the push rod **(Brader & Rocheleau, 2001).** Therefore, an unexpected surge in motive steam pressure can lead to the failure of the pump.

Installation and System Design

While all process conditions must still be accounted for when sizing pressure-powered pumps, the design of the entire system embodying the pump is the most important aspect of this application. Incorrect designs of pressure-powered pump systems have led to all of the failures at the Orange Plant and are one of the leading causes of pump failures in the industry. A typical design is illustrated in the schematic in Figure 6. The most neglected equipment in these systems is the vented receiver. The vented receiver serves a dual purpose: to vent any flash steam that can cause inefficient pumping and to provide a volume to hold condensate during the discharge stroke of the pump. The second key aspect to this design is the thermodynamic steam trap on the motive force steam line. This will ensure clean steam will enter the pump. Finally, an isolation valve and check valve should be installed immediately upstream and downstream of any pump. Check valves will prevent backflow and isolation valves allow for simplified maintenance and bypass capabilities.

Industry Alternative

Many process engineers choose electrically-powered centrifugal pumps when tasked with creating a positive pressure differential for a system. Centrifugal pumps are relatively simple, with a single impeller providing the force to increase the pressure of the fluid. These pumps can pump to a high pressure and can handle large loads of condensate.

Unfortunately, in condensate removal applications, centrifugal pumps have many disadvantages. The first and most severe issue is a phenomenon known as cavitation. Cavitation is caused by the formation of vapor cavities within the condensate from impeller rotation (TLV Euro Engineering, 2011). Cavitation occurs more frequently at temperatures of condensate greater than 80°C, as would be the case in most process equipment and steam main applications of condensate removal. Cavitation can lead to significant impeller damage and render a pump useless (TLV Euro Engineering, 2011). Therefore, CPChem would be purchasing a new centrifugal pump much more frequently than if they installed a pressure-powered pump. Another issue with centrifugal pumps is they operate most efficiently at a maximum liquid load. Varying condensate loads, as found in process equipment, can lead to inefficient pumping creating an increase in the power (and money) required to operate the pump. Finally, electrically-powered pumps require the routing of electricity to the pump. If the pump location has not been wired for the correct voltage of electricity, the upfront cost of installing this new infrastructure could be high. The above disadvantages conclude that for condensate removal applications, pressure-powered pumps are the ideal choice over centrifugal pumps.

Schematic of Pressure Powered Pump Design

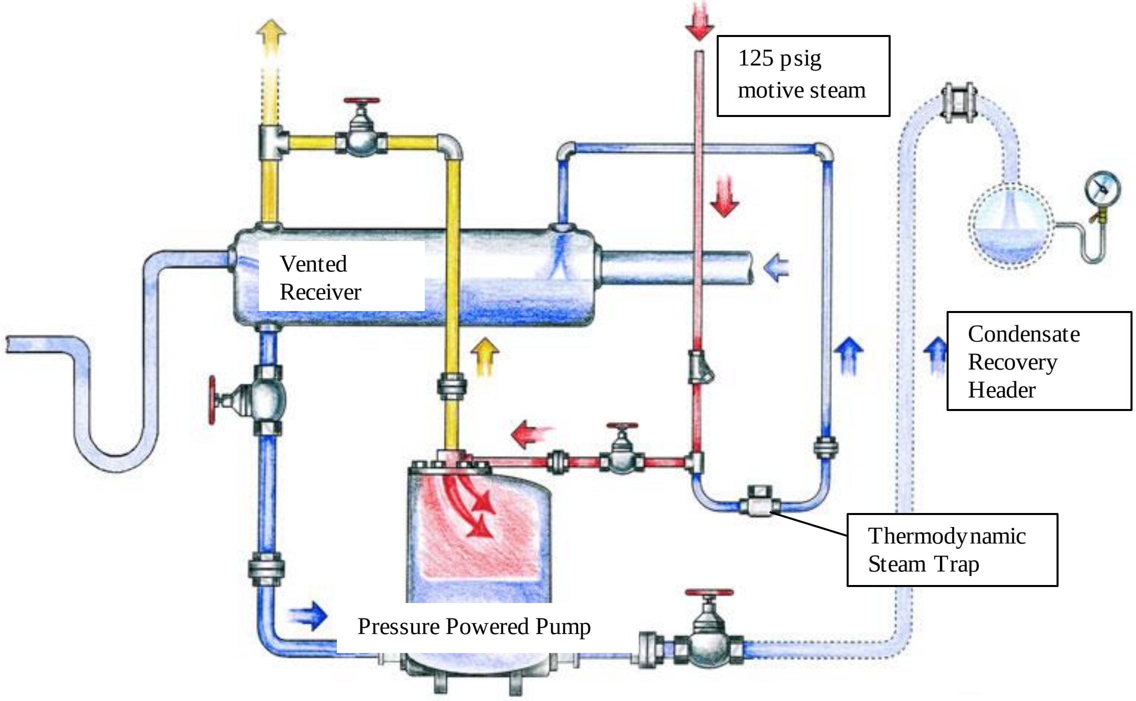

Figure 6: Condensate enters into a vented receiver, removing any flash steam present. It is pumped to approximately 50 psig by 125 psig superheated steam into the condensate recovery header (Spirax Sarco, Inc., 2014)

Maintenance Requirements

"Planned and tightly supervised maintenance is in some cases the deciding factor between making and not making a profit" (Garcia, 1986). Without routine inspection and repairs, condensate removal equipment performance can deteriorate, steam losses can increase, and safety issues can develop. When a problem is located, plants should not instantly replace-in-kind with the same equipment. Process engineers should read the above requirements for condensate removal applications in addition to consulting with the vendor for compatibility. To standardize maintenance processes, a strict inspection regiment must be created and a training program should be introduced to inform plant personnel of condensate removal operations.

Inspection

The first step in a successful condensate removal system is to identify the problems. To identify the problems, plants must perform regular steam trap and pressure-powered pump surveys. Garcia recommends performing these surveys at six month intervals (1986). Unless a sudden rise in steam usage is observed, this interval should be adequate. Additionally, the company's steam trap database must be up-to-date and recording information about the type of failure, significance of the failure, and frequency of the failure. This information helps process engineers determine if traps just need to be replaced or if a change in trap type is required.

Operators or process engineers can be trained to perform inspections so the company does not have to pay outside vendors for this task. A few simple tests can be performed to determine whether or not a trap has failed. Because condensate being discharged from a trap or pump must be cooler than the live steam, an infrared temperature gun can be used to determine failures. A correctly functioning trap will have a significant decrease in temperature from inlet to outlet. If the two temperatures are identical, then the trap has failed open and allowed steam to be discharged. If both temperatures are abnormally cool, the trap has most likely failed closed as condensate is now backing up into the piping. Finally, our senses can be useful tools to determine the functionality of traps. Thermodynamic traps, which comprise the majority of condensate removal devices, creates an audible "click" after each cycle as the metal disc hits the seat. A trap that does not click has either failed open or failed closed and needs to be replaced. Clicking that occurs faster than every 5 seconds has failed by "rapid-cycling" and can damage the trap severely (Spirax Sarco, Inc., 2014). Many companies provide condensate removal training and can provide more in-depth information than will be provided in this report.

Training

To ensure the long-term success of condensate removal systems, training must be provided to operators, maintenance workers, and engineers who will be working directly with them. Training personnel to prevent failures rather than just fixing failures has proven to be the most effective solution (Garcia, 1986). A successful training program should include the following:

- Different types of traps and their operation
- Proper selection of traps for specific applications
- Proper trap installation
- Most effective inspection methods and procedures (Garcia, 1986)

Standardizing the condensate removal systems will allow operators and maintenance personnel to become familiar with fewer trap and pump types. As a result, problems can be anticipated, located, and solved in a shorter amount of time for the cheapest price. Training and motivation to continuously inspect and improve these systems requires discipline from many plant departments; however, if done correctly, it can vastly increase the profitability of the plant.

Cost Analysis and Payback Periods

Throughout my researching process, I contacted multiple vendors of condensate removal devices including Spirax Sarco, TLV, and Armstrong International. As I was not a potential customer, none of these vendors could provide a quote. However, many case studies exist that demonstrate the exceptional payback of continuously updating steam trap systems.

E. Garcia cites a study performed on 5,000 steam traps (1986). Of those, 35% had failed open, closed, or by rapid-cycling. 1,000 traps were failed open, leaking or rapid-cycling losing approximately 265 MMLB of steam per year. With a total steam cost of $1.4 million and a replacement cost of $250,000, the total payback period for this steam trap overhaul was just 2.2 months.

Spirax Sarco performed a similar, smaller-scale survey in May 2014 for CPChem's Orange Plant. The survey found 33 failed open steam traps that were failed open and could be replaced without a steam outage. These failed open traps alone were costing the plant nearly $138,000/y in lost steam. After all repairs including parts and installation costing approximately $25,000, this overhaul had a payback period of 2.2 months as well.

According to Einstein, Worrell, and Khrushch, performing regular maintenance of steam trap systems has a payback period of around half a year while condensate return systems such as pressure-powered pumps can pay for themselves in just over one year while lasting for 20-30 years (2001). With such a short payback period, condensate removal systems can save CPChem's Orange plant thousands of dollars per year if selected, installed, and maintained correctly. As long as the plant maintains its inspection regiment and continuous training, these updated systems will significantly increase the profitability of the plant.

Governing Regulations

Because CPChem only uses steam derived from boiling water, any equipment malfunction and subsequent release of steam would be of no consequence to the environment or any employees near the location. Therefore, no environmental regulations exist involving the use of steam.

However, the Occupational Safety and Health Administration has standards involving pressure vessels. These standards can be found at their website www.osha.gov. The standards include information on general health and safety provisions, materials that can be used for pressure vessels, and how engineers can effectively track pressure throughout a process. These standards should be accounted for in every pressure vessel and especially with condensate removal systems under high pressure.

Review of Research Objectives

The proposal for this research identified four objectives that would provide Chevron Phillips Chemical Co. with a better understanding of the applications of condensate removal, how to address each application, and how to standardize its condensate removal devices. This report addresses all four of these objectives in previous sections and they are listed below:

1. The correct applications, sizing methods, and installation instructions for each type of steam trap.

2. The proper design of a pressure powered pump system.

3. A detailed overview of alternative methods of condensate removal and a comparison to ideal solutions.

4. A complete cost-benefit analysis of each method of condensate removal.

Conclusions

This report analyzes data presented by experts in the field of condensate removal to provide a general overview of the applications at CPChem's Orange Plant that can be improved with the standardization of their devices. This report examines each application and the industry best practice for each. It provides advantages, disadvantages, maintenance, and installation information for each solution. It concludes with the return that CPChem can gain from an investment in these solutions. The conclusions I have drawn from this research are as follows:

1. Float and thermostatic steam traps are the industry best practice for process equipment such as heat exchangers.

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3. Inverted bucket steam traps are the industry best practice for intense process conditions such as high pressure, high load, and loads containing a large amount of dirt and scale.

4. Pressure-powered pumps powered by motive steam are the industry best practice for recovering condensate to a pressurized header.

5. Regular maintenance and correct installation of steam traps can have a payback period of 2-6 months. Pressure-powered pumps can have a payback period of around one year.

6. Pressure vessel regulations are the only governing regulations concerning condensate removal devices. No environmental regulations exist for steam.

7. Standardization of condensate removal systems to the industry best practices will reduce energy losses, provide a safer plant, provide a more efficient process operation, and simplify training and future selection of new condensate removal devices.

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Unit 15: Appendix C: Student Problem-Solution Formal Report

A STUDY TO IMPROVE THE THERMOECONOMIC PERFORMANCE OF THE SEMINOLE UNIT 4 POWER PLANT

Submitted To:

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Submitted By:

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December 3, 2015

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Mr. Doug Riedel, Eastern Oklahoma Regional Manager
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Mr. Riedel,

I am happy to present to you my completed formal report, "A Study to Improve the Thermoeconomic Performance of the Seminole Unit 4 Power Plant," that was approved by Seminole Power Engineering Department Manager Travis Fucich on October 16, 2015. This report displays the results of my research and it provides information about different methods for improving the performance of simple-cycle power plants.

I began this study because I saw an opportunity to improve our company by increasing our revenues and upholding our environmental responsibilities. This report is divided up into four main sections: background information about simple-cycle power plants (p. 3), information about methods available for improving the performance of simple-cycle power plants and the benefits and drawbacks of each method (p. 4), a cost analysis for converting a simple-cycle power plant to a combined cycle (p. 11), and governing regulations and standards related to combined cycle power plants (p. 13). To conclude my report, I included my recommendations and a list of steps to follow for converting Seminole Unit 4 to a combined cycle power plant (p. 15).

This report provides information that is useful to OG&E for initiating and completing a project to convert the Unit 4 simple-cycle gas-fired turbine to a combined cycle power plant. My research has convinced me that combined cycle technology is the most viable option available to us for improving Seminole Unit 4 because of the potential for improved efficiency and increased power production. At this point, I believe we should immediately begin planning to convert Unit 4 to a combined cycle facility because we are currently missing out on the benefits that it can provide. I would like to obtain executive approval for this project, and then we can begin talking to engineering consulting firms that can help us execute this venture in a cost-effective manner.

I am grateful for the opportunity to perform this research and provide recommendations for improving our company. I would like to thank Mr. Travis Fucich for supporting my research to its completion. I would also like to thank Mr. Derek Damas for his assistance in my research regarding the logistics of a combined cycle power plant conversion project.

Please contact me if you have any questions or comments about the information in my report.

Regards,

Kendall Schmidt

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EXECUTIVE SUMMARY

Oklahoma Gas & Electric is one of the foremost utility companies in the Midwest, and we have experienced success in providing reliable power to our customers throughout Oklahoma and Western Arkansas. One of our core ideals is our commitment to serving our clients while doing our best to preserve the safety of our employees and our environment by adhering to legal and ethical standards. Unfortunately, our company is operating a power plant that goes against this principle by wasting large amounts of energy every day. The Seminole Unit 4 power plant in Konawa, Oklahoma only performs at an efficiency rating of 31 percent, and this means that we are wasting valuable energy we could be selling to our customers. Additionally, fear of the harmful effects of power generation on our environment is causing an increase in restrictions on power plants, such as those introduced in August 2015 by Barack Obama's new Clean Power Plan. This means that in addition to forfeiting revenues, we are also at risk for incurring hefty penalties from the government's progressing environmental legislation.

On October 13, 2015, I submitted a proposal to conduct research to improve the thermal efficiency of the Seminole Unit 4 power plant. I came up with four main goals to achieve throughout my research: (1) show that options are available for improving the thermoeconomic performance exhibited by Unit 4; (2) describe the most cost-effective strategy for improving cycle efficiency and how this strategy can be implemented to benefit our company financially; (3) provide proof that we can produce the same amount of power with less greenhouse gas emissions; (4) identify all pertinent laws, regulations, and engineering standards that will affect Unit 4 if we choose to modify this facility.

My method for achieving these goals included four main tasks: (1) review scholarly articles to learn about possible solutions for this problem and decide which solution would most effectively improve Unit 4; (2) read technical articles related to the method chosen in task 1, and learn about the benefits and drawbacks of the chosen process; (3) research regulations and engineering standards that apply to implementing the chosen method; (4) contact knowledgeable professionals with experience modifying simple-cycle power plants to obtain information about the cost and timeline associated with the chosen method. Seminole Power Engineering Department Manager Travis Fucich approved my proposal on October 16, 2015.

Conclusions

With the completion of my research, I have come to four conclusions. The complete list of conclusions can be found on pages 14 and 15 of my report, but the two major conclusions are listed below:

1. Of the three most common alternatives for improving simple-cycle efficiency, converting to a combined cycle power plant is the best option for Seminole Unit 4.

2. The best option for minimizing the cost of a combined cycle conversion project is for the our company to work with an engineering consulting firm from the Midwest region.

Recommendations

My conclusions have led me to three main recommendations. You can find the complete list on page 15 of my report, but my two major recommendations are listed below:

1. We should immediately take action to convert Seminole Unit 4 to a combined cycle power plant.

2. We should solicit bids from engineering consulting firms in the Midwest region to help us complete this conversion project.

INTRODUCTION TO THE DISCUSSION

Oklahoma Gas & Electric is one of the foremost utility companies in the Midwest, and we have experienced success in providing reliable power to our customers throughout Oklahoma and Western Arkansas. One of our core ideals is our commitment to serving our clients while doing our part to preserve the safety of our employees and our environment by adhering to legal and ethical standards. Since we are providing energy for a society that is becoming more adamant about reducing waste, we must strive for continuous improvement to ensure that our facilities don't contribute to growing concerns regarding the high amounts of pollution from the power industry.

As an Assistant Mechanical Engineer in the Seminole Power Department, I have daily encounters with one of our power plants that is not performing as well as it could be. I am referring to Unit 4 of the Seminole Power Plant in Konawa, Oklahoma, which consists of a single natural-gas-fired turbine operating on the basis of a Brayton power cycle. We hired a team of engineers from the consulting firm Burns & McDonnell to perform a study on this power plant last May, and they determined that the thermal efficiency exhibited by Unit 4 is approximately 31 percent. This number is fairly typical of simple-cycle power plants, and it is due to the large amounts of energy that we are releasing to the atmosphere from this unit. Simple-cycle power plants exhaust gasses that are very hot, and all of this heat energy is currently being wasted instead of converted to valuable electrical power. This is a problem, and we must find a way to improve this wasteful process by increasing the thermal efficiency of Seminole Unit 4.

On October 13, 2015, I submitted a proposal to conduct research to improve the thermal efficiency of Seminole the Unit 4 power plant. My method for solving this problem included four main tasks: (1) review scholarly articles to learn about possible solutions for this problem and decide which solution would most effectively improve the efficiency of Unit 4; (2) read technical articles related to the method chosen in task 1, and learn about the process, including the benefits and drawbacks; (3) research regulations and engineering standards that apply to implementing the chosen method; and (4) contact knowledgeable professionals with experience modifying simple-cycle power plants to obtain information about the cost and timeline associated with the chosen method. Seminole Power Engineering Department Manager Travis Fucich approved my proposal on October 16, 2015.

This report is the result of my research, and I begin by describing the basic characteristics of simple-cycle power plants like Seminole Unit 4. Next, I provide information about the three most common methods for improving simple-cycle power plants. These methods are conversion to combined cycle, implementation of cogeneration technology, and addition of inlet air cooling equipment. I describe how each of these methods works, and then I discuss the benefits and drawbacks of each option. After evaluating all of the options, I provide a summary that explains why converting Unit 4 to a combined cycle facility is the best option. Next, I provide a cost analysis of implementing combined cycle technology with regard to Seminole Unit 4. Then I outline all of the governing laws and engineering standards that are relevant to the chosen solution. Finally, I provide my conclusions and recommendations along with a plan to implement my solution with regard to Seminole Unit 4.

Converting Seminole Unit 4 to a combined cycle power plant would provide the most practical benefits to the facility and to our company. The initial cost would be relatively high, but I believe that the benefits that we would receive from the conversion would quickly outweigh this cost. For this reason, I recommend that the Seminole Power Department immediately begins planning to convert Unit 4 to a combined cycle power production facility.

DISCUSSION

Characteristics of Simple-Cycle Natural Gas Power Plants

Companies in the power industry have many options for choosing a method to generate electricity for their customers, and using natural gas as a fuel source is a popular choice. Our company's use of a natural-gas-fired turbine at the Seminole Unit 4 power plant, referred to as a simple-cycle (or a Brayton cycle), has advantages and disadvantages. I have created this section to provide a simple description of a Brayton cycle and introduce some of the positive and negative characteristics associated with them.

All natural gas turbines follow the same general process, and this process begins as ambient air enters the compressor at the beginning of the cycle. The compressed air is then mixed with natural gas before combusting and expanding across the blades of a turbine. The energy from combustion creates electrical power as the turbine turns the shaft of a generator. The process ends as the hot combustion products exit the back of the turbine, and they flow into a catalytic converter that removes some of the harmful sulfur and nitrogen oxides before the exhaust gasses enter the atmosphere. This process is demonstrated visually in figure 1 below.

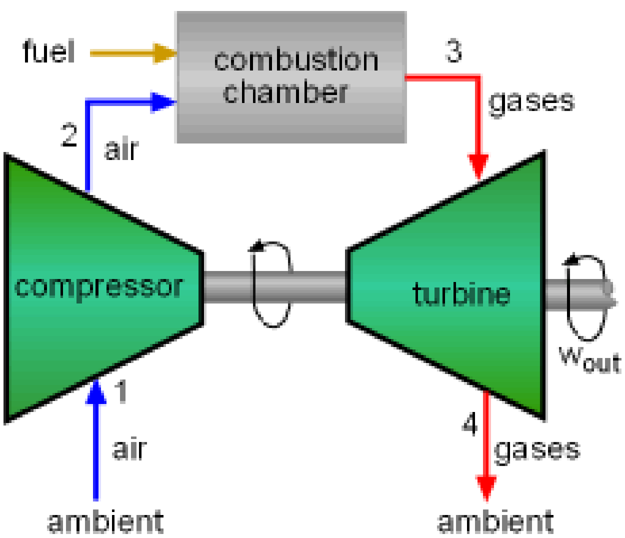

Figure 1 – Diagram Showing Brayton Cycle Process
(Huang & Gramoll, 2014)

Many different sizes of gas turbines are available on the market, and they all have different specifications. As a result, the output capacity and thermal efficiency can vary greatly from one facility to the next. A natural-gas-fired turbine will typically exhibit an efficiency between 20 and 35 percent (How gas turbine power plants work - energy.gov office of fossil energy.2015) and an output capacity between 91 and 510 megawatts (Heavy-duty gas turbines.2015). Clearly, the process description above is relatively short and simple, and this demonstrates why gas turbine power plants are simple and easy to maintain.

Gas-fired turbine power plants have many variable operating parameters, and we can use this to our advantage. By altering properties like the temperature, pressure, and mass flow rate at various points throughout the system, we can achieve different levels of performance from the power plant. We can also change the properties of the air mixture at various points throughout the turbine, and this can have a variety of effects on our overall power output and efficiency. We can demonstrate this by calculating the efficiency of a theoretically ideal Brayton cycle (also the maximum possible efficiency) from equation 1:

$$\eta_{max} = 1 - \frac{T_C}{T_H} \text{ [Equation 1]}$$

(Moran, Shapiro, Boettner, & Bailey, 2014)

In this equation, η_{max} represents maximum thermal efficiency, T_C represents the absolute temperature of the air that enters the compressor, and T_H represents the absolute temperature of the turbine exhaust. This maximum efficiency is impossible to achieve due to the second law of thermodynamics, but it demonstrates how we can increase efficiency by minimizing the temperature of incoming air and maximizing the temperature of the exhaust gasses. Unfortunately, we face a problem when we increase the exhaust temperature of a gas-fired turbine because doing this creates a large amount of wasted heat. Unless a utility company seizes the opportunity to recover this large amount of heat, the turbine will release all of this valuable energy to the atmosphere.

One final characteristic of Brayton power generation cycles is that they are often fueled by natural gas, so the power industry views simple-cycle power plants as environmentally friendly compared to facilities powered by other fossil fuels. Professionals in the power industry consider natural gas to be a ‘bridge’ fuel (a temporary fuel until we can transition to zero-emission technologies is possible) because carbon dioxide produced from combusting natural gas is less than that from burning any other fossil fuel (Zhang, Myhrvold, & Caldeira, 2014). As a result, simple-cycle power plants have less of a negative impact on the environment than the coal-fired power plants that currently dominate the energy industry. This is significant because we live in a society that is very conscious of the negative effects of releasing greenhouse gasses into the atmosphere, so the power sector is under increased scrutiny by the government. The positive attributes associated with natural gas explain why new environmental legislation is promoting the extinction of coal-fired power plants and encouraging power companies to construct natural-gas-fired power plants.

Summary

Simple-cycle power plants are a viable option for utility companies in today’s energy industry due to their simplicity, potential for customizing cycle parameters, and minor impact on the environment. Despite the advantages of this type of power plant, they also tend to exhibit low efficiencies due to the large amount of energy they waste because they release so much heat to the atmosphere.

Methods for Improving Simple-Cycle Efficiency

The relatively low efficiency exhibited by a simple-cycle power plant provides a lot of room for improvement, and engineers have come up with many solutions to solve this problem. In my research, I read several scholarly articles and visited the websites of numerous organizations, and I found that the three most common methods for improving efficiency are for a utility company to convert to a combined cycle power plant, implement cogeneration technologies, or add inlet air cooling equipment. I have described these methods below and provided the benefits and drawbacks of each technology:

Converting to Combined Cycle

Combined cycle technology has been around since the 1950’s in its most primeval form, but the low cost of natural gas and the increasing push to preserve the environment caused a large increase in combined cycle applications in the past 10 years in the United States (Chase, 2001). Converting a natural gas turbine into a combined cycle power plant involves attaching a heat recovery steam generator (also referred to as a HRSG) to the outlet of the gas turbine. By attaching a HRSG, we are adding a Rankine power cycle to the power plant to complement the existing Brayton power cycle. The following text describes how the process works along with the benefits and drawbacks of implementing this technology:

How It Works

All combined cycles involve a gas turbine, a HRSG, a steam turbine, a condenser, and a cooling tower and pumps. The most basic combined cycle configuration is a once-through HRSG, and Figure 2 shows a simple diagram of this type of power plant. These cycles all follow the same general process, and this process starts after natural gas is combusted in a gas-fired turbine as described above.

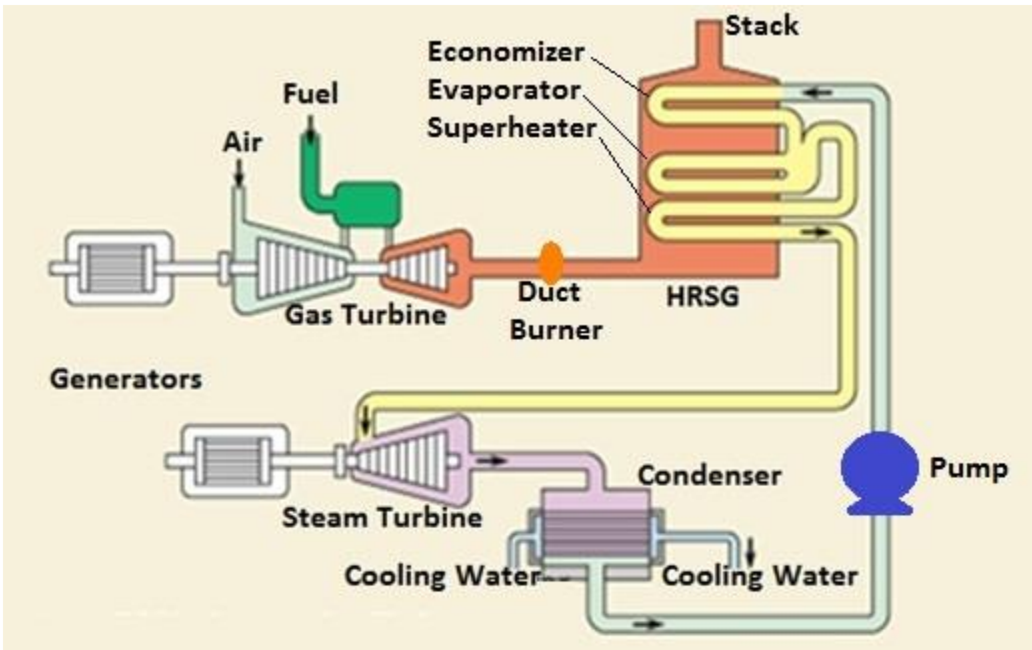

Figure 2 – Diagram Showing Process of a Typical Combined Cycle Power Plant,
Adapted from (Mechanism of combined cycle power plants.2014)

The combined cycle process begins when the hot gas mixture is exhausted from the gas turbine and enters the HRSG. Many HRSG's heat these exhaust gasses even further by including a component called a duct burner. A duct burner burns natural gas to produce a large flame, and the flue gas flows through this flame before passing through various heat exchangers. These heat exchangers are nothing more than large arrangements of pipes that contain water in the liquid or vapor phase (Combined cycle plant for power generation: Introduction.2015). The number of heat exchangers within a HRSG can vary from one facility to the next, but all will have at least three. Engineers call these three basic heat exchangers the economizer, evaporator, and superheater (Combined cycle plant for power generation: Introduction.2015). The heat exchangers carry out the primary function of the HRSG as the economizer preheats the water, the evaporator converts it to a saturated vapor, and the superheater turns the saturated vapor into a superheated vapor. Once the turbine exhaust gasses have passed through the three heat exchangers, the HRSG will have extracted most of the heat energy from the gasses. Finally, the flue gasses pass through a series of catalytic converters (or "scrubbers") to remove pollutants such as nitrogen and sulfur oxides before exiting through the stack to the atmosphere.

While this process occurs, the HRSG acts as the boiler for the attached Rankine cycle. The superheated vapor from the HRSG expands across a steam turbine to produce electrical power before entering the condenser. The condenser is also a heat exchanger, and the steam from the turbine outlet passes over pipes filled with cold water. This process converts the steam back to liquid water, and then a pump pushes the water back to the HRSG. Once the water gets back to the HRSG, hot exhaust gasses turn it back into superheated steam, and the process repeats.

Benefits

The benefits of a combined cycle power plant are numerous, and the biggest advantage is the large increase in thermal efficiency. Some of the most efficient combined cycle power plants in the United States exhibit thermal efficiencies of approximately 60 percent, which is nearly double the efficiency of our Seminole Unit 4 plant (Ray, 2014). This directly affects a company's profits, and occurs because a company that converts a simple-cycle power plant to a combined cycle facility has the potential to produce up to 50% more energy with nearly the same amount of fuel (Combined cycle power plant - how it works - GE power generation.2015). By adding additional power output, we are creating 50% more money to supplement our company's bottom line.

Another significant benefit is the relatively low cost for a company to construct a combined cycle power plant, partially due to the short installation cycle. Many power plant construction processes, such as constructing a new coal-fired power plant, require a huge variety of expensive parts. Contractors then must assemble these parts in the field, resulting in more downtime and more labor costs. Fortunately, most combined cycle facilities require fewer components, and specialized companies pre-package and pre-assemble this equipment in a factory. This minimizes the time to install combined cycle equipment and the cost to construct these power plants (Chase, 2001).

One last benefit is the low maintenance and operating costs that come along with a combined cycle power plant. The manufacturers of most HRSG components thoroughly pre-engineer and assemble their products in factories, so the quality of work in the assembly stage is much more reliable and controlled (Chase, 2001)**.** The configuration of combined cycle power plants also allows plant workers to inspect the components on a regular basis due to the extensive planning that engineers carry out in creating these plants.

Drawbacks

The main drawback of this technology is the up-front cost associated with constructing a large heat recovery steam generator equipped with Rankine power cycle capabilities. The preceding section mentions that these costs are relatively low, but this is true when comparing a combined cycle construction project to a coal power plant construction project. We would have to finance a project of this type carefully, as these facilities often cost over $100 million (Derek Damas, personal communication). Please see the cost analysis section for further detail regarding costs.

If we commit to building these facilities, we must be certain that they will not become obsolete in the near future. It generally takes about three years to complete a combined cycle conversion project from the moment a company begins designing the power plant to the day that company begins operating the finished plant (Derek Damas, personal communication). Fortunately, combined cycle technology is becoming more common in the United States, and this indicates that companies within the energy industry are confident that combined cycle power plants are a safe investment for the near future (Chase, 2001).

One last minor drawback of converting to a combined cycle power plant is the increase in carbon dioxide emissions from adding a duct burner within the HRSG. Purchasing and burning additional fuel for this burner will raise our greenhouse gas emission rates slightly, but the additional power output that we will obtain will offset this problem. As described in the benefits section above, this modification provides the potential for a 50% increase in power. This increase in production vastly outweighs the additional emissions, and the decreased rate of carbon dioxide output per megawatt of capacity makes this drawback negligible.

Implementing Cogeneration Technologies

A second technology that many utility companies implement is cogeneration. This type of power plant is very similar to a combined cycle plant, and Kanoglu and Dincer explain that “cogeneration systems often capture otherwise wasted thermal energy, usually from an electricity producing device like a gas-turbine, and use it for space and water heating, industrial process heating, or as a thermal energy source for another system component” (Kanoglu & Dincer, 2009). The difference is that a power plant captures this heat and does not convert it into another form of energy. Instead, the plant uses the heat for various external applications. In the following sections, I have described some typical applications for cogeneration along with the benefits and drawbacks of these types of power plants:

How It Works

A gas-turbine cogeneration power plant produces power using a simple-cycle process and then forces the turbine exhaust gasses through a heat exchanger filled with water. This is similar to the combined cycle application, but the next step is very different from that of the process described in the previous section. The water absorbs heat energy from the turbine exhaust gasses so the plant can pump it away to a residential, commercial, or industrial heat user. A heat user can be a variety of different facilities including an office building, a residential development, a factory, or even an airport (Cogeneration & CHP.2015).

The heat user receives heat energy and then uses it for a variety of purposes. Some cogeneration plants provide hot water to the heat user, and this replaces the need for a residential or commercial water heater. Building heating is another application that homes, office buildings, or factories can implement in place of furnaces. Similar to building heating, these different types of buildings can also implement cooling or refrigeration applications when the owner installs an absorption chiller and uses the captured heat to run it. Lastly, industrial facilities like oil refineries, chemical production plants, and other manufacturing plants can use the heat energy captured from the exhaust gasses in various steps within their respective processes (Cogeneration/combined heat and power (CHP).2015). Figure 3, shown on the following page, provides a diagram that demonstrates the cogeneration process.

Benefits

The first benefit of cogeneration is the reduction in energy costs for heat users who use this process as a substitute for a water heater or a heating/cooling unit. Clarke Energy estimates that cogeneration can achieve primary energy savings of approximately 40 percent compared to purchasing electricity from the national grid to power an on-site boiler for heating (Cogeneration & CHP.2015). The owners of cogeneration plants can increase their profit margins by selling this heat energy, and in some places, the government will even provide tax benefits to the owners of cogeneration plants (Cogeneration & CHP.2015).

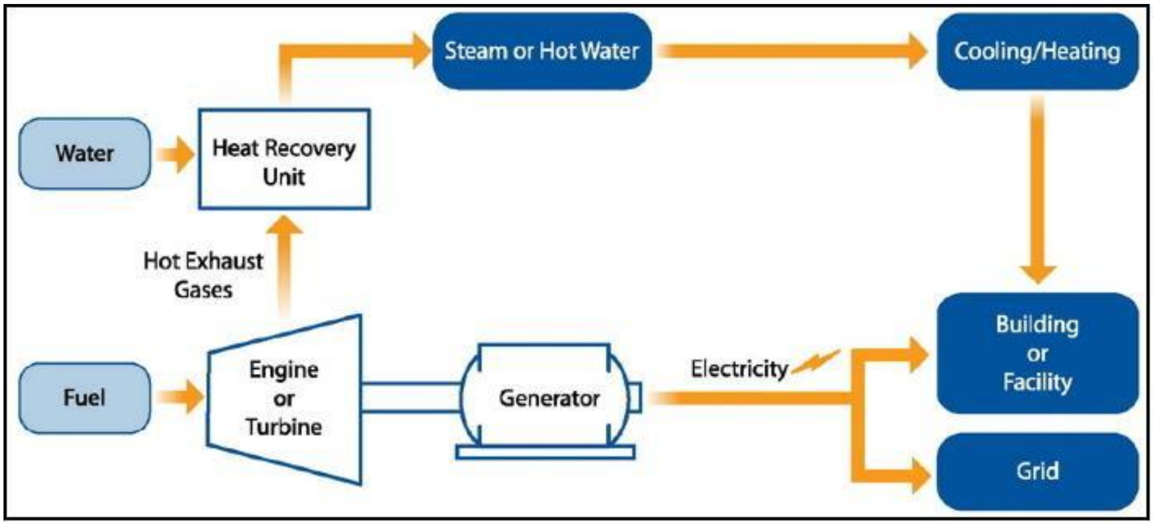

Figure 3 – Diagram Showing Process of a Typical Cogeneration Power Plant,
(Combined heat and power partnership - basic information.2015)

In addition to financial and energy savings, implementing cogeneration technologies has the potential to reduce greenhouse gas emissions. Kanoglu et al. have determined that these systems often have an energy efficiency around 47% (Kanoglu et al., 2009), so if we effectively implement this process we could increase the efficiency of Seminole Unit 4 by 50%. Additionally, a decrease in electricity consumption by heat users who are not using appliances such as boilers and heating/cooling units will reduce the heat user's "carbon footprint."

Drawbacks

For a power plant to implement a cogeneration power system optimally, the user of the electrical and heat energy must be very close to the production facility. These types of power plants are best when a company designs them around the user of this energy, and they are not ideal for applications involving long distance energy transmittal (What is cogeneration.2015). Since the Seminole Unit 4 power plant is in an isolated part of Konawa, Oklahoma, no potential residential or commercial heat users exist within 5 miles of this plant. If we try to transmit this heat energy to the nearest residential or commercial user, the system will experience large energy losses. Additionally, if we install the piping and pumping systems required, we will face a large cost for materials and labor.

Industrial heat users are available near the Seminole Unit 4 power plant, but these facilities do not have an economical use for additional heat energy. Seminole Units 1-3 are all within one mile of Unit 4, but these are coal-fired power plants that already produce enough heat. Despite the numerous potential benefits of cogeneration power production, applying this technology to Seminole Unit 4 is not a practical option for us.

Adding Inlet Air Cooling Equipment

As the name of this method suggests, inlet air cooling involves lowering the temperature of the air entering the compressor of a simple-cycle gas-turbine power plant. When ambient air temperatures are relatively high, a gas turbine power plan can experience power loss of more than 20% compared to standard conditions (Kakaras, 2004). Engineers have developed a few different methods to cool the air at the compressor inlet, and one of the most effective is evaporative cooling.

How It Works

Evaporative cooling is a simple method that uses the latent heat of vaporization of water to reduce inlet air temperature. This process begins when water is injected into the intake air of the gas turbine. "As water evaporates, the latent heat of evaporation is absorbed from the water body and the surrounding air. As a result, both the water and the air are cooled during the process" (Kakaras, 2004). The following diagram, Figure 4, shows how an evaporative cooler works to cool ambient air before it enters the compressor of a simple-cycle power plant.

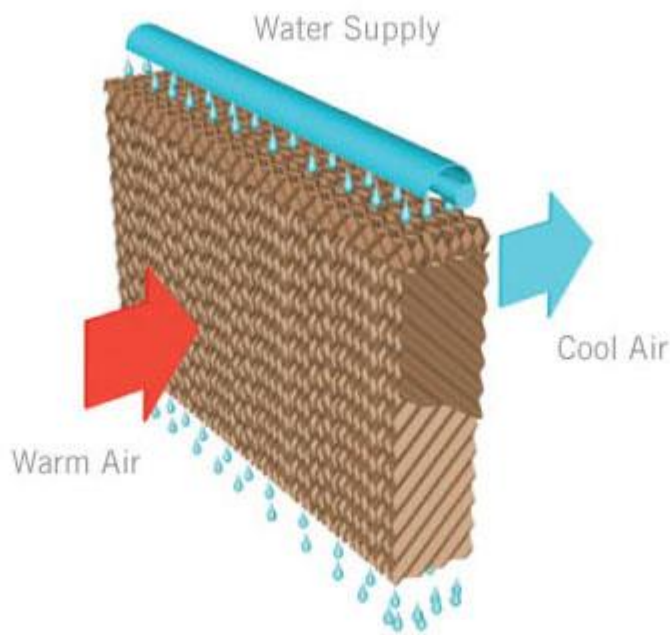

Figure 4 – Diagram Showing Evaporative Cooling Process
(The most natural system of cooling.2015)

If we cool the air that enters the compressor of a simple-cycle power plant, this improves the efficiency of the system by increasing the net power output of the cycle in two distinct ways (Kakaras, 2004). First, the increased mass flow rate of air through the turbine improves its power production capacity. Cold air is denser than warmer air, so the result is a larger mass flow rate through the system than if warmer air enters the compressor. Equation 2 provides a reduced version of the first law of thermodynamics, and it explains how an increase in mass flow rate will result in an increase in power produced by a turbine:

$$\dot{W} = \dot{m}(h_i - h_e) \text{ [Equation 2]}$$
(Moran et al., 2014)

In this equation $\dot{W}$ stands for work done by the turbine, $\dot{m}$ is the mass flow rate through the turbine, h_i is the specific enthalpy of the mass entering the turbine, and h_e is the specific enthalpy of the mass exiting the turbine. Assuming that the enthalpies remain unchanged, this equation shows how mass flow rate directly relates to power production.

The second reason for an increase in net power output is reduced power required to compress the air. This is simply because less work is required to compress cold air than to compress warmer air (Kakaras, 2004). This is true because the air compressor heats up as it operates, and the cooler air will keep the compressor temperature lower, resulting in higher compressor efficiency.

The resulting increase in net power increases capacity and efficiency. This increase in efficiency agrees with the concept established by equation 1 on page four. Cooler inlet air results in a lower value of T_c in equation 1, and this provides a higher theoretical maximum efficiency for the cycle.

Benefits

If we add an evaporative cooler attachment to the front end of Seminole Unit 4, we have the potential to increase the power production capacity by about 6.8% (Kakaras, 2004). This equates to approximately 9.5 additional megawatts of power production, and this would increase the total capacity from 140 megawatts to nearly 150 megawatts.

A small increase in the power plant's thermal efficiency is another benefit that an evaporative cooling unit provides. This attachment could add up to 0.44% to the existing simple-cycle efficiency, so this small increase would improve the thermal efficiency of Unit 4 to about 31.44%.

Lastly, the evaporative cooler would improve compressor efficiency. This would extend the life of the air compressor and reduce maintenance and repair costs.

Drawbacks

Although this method increases power generation capacity and efficiency, it does not fix our problem that we are releasing massive amounts of heat energy to the atmosphere. Additionally, the increases in power production capacity and thermal efficiency are not very substantial compared to the large amounts of energy that we are wasting.

To install the evaporative cooling system, we would need to stop producing power during the construction phase, and this could cause several months of costly downtime. Additionally, an evaporative cooling unit would require its own water supply, and we would have to treat the water supply effectively to guarantee that it operates correctly (*GE oil & gas - evaporative cooler*2008). If we do not treat the water supply correctly, buildup of minerals could clog up the working components of the evaporative cooler, and we would have to shut down the power plant to fix this problem.

Summary

After considering the three most widely used technologies for improving simple-cycle power plant efficiency, I have determined that the best solution for Seminole Unit 4 is for our company to convert the gas-fired turbine into a combined cycle power plant. This option stands out as the best method for improvement compared to the other two alternatives for the following reasons:

- Cogeneration is not practical because Unit 4 is too far from any other facilities that could act as the "heat user" for the system. We would not be able to use a great amount of heat energy that we could capture from cogeneration because of substantial losses during transmission, so the energy capture effectiveness of a combined cycle would be much more beneficial to us.

- Inlet air cooling has the potential to increase the capacity of Seminole Unit 4 by approximately 9.5 megawatts. This 7% increase in capacity is much lower than the up to 50% increase that is possible from combined cycle technologies. Efficiency usually increases by about 0.5% from inlet air cooling, and this compares poorly with the nearly 100% increase in efficiency that we could achieve if we add a HRSG to Unit 4.

Cost Analysis for Converting to a Combined Cycle

If we convert Seminole Unit 4 to a combined cycle power plant, the cost would be lower than that of constructing a new power plant, but it would be a large capital investment. The scale of this project exceeds the engineering capacity of the Seminole Power Engineering Department within our company, so we would have to consider hiring engineers from an engineering consulting firm to assist us with this project. With this in mind, I contacted Assistant Mechanical Engineer Derek Damas from the engineering firm Burns & McDonnell in Kansas City, Missouri. Derek provided estimates regarding the timeline and cost of a project of this nature. Derek has experience working with utility companies like ours, and he has worked on project teams that have completed combined cycle projects. I completed the following analysis after speaking with Derek and consulting other resources online.

The major cash costs of combined cycle projects come from consulting fees, the HRSG components we would acquire from vendors, and contractor labor. Contractors must also use heavy equipment to assemble components of the power plant, and this is an additional cost within the contractor labor category. We would also encounter opportunity cost for every day that construction prevents normal operation of Seminole Unit 4. Fortunately, we would likely be able to continue normal power plant operation until the final stages of the construction phase (Derek Damas, personal communication). This would be possible because the stack of the existing gas turbine is tall enough that no risk of heat exposure to laborers exists until the part of the project where we would demolish the stack and attach the HRSG to the gas turbine outlet.

One example of a combined cycle project that reflects our needs is the Empire District combined cycle power plant currently under construction in Riverton, KS. The Empire District Electric Co. is working with Burns & McDonnell to convert its simple-cycle power plant to a combined cycle plant, and an article released in September by Power Engineering Magazine estimates the cost of this project to be around $165 to $175 million (Kansas gets 1st combined cycle power plant with conversion of coal-fired plant.2015). I was able to confirm this number with Derek Damas in our phone conversation, and he informed me that the cost of the Riverton project is very typical for these types of combined cycle conversions (Derek Damas, personal communication). Unfortunately, Derek was not able to disclose details related to the breakdown of this cost for confidentiality reasons.

To complete this project, we would first solicit bids from multiple engineering firms and determine which consulting firm we would like to work with. This process can take a few months, and selecting a firm to work with will have a huge effect on the total cost of the project. Factors like a company's reliability, past experience, and efficiency will all determine the final price. We must also be very careful when we consider factors associated with the contract, because the contract will determine who will pay for unexpected rises in cost if they occur.

The next step would require us to sign the bid contract that we find to be the best, and then we would move into the design stage. Consulting engineer Derek Damas explained that once the design process begins, engineers will continue to work on designing the power plant until construction is completed and the combined cycle power plant begins operation. His experience has shown that the amount of time between the start of design process and plant startup is typically three years. This stage of the process would be most intense for the first year because this is usually how long it takes a company to prepare for construction (Derek Damas, personal communication). Based on the 2011 IEEE-USA Consulting Fee Survey Report, the median hourly rate for power engineering consultants in our geographical region is $130 per hour (*IEEE-USA consultants fee survey report.*2011). We would begin to incur expenses at this rate from the labor of the fees from engineers helping with design, and this would be our only major cost until the initiation of the construction phase.

Once construction begins, the magnitude of the expenses would ramp up because we would be paying for millions of dollars in power plant components, contractor labor, and rental of heavy-duty construction equipment. Construction usually lasts about two years, but we would still be able to produce sellable power from the gas-fired turbine until the final 30 to 90 days of construction (Derek Damas, personal communication).

As mentioned earlier, the total cost of this project would be approximately $165 to $175 million. Our company has enough capital to pay for this project, but Seminole Unit 4 must be able to replenish these funds and repay this capital investment when we finish construction. The existing plant provides approximately 140 megawatts of power at full load, and we have the opportunity to gain an additional 70 megawatts of output capacity from this conversion. The U.S. Energy Information Association website says the price of a kilowatt-hour of electricity in Oklahoma is approximately $8.50, so the additional 70 megawatts of power production capacity can provide an additional $595,000 per hour in revenues (Electric power monthly - U.S. energy information administration.2015).

Financing this investment would take many years, and I have provided a conservative estimate of the financial details below. Assuming a cost of $175 million and an APR of 5 percent, the monthly payment required for paying off interest and principle in five years would be $3.3 million. The 5 percent annual rate provides a conservative estimate that accounts for any costs associated with borrowing money from our investors, and it accounts for the effects of inflation. I have provided the calculation for finding this number using equation 3 below:

$$P = \frac{r(PV)}{1-(1+r)^{-n}} \text{ [Equation 3]}$$

(Finance formulas - loan payment.2014)

In this equation, P is the monthly payment amount, PV is the present value of the principle, r is the interest rate per period (APR/12 months), and n is the number of periods (in months). I have provided the formula again below, but this time I inserted the numbers from our calculation in place of the variables.

$$Monthly\ Payment = \frac{\frac{0.05}{12}(175{,}000{,}000)}{1-(1+\frac{0.05}{12})^{-5*12}} = \$3{,}302{,}465.89$$

If we assume that the power plant runs 75 percent of the time every month, then Seminole Unit 4 is currently producing approximately $643 million in monthly revenue. Although this number seems large, the monthly profit from Seminole Unit 4 is not as impressive after subtracting costs of fuel, employee salaries, and other fixed expenses. Our company has a strict budget for the profits from each unit, but we could afford to make monthly payments on a loan for a combined cycle conversion project during the three years of construction using some of the profits from operating Unit 4. Once the combined cycle power plant starts up, the same assumptions from above allow us to approximate that we would earn $321 million in extra revenues from the additional 70 megawatts alone. The additional power generation capacity would allow us to finish paying the loan within two years of startup because we could use the additional profit entirely for repayment of the initial investment. Once we pay off our loan, the combined cycle addition would result in extra profit for our company.

Summary

I believe that we should consider working with an engineering consulting firm to help us convert Seminole Unit 4 to a combined cycle power plant. I have determined that it would cost approximately $175 million to complete a combined cycle conversion, and the project would take approximately three years. The gas-fired turbine would be able to continue producing power until the last 30 to 90 days of the construction phase and we could use some of the profits from operating the plant to fund the project for the first three years. Upon project completion, the profit from the HRSG could pay off the remainder of the loan within two years.

<u>Regulations and Standards to Consider</u>

Government entities at the federal and state level have enacted laws and regulations that power plants in the United States must follow. We must consider these regulations to ensure that our company avoids costly fines and upholds its ethical and legal responsibilities. We must also adhere to all engineering standards for combined cycle power plants to ensure that our facilities are safe for our employees.

In recent news, the Environmental Protection Agency released a new set of rules on August 3, 2015 called the Clean Power Plan, and this legislation primarily focuses on reducing carbon emissions from power plants. Fortunately, Seminole Unit 4 is a natural gas fired plant, and the Clean Power Plan encourages utility companies to use natural gas instead of coal for fuel (Andracsek, 2015). Modifying this unit will not conflict heavily with this set of laws, but the Clean Power Plan does include a set of standards for reconstructed natural gas power plants, and we must adhere to the rules outlined in this legislation (EPA fact sheet: Carbon pollution standards.2015). The federal government also set goals for every state regarding the amount of CO_2 released by power plants within that state, so Oklahoma Gas & Electric must recognize these goals and do everything in our power to ensure they are met (Clean power plan: State at a glance, oklahoma.2015).

In addition to adhering to the clean power plan, we must also obtain all necessary permits from federal, state, and local governments. I examined a report on the Mooreland Unit 4 combined cycle power plant project in Woodward County, Oklahoma from April 2013 to find out which organizations we must consult for these types of construction projects. This project is currently in progress, and Western Farmers Electric Cooperative and Burns & McDonnell are the two companies that are working together to complete it. The report explains that the federal agencies from which we must obtain a permit or approval are the Federal Aviation Administration, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service (*Alternative evaluation/site selection study.*2013). At the state level, we must obtain a permit or approval from the Oklahoma Department of Environmental Quality, and the Oklahoma Department of Wildlife Conservation (*Alternative evaluation/site selection study.*2013). Finally, at the local level we must obtain a building permit with Seminole County (*Alternative evaluation/site selection study.*2013).

In addition to laws and regulations, we must also follow standards set by the American Society of Mechanical Engineers (also referred to as ASME). The ASME Handbook for Cogeneration and Combined Cycle Power Plants is a resource that we must obtain (ASME books.2015). This handbook will help us complete this project in a way that ensures safety for all employees who work with the Seminole Unit 4 power plant.

Summary

If we convert Seminole Unit 4 to a combined cycle, we must adhere to the binding principles of the federal government's new Clean Power Plan, and we must obtain permits and approval from government organizations at the federal, state, and local levels. In addition to following government legislation, we must also follow the American Society of Mechanical Engineers Handbook for Cogeneration and Combined Cycle Power Plants. If we do this, we will uphold the ethical and legal standards of our company and our stakeholders.

Review of Research Objectives

In my proposal to research options for improving Seminole Unit 4, I offered four objectives that would ensure a thorough analysis of the different options available to us. I have completed these objectives and they have been addressed throughout this report. My objectives are reiterated below:

1. Show that options are available for improving the thermoeconomic efficiency exhibited by Unit 4

2. Describe the most cost-effective strategy for improving cycle efficiency and how this strategy can be implemented to benefit our company financially

3. Provide proof that we can produce the same amount of power with less greenhouse gas emissions

4. Identify all pertinent laws, regulations, and engineering standards that will affect Unit 4 if we choose to modify this facility

Conclusions

This report is the result of three months of research for possible solutions to improve the efficiency of the Seminole Unit 4 simple-cycle power plant. The contents of this report evaluate characteristics of simple-cycle power plant, describe different options for improving Unit 4, analyze of the cost for us to implement the best option, and explain the various regulations and standards to consider for this project. The following statements show what I have concluded from my research:

1. Seminole Unit 4 is more environmentally friendly than many types of power plants, but the plant's thermal efficiency is worse than we would like it to be.

2. The best three options for simple-cycle power plant improvement are conversion to combined cycle, implementation of cogeneration technologies, and addition of inlet air cooling equipment. Of these three options, the best option for us is to convert Seminole Unit 4 to a combined cycle power plant.

3. The best option for minimizing the cost of a combined cycle conversion project is to work with an engineering consulting firm. The best-case scenario for this project is for the conversion to cost about $175 million and require no more than three years to finish.

4. The best way to ensure that this project is ethical and legal is to consult government agencies at the federal, state, and local levels to obtain permits and authorization for various aspects of construction. Adhering to the ASME standards related to combined cycle power plants is the best way to ensure the safety of the employees and stakeholders of our company.

Recommendations

The following statements are a result of the research I have completed and the conclusions I have made. I believe these actions will benefit our company by reducing the amount of energy we waste, minimizing our "carbon footprint," and increasing the profits that we earn. I have listed my recommendations below:

1. I recommend that Oklahoma Gas & Electric immediately take action to convert Seminole Unit 4 power plant from a simple-cycle power plant to a combined cycle power plant with a once-through heat recovery steam generator.

2. We should solicit bids from engineering consulting firms in the Midwest region so we can evaluate our options and select the best firm for helping us with the project explained above.

3. We should obtain the necessary permits and authorizations from governmental agencies for construction of a combined cycle power plant.

Steps to Convert Unit 4 to a Combined Cycle

I have included a basic plan for the Seminole Power Department to follow to convert Seminole Unit 4 to a combined cycle power plant below:

1. Contact engineering consulting firms in Oklahoma, Kansas, and Missouri and obtain bids for a project to convert a simple-cycle gas turbine to a combined cycle power plant.

2. Receive all of the bids and select the best option based on estimated cost, and time, as well as the company's experience and resources. Work with accountants and financial advisors within our company to establish the budget for the project.

3. Begin working with the chosen engineering firm to exchange information, formulate design plans, and eventually facilitate construction.

4. Contact the necessary government agencies for permits and authorization. Obtain a copy of the ASME Handbook for Cogeneration and Combined Cycle Power Plants, and read this manual to become familiar with safety standards.

5. Continue normal operation of Seminole Unit 4 until it is necessary to shut down for the final stages of construction. Train all Seminole Power Department engineers how to operate the new plant, and then start up the plant upon project completion.

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