SENIOR PROJECT GUIDELINES

BioResource and
Agricultural Engineering Department
California Polytechnic State University
San Luis Obispo, California

Updated: August 2009

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

INTRODUCTION

As a student at Cal Poly, you have a unique opportunity. You may explore an area in which you have a personal interest and receive academic credit for this effort. This opportunity is called the senior project. You are personally responsible for the conception, planning, implementation, and write-up of a project pertinent to your field of study.

The senior project is meant to build upon knowledge and skills learned in a great many of the college classes you have taken. The senior project is a challenge for you to put together a solution to a problem of greater scope than you have encountered in routine class assignments. As a consequence, your senior project is preparation for tackling *real world* problems you will find in the realm beyond the classroom.

Many students have found that the senior project report can be a useful tool when they interview for a job. The potential employer can see firsthand the effort you have made and the results you have achieved in the project.

Perhaps, most importantly, it is an opportunity to demonstrate the ability to complete a special project within a specified time. Senior project preliminaries are conducted in a regularly scheduled class, BRAE 460 Senior Project Organization. By the end of this class, you will have prepared and had approved the contract and the planned schedule for completing your senior project. However, the remainder of the senior project is conducted under a different time framework than your regular classes. None of your peers are attempting to do exactly the same assignments on the same time schedule. The arts of self-discipline, setting priorities, and establishing and keeping schedules are important for successfully completing your senior project.

Many alumni of the BioResource and Agricultural Engineering Department rate the senior project as the single most important class in their college career and insist upon its retention in the curriculum.

This SENIOR PROJECT GUIDELINES booklet has been written in response to a need. The concept is to provide information that will aid in successfully completing the course requirements. Specific departmental requirements and deadlines are explained. Matters of format are spelled out in order to achieve uniformity in the report. Examples and other useful information are given in the appendices to assist in the preparation and presentation of the actual report and posters:

- Appendix A: Sample Senior Project Contracts
- Appendix B: Sample Schedule of Progress
- Appendix C: BRAE Lab Policies
- Appendix D: Checklist for Senior Project Posters and Reports
- Appendix E: Technical Writing Tips
- Appendix F: Sample Senior Project Report

SELECTION AND APPROVAL OF PROJECT

This section presents the procedures for selecting and obtaining approval of your senior project. Specific requirements for senior projects in each major are explained. Some points to consider when choosing the scope and size of the senior project are discussed. The roles of the project supervisor, project sponsor, and department head are clarified.

Project Selection and Sponsor

Each senior project should be student initiated. Projects for which you initiate the original idea or proposed development are more likely to hold and sustain your interest than those assigned directly by an instructor. Your project should be a solution to a problem directly relating to your major field of interest. Ideally, the senior project should bear a direct relationship to future employment.

Students in this department may elect to undertake a senior project that is financed by a company or individual that will directly benefit from the project. If this route is taken, it is important that you obtain a firm financial commitment towards project expenditures from this third party. Your senior project contract will document this commitment. The BioResource and Agricultural Engineering Department has sponsored certain projects, such as the development of teaching aids, which remain in the department when completed.

Project Requirements

General Requirements. Emphasis is on learning by doing; consequently, *hardware* projects involving design, construction, and testing of a prototype are encouraged. *Software* projects such as planning, design, and evaluation are also satisfactory if they relate to problems within the broad fields of BioResource and Agricultural Engineering or Agricultural Systems Management.

The University defines the senior project as a formal report of the results of a study, experiment, engineering design or systems management problem. Note that the project *is* the report. The report is based on your design/build/test experience, but the report is of primary importance. Do not fall into the trap of believing that what you design, build and test is the project, while the report is only a secondary afterthought. Plan from the start how various aspects of your design/build/test experience will be documented in your report: pictures, tables, descriptions, citations for sources of information, etc.

Your senior project experience is a *capstone* for your educational career and should incorporate knowledge and skills developed during past course work. Not every prior class may have relevance to your project, but the project should not be so narrow that it depends on knowledge and skills derived from only one prior class. The project should focus your attention on how a particular problem would be handled in professional practice.

<u>Requirements for ASM Majors</u>. Senior projects for students in the Agricultural Systems Management major must include a problem solving experience that incorporates the application of technology and the application of business or management skills.

Agricultural systems management involves the application of quantitative, analytical processes for developing solutions to technological, business or management problems associated with agricultural production, processing, or the distribution of agricultural products and support services to agricultural or related industries. A systems approach, interdisciplinary experience and agricultural training in specialized areas are common features of this type of problem solving.

<u>Requirements for BRAE Majors</u>. Senior projects for students in the BioResource and Agricultural Engineering major must include a significant *engineering design* experience: one that builds upon the fundamental concepts of mathematics, basic sciences, the humanities and social sciences, engineering topics and communication skills to solve a problem.

Engineering design is the process of devising a system, component, or process to meet specific needs. It is a decision making process in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. The design process includes these elements:

- The establishment of objectives and criteria
- Synthesis and analysis
- Construction, testing and evaluation
- Consideration of applicable engineering standards

The engineering design activity should include most of these features:

- Creativity
- Modern design theory and methodology
- Formulation of design problem statements and specifications
- Consideration of alternative solutions
- Consideration of realistic design parameters and constraints, such as:
    - Physical constraints
    - Economics
    - Environmental factors
    - Sustainability
    - Manufacturability
    - Health and safety
    - Ethical concerns
    - Social concerns
    - Political factors
    - Aesthetics

Scope of Project

A minimum of 30 hours of total work input are required for each unit of senior project credit (150 hours minimum for the entire project). Included is the time spent in writing the final project report. Most students who have completed the senior project have reported spending an excess of 30 hours per unit on the total project. For this reason, you should give serious thought to the scope of your project. Some preliminary research is necessary to determine the best course of action and the probable time involved. If you estimate that your project will require more than about 200 hours of work, you may want to scale down your original project idea to insure that it can be completed on time. Generally, a small project where creativity and workmanship can be kept high is preferred over a large project that may require excessive time performing routine skills. Don't try to do too much.

Not all project ideas may be of a suitable scope when first conceived. But, in cooperation with your project supervisor, you may be able to adjust your idea to fit the target scope for the senior project. For projects that are too large, focusing on a smaller piece of the overall problem may shrink the idea to a suitable scope. For projects that are too small, considering additional background or perspectives on the problem may grow the idea to a scope suitable for a senior project.

When considering the scope of your project, part of the project may require some work done separately from your actual senior project time schedule. For example, concurrently scheduling a *BRAE 400 Special Problems* course as an independent effort to cover the expected extra time required by a larger than normal project may insure completing the project on time. If additional lab time is needed, concurrently scheduling a *BRAE 240 Agricultural Engineering Laboratory* course may be appropriate.

You must also consider the financial requirements to complete the scope of the project. You should know the projected cost and the source of revenue for constructing the project before you commit to doing the project.

Responsibilities of Department

You have primary responsibility for all phases of the senior project. However, the faculty of the BioResource and Agricultural Engineering Department will provide guidance and assistance throughout the senior project experience.

The BioResource and Agricultural Engineering department head coordinates the BRAE 460/461/462 activities. This includes the formal approval of the scope of each project as detailed in the project contract. The department head may witness the demonstration of each completed project, will approve the final report, and will review the grading to insure a uniform standard throughout the department.

Project Supervisor

The project supervisor is the faculty member who provides technical guidance and direction for your senior project. Try to select a faculty member who has expertise in your proposed project area. [Note that the supervisor for your senior project doesn't have to be the same faculty member who has served as your academic advisor.] Seek your supervisor's counsel on the pros and cons of your proposed project idea. The supervisor will review the initial contract statement and give suggested changes, if needed. Your supervisor will also act as a resource person when needed at any stage of the project activity. Your senior project supervisor will be the primary evaluator of both your hardware (or other product) and your written report. Maintain good communications with your supervisor throughout the entire senior project period (weekly meetings regularly scheduled at a mutually agreeable time are a good idea). Senior projects may only be completed during a quarter when your project supervisor is available for final evaluation.

PROJECT CONTRACT

Overview

The project contract is a binding statement of the work to be undertaken in order to receive five units of university credit and to satisfy the senior project requirement. The parties to this written document are you, the student, your project supervisor, the department head, and your project's financial sponsor (if appropriate). Sample contracts are shown in Appendix A.

Components

Each of the parts of the project contract are described below.

Title. The project title should describe the study undertaken. It should be descriptive, but not too long (an ideal title is only about seven words). The title should accurately reflect the scope of work. For example, do not include *Evaluation* in your title unless your project includes a significant testing and evaluation component. Discuss the title with your project supervisor once the project has been determined.

Background Information. Briefly discuss why this particular project (aside from needing it to graduate) was chosen and what the outcome probably will be.

Statement of Work. State specifically what work will be undertaken.

How Project Meets Requirements for the ASM (or BRAE) Major. Explain briefly how your proposed project will meet the requirements for a senior project for your specific major (check the *Project Requirements* portion of these Guidelines, pages 2-3, for more about the requirements for each major). This section of the contract will contain several sub-sections where you can explain briefly how your project meets each element of the requirements for your major.

ASM Project Contracts - In this section, your ASM project contract should state how your proposed project will incorporate the quantitative analysis and solution of technical, business or management problems. If the project is primarily technical, what impact will it have on the client's business or management practices? If the project is primarily business oriented, how will the technical facts, limitations, or capabilities affect the business/management decisions that are to be made. Elements to discuss (the details will depend on your project) include:

- ASM Project Requirements
    - Application of agricultural technology
    - Application of business and/or management skills
    - Quantitative, analytical problem solving
- Capstone Project Experience
    - Incorporates and integrates knowledge/skills from earlier coursework

- ASM Approach
  - Systems approach
  - Interdisciplinary features
  - Specialized agricultural knowledge.

BRAE Project Contracts - In this section, your BRAE project contract should state how the proposed project will incorporate the fundamental elements and features of the engineering design process. Elements to discuss (the details will depend on your project) include:

- Major Design Experience
  - Establishment of objectives and criteria
  - Synthesis and analysis
  - Construction, testing and evaluation
  - Incorporation of applicable engineering standards
- Capstone Design Experience
  - Incorporates and integrates knowledge/skills from earlier coursework
- Design Parameters and Constraints [the project should address a significant number of these categories of parameters/constraints, although if a particular constraint category does not apply to your project, you may insert N/A]
  - Physical economic and environmental constraints
  - Sustainability and manufacturability
  - Health and safety concerns
  - Ethical, social and political considerations
  - Aesthetics

Project Parameters. Note: For ASM contracts, this is a separate section. For BRAE contracts, parameters and constraints are considered together in the previous section. In either case, parameters should list the specific criteria that apply to the project, such as required capacity, cost of materials, and the required values for any special performance measures.

Parameters should be quantitative and objectively verifiable if at all possible. For example, don't say *Must be economical and easy to operate*. How economical? Who decides how easy is easy enough? Different people will interpret this statement differently. Consequently, when the project is completed, there is no way to determine objectively whether or not this parameter has been achieved. These vague goals can be rewritten in a quantitative, verifiable way as follows: *The cost to construct the unit shall be no more than $X, and the estimated operational costs shall be no more than $Y/hour. A team of two workers shall be able to assemble/attach the unit in less than Z minutes.*

List of Tasks and Time Lines. This list is an expansion of the statement of work. Break down the project into a number of specific tasks that must be accomplished before the project is completed. Next, estimate the time it will take to perform each of the tasks on the list. By adding the small jobs one by one, you can determine an overall project time estimate. Include an allowance for everything done on the project including reading these instructions, preparing the contract meeting with the project supervisor, preparing project posters, and writing and revising the project report.

Financial Responsibility. Make an estimate of the cost for materials or any other out-of-pocket expenses. Discuss this with your project sponsor (if other than yourself). Obtain the signature of the person responsible for paying for these expenses (yourself or the project sponsor, as appropriate) to document their agreement to supply the necessary funds.

Final Report Due Date. The final draft of the project report (after all reviews and corrections) is due the Friday of the last week of classes of the quarter in which you take BRAE 462. Note: The due date is *not* the Friday of Finals week. Check the Cal Poly catalog or web page for the dates for future quarters.

Number of Printed Copies Required. The university only requires that one copy of the senior project report be submitted. This will be sent to the library for microfiche, and then returned to the department. However, you may wish to produce additional copies of your senior project report for yourself, your project supervisor, or your project sponsor (if any). You must determine how many copies are required.

Electronic Copy Required. The department requires an electronic copy (PDF file) of your report for use in its program accreditation and recognition processes. Burn this file onto a CD and submit it with your printed copy.

Approval Signatures. As part of BRAE 460, you must submit 2 clean, printed copies of the project contract, signed by you, your project supervisor, and your project sponsor (if you have one). After review and signature by the department head, one copy will remain in the department office, and the other will be returned to you. You are responsible for photocopying the additional contracts as needed for the project supervisor and others.

Schedule of Progress. A schedule of progress must be attached to the senior project contract. This illustrates the calendar for your project plans in a graphical style, showing what period of time is planned for the different tasks that must be accomplished. A Gantt chart (see Figure 1), or any other form of task calendar may be used. The chart should list in some detail the tasks and sub-tasks to be done, indicate the logical order of the tasks, and highlight special milestones for the project. The schedule should be approved and signed by your project supervisor. A sample schedule of progress is shown in Appendix B.

Schedule of Progress	Week									
Task	1	2	3	4	5	6	7	8	9	10
Literature Review	■	■	■	■	■	■				
Library & Internet	■	■								
Interviews	■		■							
Write 1st Draft				■						
Edit Draft				■						
Submit for Review				X						
Supervisor Reviews					■					
Correct as Needed						■				
Final Draft Complete						X				
Design			■	■	■	■	■	■	■	■
Concept			■	■						
Preliminary Calc's					■	■				
Preliminary Drawings							■	■	■	X

Figure 1. A Gantt chart format may be used to display the schedule of progress.

Modification

You must obtain prior approval from the project supervisor and the department head if you find it necessary to make deviations from your original project contract. For minor changes, this can be done through a memorandum which states the proposed changes and reasons for them. The memo should be addressed to the department head, with copies to the project supervisor and sponsor (if any). If approved, the signed modification agreement will then become a part of the contract. Major changes will require submission and approval of a new contract.

Sample Contracts and Schedule

Sample senior project contracts are shown in Appendix A. A sample schedule of progress shown in Appendix B.

Blank Forms for Contracts and Schedules

Blank forms for senior project contracts and schedules of progress may be downloaded from the BRAE Senior Project web site on BlackBoard. This web site is accessed through the *My Cal Poly* portal at http://my.calpoly.edu/.

PROCEDURES

This section of the guide is intended to provide assistance in accomplishing the requirements that have been previously given. Grading procedures and specific deadlines are clarified. Some suggestions to help plan and complete the various phases of the project work are given.

Time Schedule and Penalties

You are expected to complete your senior project by the end of the quarter in which you are enrolled in BRAE 462. Plan ahead, and allow for unforeseen delays (such as delivery times for parts ordered), so the project may be completed on time. When circumstances require a time extension, advance approval by the department head will be required.

A typical time line for a senior project is outlined below. Minimum requirements are given for BRAE 460/461/462. Additional tasks may be added by your BRAE 460 instructor or your BRAE 461/462 project supervisor. Appropriate calendar deadline dates can be obtained by referring to the current Cal Poly Class Schedule or Catalog.

First Quarter (BRAE 460). These are the requirements for BRAE 460.

1. Enroll in BRAE 460 during registration. Participate in the class and complete the assignments given.
2. Read and critique previously done senior projects.
3. Participate as an observer in the "poster session" during college hour (Thursdays at 11:00 a.m.) the last week of regularly scheduled classes for the quarter. Critique the poster displays presented at this session, as directed by your instructor.
4. Develop a contract for your senior project with counsel from project supervisor. The contract will describe the project, explain how it will meet the requirements for senior projects for your major (ASM or BRAE), and document approvals from your project sponsor (if any), your project's supervising faculty member, and the BRAE department head.
5. Develop a schedule of progress (calendar-task-chart) with counsel from your project supervisor. This schedule will identify specific tasks to be done, the schedule for performing these tasks, and the target dates for completion.
6. Submit typewritten and signed copies of final drafts of your project contract and schedule of progress to the BRAE 460 instructor by the last day of classes.

A letter grade will be assigned based on the following:

1. Class assignments
2. Quality of Contract and Schedule submitted. Both the quality of the project proposed and the written contract and schedule will be considered.

Failure to pass will require re-enrolling in BRAE 460. Failure to turn in an acceptable project contract or schedule of progress, with signatures documenting required approvals, may result in failure to pass BRAE 460.

Second Quarter (BRAE 461). These are the requirements for BRAE 461.

1. Enroll in BRAE 461 during registration.
2. Weekly communication with project supervisor is expected.
3. Turn in to your project supervisor for evaluation by last day of classes:
   a. The final version of the following portions of the senior project report:
      i. Introduction
      ii. Literature review
   b. For hardware projects, submit complete working drawings and a materials list approved by your project supervisor. You should have already ordered the materials from this list. Enough lead time must be allowed to enable construction to begin no later that the first week of the quarter when you enroll in BRAE 462.
   c. For software projects, a submit a preliminary design for the program or other work to be done, or the data you have collected. Data collection should be complete enough that you can start the data analysis and summary no later that the first week of the quarter when you enroll in BRAE 462.
   d. Detailed outline of the planned procedures and methods for completing the project. This outline will form the basis of the "Procedures and Methods" portion of your senior project report. This section may require modification as the project is being constructed or the design altered so that such changes will be reflected in the final report turned in at the end of BRAE 462.
   e. Submit a revised and updated schedule of progress for the work remaining to be done on your senior project.
   f. Submit an updated explanation of how your project meets the requirements for senior projects for your major. As you work through your project, you may realize that the explanation you provided in your project contract needs to be revised or expanded. The final version of this explanation will be included as an appendix in your senior project report.
4. Prepare a project poster and participate in the poster session during college hour (Thursday at 11:00 a.m.) the last week of regularly scheduled classes for the quarter. The poster display should reflect the nature of the project and the progress made during the quarter. Non-participation in the poster session will result in an F grade for BRAE 461.

A letter grade will be assigned based on the following:

1. Progress made

2. Quality of work done
3. Informativeness and quality of the poster presentation

Failure to pass will require re-enrolling in BRAE 461. Failure to pass BRAE 461 may result from failure to turn in any of the items listed under #3 above, in acceptable form, and on time, or failure to prepare and present your BRAE 461 poster.

Third Quarter (BRAE 462). These are the requirements for BRAE 462.

1. Enroll in BRAE 462 during registration.
2. Complete all senior project requirements. Weekly communication with project supervisor is expected. Early submission of the drafts of the remaining sections of your project report are encouraged, so that they may be reviewed and returned in time to allow submission of the final draft by the end of the quarter.
3. Prepare a project poster and participate in the poster session during college hour (Thursday at 11:00 a.m.) the last week of regularly scheduled classes for the quarter. The poster display should reflect your completed project, illustrate your hardware or software solutions to the key problems solved, etc. Non-participation in the poster session will result in an F grade for BRASE 462.
4. Turn in to your project supervisor by last day of regularly scheduled classes the final typewritten senior project report, including all supplemental materials. This will require, of course, that you hand in draft sections of the report much earlier, so they can be reviewed by your project supervisor, and so you can make the suggested revisions prior to the due date for the final copy of the report.
5. Turn in an electronic copy (PDF file) of your report for use in the department's program accreditation and recognition processes. Burn this file onto a CD and submit it with your report.
6. Complete an ASM or BRAE Graduating Senior Survey. The surveys are available at these web addresses:

   a. (for ASM) http://brae.calpoly.edu/students/asmsurvey.html

   b. (for BRAE) http://brae.calpoly.edu/students/braesurvey.html

   When you complete the survey form and click the *submit* button, the site will show you a receipt form indicating that you have taken the survey. Print out this receipt, and submit it with the final copy of your senior project report.
7. Submit your senior project report to the Cal Poly Library. Detailed information regarding this procedure can be found at: http://lib.calpoly.edu/seniorprojects/seniorproject_infopacket.pdf . A tutorial can be found at http://lib.calpoly.edu/research/tutorials/seniorprojects/

   Step A. Pay the $12 senior project fee either in person at the Cashier's Office in the administration Building or online through the Cal Poly Portal.

Step B. Download and fill out the Senior Project Requirement Form. Obtain the form from: http://www.lib.calpoly.edu/collections/seniorprojects/submissionform.pdf. Submit the completed form and the receipt for the senior project fee with the final copy of your senior project report.

Step C. Upload an electronic copy of your senior project in the Cal Poly Library's DigitalCommons at http://www.digitalcommons.calpoly.edu/.

A final letter grade for the project will be given based upon the following:

1. Work habits during the completion of the project
   a. Ability to work independently, yet keep project supervisor informed of status
   b. Maintaining a continuous work activity and meeting deadlines as required
2. Demonstrated creativity on project hardware and software
3. Quality of completed project hardware (or design)
4. Quality of project written report
5. Informativeness and quality of the poster presentation

Failure to pass BRAE 462 may result from failure to turn in the completed senior project report, in acceptable form, and on time, or failure to prepare and present your BRAE 462 poster. Failure to pass will require that you re-enroll in BRAE 462, and establish a revised calendar of progress for the new quarter.

Conducting the Project

Project Planning. Throughout the senior project, success will depend on how well the work is planned and scheduled. The list of tasks and time schedule breakdown required on the contract will cover the broad activities involved in the project. For your schedule of progress, you should identify subtasks in greater detail to help schedule the performance of each of the major phases of project work. Considerable lead time is necessary for procurement of special equipment or materials and should be planned for well in advance. One good method is to sketch out the various jobs on a calendar-task-chart or schedule of progress, thus showing the span of time required to do each task. A Gantt chart is one simple format for this schedule of progress (see Figure 2). If the start of one task is dependent upon the completion of another task, this should be shown on the chart. If the overall span of time for completing all of the events exceeds the available time, some adjustments will be necessary. The most important thing that the chart will show is the necessity for maintaining a steady activity of work throughout the senior project course. A sample schedule of progress is shown in Appendix B.

Schedule of Progress	Week									
Task	1	2	3	4	5	6	7	8	9	10
Literature Review										
Library & Internet										
Interviews										
Write 1st Draft										
Edit Draft										
Submit for Review				X						
Supervisor Reviews										
Correct as Needed										
Final Draft Complete						X				
Design										
Concept										
Preliminary Calc's										
Preliminary Drawings										X

Figure 2. A schedule of progress will aid in project planning.

Hardware (Construction) Phase. Most senior projects in the BioResource and Agricultural Engineering Department involve some shop work or construction. The Ag Engineering Lab (Labs 6/7) has been set up to facilitate this type of activity. Check in advance with your faculty supervisor or the Lab 6/7 supervisor to see if the type of construction activity needed can be accommodated in this lab. Special approval of the department head and project supervisor is needed for senior project construction work done outside of the BioResource and Agricultural Engineering Department.

Appropriate materials and construction procedures should be used for the project. Although the project may be one of a kind, it may serve as a prototype for others. Good workmanship and eye appeal are important.

A diary kept on construction activities will come in handy when writing the *Procedures and Methods* section of the report at a later date. Note all expenses, as a cost analysis should be included in every hardware project report detailing the cost of all supplies and materials.

Figure 3. A project diary and digital photographs of your project activities will be helpful as you prepare your senior project report and poster.

Take lots of photographs as the work proceeds. Digital photographs are easy to insert into your senior project report, and are be the best way to present some types of information (e.g., construction and assembly details, physical constraints, test set-ups, etc.). Select the best pictures for inclusion in the report. Remember that pictures used in the project posters will be printed on a large scale, so high resolution images will be required.

Senior Project Lab (Labs 6/7) Utilization. The department has a technician assigned to Labs 6/7 Monday through Friday. The hours Labs 6/7 will be open will be posted outside of the Lab. The technician, a bona fide student assistant, or a faculty member must be present in Labs 6/7 to use the Lab facilities. If the construction phase requires an estimated 80 hours, every available Lab hour must be utilized in order to get the job done. Keep in mind that the actual time required to complete the senior project may be 1.5-2 times the estimated time. During quarter break Labs 6/7 may be open on a reduced time basis, as the technician may be assigned to other projects.

You are responsible for knowing and following department policies regarding Lab use. A copy of the current department lab policies is included in Appendix C. A signed work permit is required to authorize you to work in the labs on your senior project. This work permit must be signed by your senior project supervisor, and will be kept on file in the lab 6/7 technician's office.

Poster Session Presentations

Poster presentations have become a common method to communicate technical information at professional society and industry trade meetings or conferences. With poster presentations the audience determines the speed at which the material is communicated - not the presenter. Poster sessions provide an opportunity for members of the audience to quickly see what the project is about, or to ask brief questions on specific issues, or to develop conversations which can evolve into in-depth discussions of the project, depending on their level of interest. Preparing poster presentations about your senior project will give you valuable experience with this form of visual communication.

Note: The department will keep your posters after the poster session, for future use when displays of student work are shown (Fall Preview Day, Open House, etc.). If you need your poster for some reason after the poster session (for example, the student project and poster competition at the ASABE California-Nevada Section meeting), contact the department office.

Poster Production. Posters printed on a large scale printer are preferred. This production technique has become the standard for professional society or commercial poster sessions because it results in a more professional appearance for your poster than the old-style technique of cutting and pasting items to a poster board.

Use PowerPoint for the layout of your poster, with a 29 x 39 inch page size. You are responsible for preparing a PowerPoint file, complete with all text and images ready to print. *Pony Prints* in the Cal Poly library is set up to print posters at a reasonable cost. It is not necessary to print on the more expensive glossy photo paper. The department will make available a 30 x 40 inch backboard and stand for the display of your poster at the poster session.

Poster Design. To serve as an effective communication tool, the poster must be well designed and executed. The poster should be an organized, concise, structured and pointed presentation. Systematic planning of the poster design and its layout is crucial in effectively communicating with the audience. Following are some key principles for effective poster design.

General - You will be judged more on the soundness of the work being reported than on the flashiness of your display. However, poor poster design or execution will prevent effective communication with your audience.

Avoid unnecessary words, charts, and tabulations on the poster. Every excess line on your graph, every excess word (included for no better reason that *It's usually stated that way.*) buries you deeper in the general noise. Save the subsidiary detail for the chats, and for the display notebook that you will be handing the deeply interested visitor to examine while your converse with others.

Focus - It is impossible to present in a poster format all the information contained in the senior project report. A key planning decision is what to exclude, and what to incorporate. Focus on the most important aspects of your project, and limit your poster to a presentation of those aspects.

Identification - Your name, project, status (461/462), and major should be prominently displayed. A modest portrait appropriately placed helps the approaching stranger distinguish the busily engaged presenter from animated visitors and helps draw the newcomer comfortably into friendly conversation. Your major is important because senior project requirements for ASM are different than for BRAE. Identifying your major will help orient the viewer and allow them to judge your poster and project against the appropriate expectations.

Clearly indicate whether your poster is a BRAE 461 or a BRAE 462 poster, since these will have different objectives. The BRAE 461 poster should tell the viewer what you plan to do, and explain why this is important (what problem will be solved). The BRAE 462 poster should tell the viewer what you have accomplished, including (probably) test results showing that design requirements have been met and/or that the targeted problem has been solved. Because of these differing requirements, it is important that the poster for BRAE 462 be developed afresh, and not merely recycle what was shown in the BRAE 461 poster.

Sections, Panels or Frames - Posters generally contain several panels or frames, which may include text, graphs, diagrams or pictures. The message of each frame must be grasped quickly by members of the audience, not all of whom may have a deep interest in your topic. Objectives and conclusions or results must be clearly and quickly understood by the viewer.

Usually, individual sections of the poster (Objectives, Methods, Results, etc.) should be placed on separate panels, with good visual spacing between sections. This *white space* contributes to eye flow and readability. Headings for these sections should stand out from the body text. Headings give the viewers organizing clues - making it easier for them to categorize and find information quickly. Section headings serve to sequence the content and identify the visual flow.

Textual Elements - The message of any textual elements must be easy to grasp. Therefore effective text design will be a major contributor to a successful poster. It is often more effective to use short phrases emphasizing key words or concepts than grammatically correct full sentences. A bulleted list format eliminates the need for full sentences. If you do use full sentences, make them short, and employ simple sentence structures. Use common, easily understood words, not jargon.

Use upper and lower case letters in both headings and body text. Any copy of more than five or six words will be more readable if both capital and lower case letters are used instead of capitals only.

Select a good, readable font (alphabet style) in which all letters are easily recognized with a minimum of confusion. A Gothic type sans-serif style such as Arial or Helvetica might serve as a model.

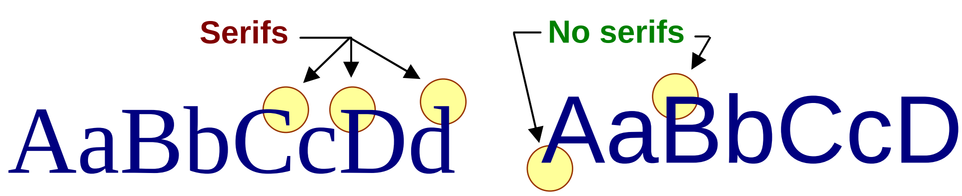

Figure 4. *Serifs* are the stylistic flourishes added to the basic strokes forming each letter (left). A *san-serif* font (right), which leaves the basic strokes of each letter unadorned, is generally easier to read in a poster format.

Select a font size so that your smallest lettering is at least 1/4" in height, 1/32" in thickness of line and at least 3/8" in the space between lines. For example,

24 point HELVETICA

is a font and size that just does meet these size specifications.

Visual Elements - The visual elements of the poster should be arranged to optimize audience understanding. A few, large, simple illustrations will generally work better than a greater number of smaller, more complex ones.

Remember that viewing a poster is very different than reading a written report. It is almost never correct to use a drawing or graph directly from your written report as a visual for your poster, even if enlarged. Drawings, graphs or tables for the report usually contain more detail than can be effectively communicated in a poster format. Re-draw the drawings or graphs for your poster to emphasize a single, unified idea. Make drawings and diagrams bold and simple, and include only the essential details.

Photographs, to be effective in the poster format, will have to be enlarged. So use high resolution images that don't lose clarity or focus when enlarged.

Plan visuals so their longest dimension will be horizontal. It is difficult to view vertically oriented materials in rooms with low ceilings.

Check List **-** A checklist for senior project poster design is given in Appendix D.

Project Report

The project report is the means by which the sum total of the project activity and results is communicated to others. Take extra effort to make sure good grammar and sentence construction are used. Report specifications and formative requirements are given in detail in the *Report Specifications* section of these Guidelines.

Report Submission

Required Copies. The university only requires that one printed copy of the senior project report be submitted. However, you may wish to produce additional copies of your senior project report for yourself, your project supervisor, or your project sponsor (if any). You must determine how many copies are required.

Turn in an electronic copy (PDF file) of your report for use in the department's program accreditation and recognition processes. Burn this file onto a CD and submit it with your report.

Graduating Senior Survey. Complete an ASM or BRAE Graduating Senior Survey. The surveys are available at these web addresses:

a. (for ASM) http://brae.calpoly.edu/students/asmsurvey.html

b. (for BRAE) http://brae.calpoly.edu/students/braesurvey.html

When you complete the survey form and click on the "submit" button, the site will show you a "receipt" form indicating that you have taken the survey. Print out this receipt, and submit it with the final copy of your senior project report. [We have on occasion experience some difficulties when accessing these surveys through certain web browsers. Internet Explorer seems to work fine, as do some (but not all) versions of Netscape. If you have troubles, try using a different web browser.]

Cashier's Receipt. Go to the state cashier's window at 131E Administration Building or go online at the Cal Poly Portal and pay the library submission fee. Submit copy of the receipt with your senior project.

Signatures. The required number of senior project copies is turned in to the project supervisor for signatures. The receipt for the library submission fee must be attached.

Electronic Submission to the Library. Download and fill out the Senior Project Requirement Form. Obtain the form from: http://www.lib.calpoly.edu/collections/seniorprojects/submissionform.pdf. Submit the completed form and the receipt for the senior project fee with the final copy of your senior project report to your advisor. Upload an electronic copy of your senior project in the Cal Poly Library's DigitalCommons at http://www.digitalcommons.calpoly.edu/. Detailed information regarding this procedure can be found at: http://lib.calpoly.edu/seniorprojects/seniorproject_infopacket.pdf . A tutorial can be found at http://lib.calpoly.edu/research/tutorials/seniorprojects/.

REPORT SPECIFICATIONS

This section will spell out the specific style and format to be used in the senior project report. The format which has been selected by the BioResource and Agricultural Engineering Department is a report style widely used for technical writing in industry today. Instructions detailed in this section must be followed very closely. The final copy must include the required sections shown below and in the exact order listed. The organization of paragraphs, spacing, and referencing format must be exactly the same as indicated here. A sample senior project is included in Appendix F of these guidelines to illustrate the proper layout and use of the following sections of the senior project.

Technical Writing Style

[This section currently being revised. In the meanwhile, an excellent Internet reference for technical writing is found at:

http://www.io.com/~hcexres/tcm1603/acchtml/process_over.html

The sections entitled *Power-revision techniques* and *Overview of sentence-level revision* on this site are particularly helpful. Examples of problem sentences and suggested revisions are provided.]

[Additional technical writing tips will be found in Appendix E, as yet to be written.]

Past tense shall be used in the Introduction and other early sections of the report, but present tense is acceptable for the *Discussion* section and for the *Recommendations* section (see Figure 5).

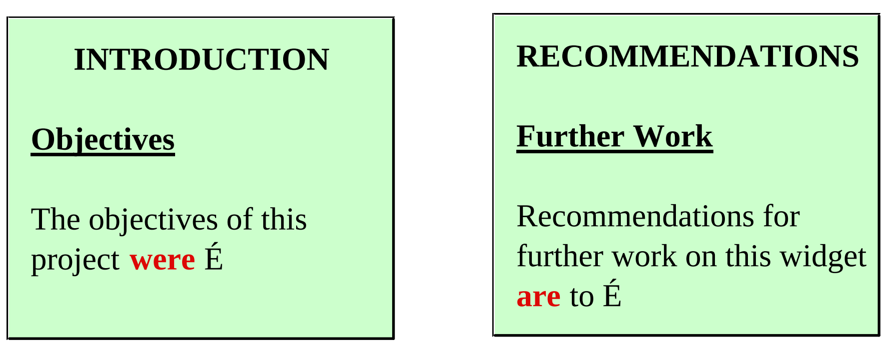

Figure 5. Use past tense in the first sections of the report, but present tense for the Discussion and Recommendation sections.

Sections of the Senior Project Report

General. All reports must have the following sections, with the exception of a few as noted. Each of the following sections should be in the same order in the senior project report as presented here. A copy of the senior project contract is not included in the final report copy.

Cover Binder. The senior project report must be turned in unbound in a single black pressboard cover (see Figure 6).

Figure 6. The upper two photos depict an acceptable black pressboard cover. The lower three photos are not acceptable.

Cover Label. The cover label must show the title, author, major (BRAE or ASM) and year of submission (see Figure 7).

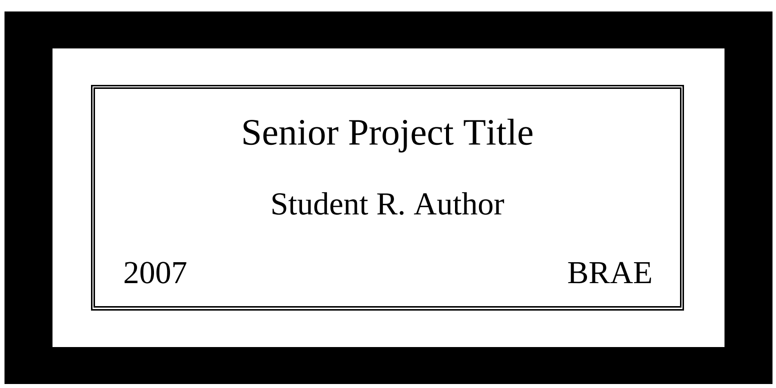

Figure 7. Layout for the cover label.

Title and Signature Pages. Examples of the required content and layout for these pages are shown in the sample senior project report found in Appendix F.

<u>Preface or Acknowledgments</u>. This section is optional. A preface is a short statement relating the report to some prior work done in the same general area. Acknowledgments of support or assistance can be made in this section.

<u>Abstract</u>. An abstract is a brief summary paragraph or two telling what was done and the results obtained. The abstract will provide a quick reference to the project by other persons in the future. The abstract should be written after the report itself is completed, so you will know the details and most significant points to be summarized in the abstract.

<u>Disclaimer Statement</u>. A disclaimer statement as shown in the sample senior project report (Appendix F) must be included in all senior project reports to satisfy legal requirements of the university. Word the statement exactly as given.

<u>Table of Contents</u>. Follow the layout of the *Table of Contents* shown in the sample senior project found in Appendix F.

<u>List of Figures</u>. All blueprints, drawings (including oversize drawings), graphs, and photographs are considered to be figures. They must be numbered consecutively with Arabic numerals and have an appropriate caption. See the *Drawings* subsection under the *Format* heading below concerning the placement of oversize drawings in the report. If there are no figures in the main report body, no list of figures is required.

<u>List of Tables</u>. Tables are numbered consecutively with Arabic numerals and must have an appropriate title. If there are no tables in the main report body, no list of tables is required.

<u>Introduction</u>. The purposes of the introduction are to (1) present background information on the subject matter of the report, (2) explain the need for the project, and (3) list the goals or objectives of the project. The background portion of the introduction should be general and relatively brief. The Literature Review section of the report is the place to present a comprehensive discussion of the technical background for the project. Since the introduction will vary according to the nature of the project, it is advisable to break down the various topics with subheadings. Some possible subheadings are:

Background

Justification

Objectives

The Objectives section would include discussion covering the scope of work involved with the senior project, and a listing of the specific goals or objectives for the project. A summary of design parameters and/or constraints is appropriate here.

<u>Literature Review</u>. A literature review is required for all senior projects. No project should be conducted in a vacuum; information about the problem, construction techniques, and solutions can be found in professional journals, through interviews with industry specialists, and books. When citing a source in the text, use the author-year format. The complete details for that source will be given in the *References* section of the report. ASABE format should be used for both citing sources in the text, and for providing complete citation details for each source in the *References* section.

The literature review summarizes and integrates the knowledge you've gathered on the various facets of your senior project topic. Writing a literature review is like doing a term paper on the topic of your project. The literature review will help you find out if problems you may face in your project have been solved before, and how. It will help you identify standards, laws, theories, data or facts related to your project. Preparing the review will help you identify the proper methods, data and analytical procedures for your project. Reading will familiarize you with the subject. Putting your knowledge into writing will ensure you understand it clearly.

Your *Literature Review* and *References* sections must be linked (see Figure 8). Everything discussed in the literature review must be cited in the reference list. Everything listed under references must be discussed, even if briefly, in the literature review. If a source isn't worth discussing in the literature review, it shouldn't be listed as a reference.

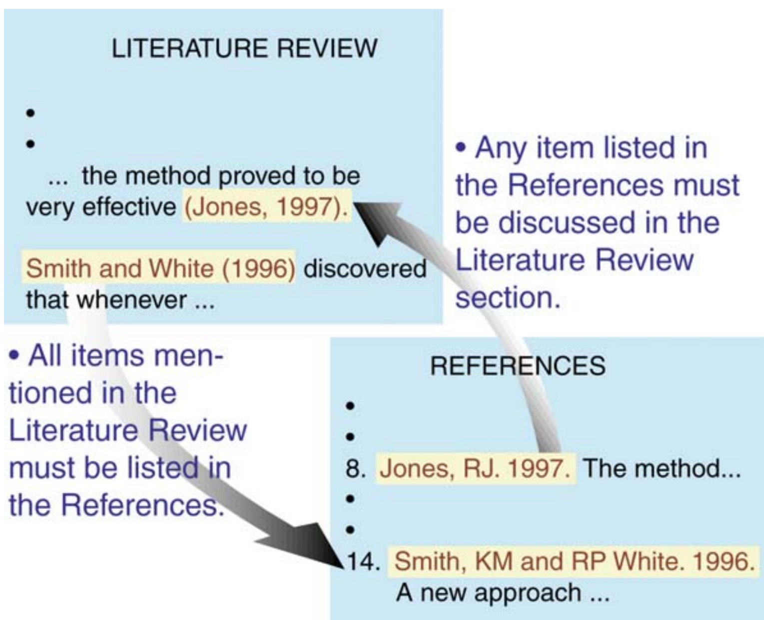

Figure 8. Sources discussed in the text must be listed in the Reference section, and sources listed in the Reference section must be discussed in the text.

The literature review should not be merely a summary of what was found in each reference, presented one source after another. Rather, it should be organized under sensible sub-topics, such as materials, design approaches, problems with existing solutions, etc. All the information found regarding a sub-topic should be presented together, even if gathered from several sources.

Procedures and Methods. This section elaborates on what was actually done, the methods used, and the equipment needed. There may be several subheadings needed to adequately cover the topic. The purpose of this section is to provide enough information that another person could duplicate the study or project. Do not discuss results, nor speculate, imply, assess, evaluate or interpret any results in this section. Some possible subheadings for this part of the report are:

- Design Procedure
- Construction Procedure
- Measurement Procedure
- Survey Procedure
- Chemical Analysis Method
- Statistical Method and Data Processing
- Equipment Selection
- Testing Procedure
- Evaluation Procedure
- Cost Analysis
- Laws, Regulations, and Standards

Results. The purpose of this section is to summarize the results. A description of the final product or summarization of data is included in this section. For a construction project a few scaled drawings or photographs may be presented. For a laboratory analysis the final data and statistics are described.

The majority of design drawings, plus detailed design calculations, are often included in an appendix. However, some projects are better explained if the majority of drawings or data appear in this section rather than in an appendix. Comments regarding the validity of the results, recommendations, etc. are not included in this section.

Discussion. This section includes comments regarding the final product or results. Where pertinent, it should include:

1. A discussion about a particularly difficult construction technique
2. The expected accuracy or transferability of results
3. Design changes made during construction
4. A safety analysis
5. A cost and management comparison between alternative designs

Recommendations. Recommendations for improvement upon the senior project results or methods are included here. It will also include suggestions regarding the best manner to proceed on a continuation of the project.

References. The references are listed using American Society of Agricultural Engineers (ASABE) format, in alphabetical order by the author's last name. References are numbered consecutively from one, on. Although the examples below are assembled by category, the reference section should mix all types of references together. Examples of correct referencing are shown in the following examples.

Book

1. Addison, H. 1966. Centrifugal and other rotodynamic pumps. Chapman and Hall, London, 565 p.

2. Jensen, M.E. 1969. Programming irrigation for greater efficiency. In: Optimizing the Soil Physical Environment Toward Greater Crop Yields. D. Hillel (Ed.). Academic Press, Inc., New York. pp. 133-161.

3. Sprinkler Irrigation Association. 1977. Sprinkler irrigation. Irrigation Association, Silver Springs, MD, 615 p.

Journal article

1. Haise, H.R., and E.G. Kruse. 1966. Automation of surface irrigation systems. Proc. Am. Soc. Civil Enineers., J. Irrig. and Drain. Div. 95(IR4):503-516.

2. Hiler, E.A. and T.A. Howell. 1973. Grain sorghum response to trickle and subsurface irrigation. TRANSACTIONS of the ASAE 16(4):799-803.

3. Hsiao, T.C. and E. Acevedo. 1974. Plant responses to water deficits, water use efficiency and drought resistances. Agric. Meteorol. 14:59-84.

Technical report, miscellaneous publication, and extension service bulletin

1. Bloodgood, D.W., R.E. Patterson, and R.L. Smith, Jr. 1954. Water evaporation studies in Texas. Bul. 787, Texas Agr. Exp. Sta., 83 p.

2. Skogerboe, G.V., V.T. Somoray, and W. R. Walker. 1971. Check-drop-energy dissipator structures in irrigation systems. Water Management Tech. Rep. 9, Colorado State University, Ft. Collins, CO.

3. U.S. Department of Transportation, Federal Highway Administration. 1973. Design series No. 3. 105 p.

Conference proceedings

1. Haise, H.R. and E.G. Kruse. 1966. Pneumatic valves for automation of irrigation systems. Proc. 6th Congr. Internatl. Comm. on Irrig. and Drain. Specialty Sessions Rept. No. 1:S-1 to S-8.

2. Hanson, E.G. 1966. The seepage problem defined. ASAE Paper No. 66-728. ASAE, St. Joseph, MI 49085.

Unpublished conference proceedings

1. Jones, J.M. 1979. Design of trash compactors. Presented at the annual convention of the American Society of Trash Compactors, Denver, Colorado, July 22-23. 13 p.

Other

1. American Society of Agricultural Engineers. 1978a. Agr. Eng. Yearbook, St. Joseph, MI. S359.1:Trapezoidal flumes for irrigation flow measurement, pp. 534-536.

2. American Society of Agricultural Engineers. 1978b. S263.2: Minimum standards for aluminum irrigation tubing, pp. 524-525.

3. American Society for Testing Materials. 1977. C118: Specifications for concrete pipe for Irrigation or Drainage, Pt 16.

4. Smith, J.D. 1985. Personal communication. Janice D. Smith, PE, Chief Engineer, Brocker Manufacturing, Jafeston, NC.

5. XYZ Company. 1998. XYZ Company Internet Home Page. <http://www.xyzco.com>, referenced July 4, 2000.

<u>Appendices</u>. Appendices are attachments in support of the main body of the report. Each appendix should contain only related material. If there is only one appendix, it is identified only as *Appendix*. If there are two or more appendices, identify them as *Appendix A, Appendix B*, etc.

The first appendix for all senior project reports is titled: *How Project Meets Requirements For The ASM (or BRAE) Major*. This appendix presents in paragraph form the same type of information contained in the project contract section of the same name. Examples of material for this appendix are shown in the sample senior project report found in Appendix F.

Examples of other material suitable for inclusion as an appendix are:

1. Detailed design calculations
2. Original project test data
3. Project construction drawings (as built)
4. Any special form used on the project (e.g., a questionnaire used to conduct a survey)

Format

General. Illustrations such as photographs, drawings, graphs, and charts are valuable in presenting ideas. Use of these illustrations in conjunction with a few well chosen paragraphs describing the construction of a part of a machine may be the best way to make a point.

These types of illustrations must be labeled as figures. A figure or table must have a title which consists of the figure or table number and the caption. The caption should be descriptive of the figure or table contents. The figure or table should be located in the project report immediately after the discussion covering it if possible. Figures should appear in the order in which they are cited in the text. An example of citing a figure is:

> The braces are welded on the inside of the plates to allow the scraper to get close to fences and buildings without scratching them and at the same time scrape close to them. The braces are shown in Figure 7 below.

The format for headings, pagination, etc. must be strictly followed. Each professional organization has its own set of guidelines for proper formatting; the senior project must follow the guides in this publication as listed below.

Figures Other Than Photographs. A figure is to have a single space between the top and the preceding text. A space follows the figure title. The title, including the figure number, is centered beneath the figure. The following example illustrates the placement and format of a figure.

text text text text text text text text text text text text text text text text text text text text text text text text text text text text .

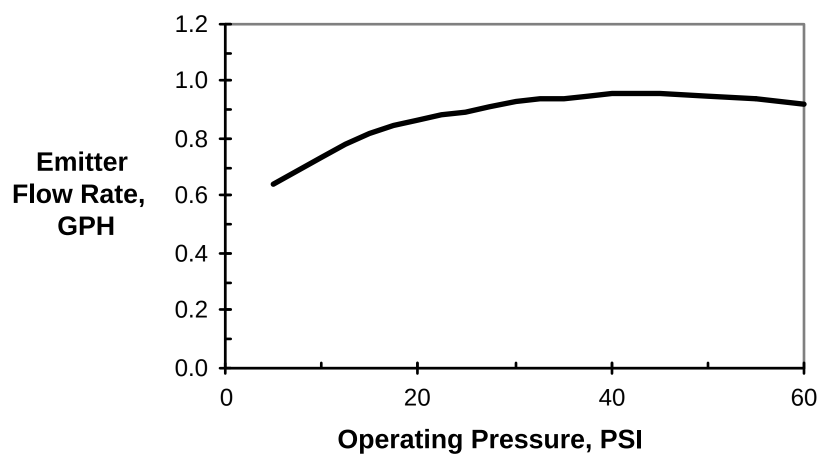

Figure 9. Graph of flow rate versus pressure for an XYZ emitter.

Text text text text text text text text text text text text text text text text text text text text text text text text text text text text

Photographs. Photographs are considered to be figures and must be assigned a figure number and an appropriate caption. The use of photographs is strongly encouraged in the senior project report. Photos may be black & white, or color. Digital images photos may be printed directly on the report pages. If traditional photo prints are used, the final copy of the report which is submitted to the department must be furnished with actual photographic prints. The photographs should be dry-mounted to standard typing paper. Plastic page protectors are not necessary for the photograph and only increase the cost and the bulk of the report.

Tables. The example below illustrates the placement and format of a table. The table number and title are at the head (top) of the table.

text text text text text text text text text text text text text text text text text text text text text text text text text text text text .

Table 1. Properties of various standard beams.

Nominal Size (in.)	Weight per Foot (lb)	Web Thickness (in.)
24 x 7	100	0.747
20 x 7	95	0.800
18 x 6	90	0.624

Text text text text text text text text text text text text text text text text text text text text text text text text text text text text

Drawings. These are labeled as figures and must be assigned a figure number and an appropriate caption. All drawings (including oversize drawings) shall have a title block and be self-explanatory. Standard size drawing sheets should be used. Drawings should be computer prepared, using CAD or other appropriate software. Oversize drawings must be placed in a special envelope which is placed at the end of the report. The special envelope must be three-hole punched and the envelope (with drawings inside) must fit within the cover, not protruding from the sides. Also available are top open-ended plastic sleeves which work well for inserting oversized drawings.

Units. Either English or SI units may be used within the text main body, depending upon the nature of the project and the recommendation of the project supervisor. The SI units may be followed by English units in parenthesis. Units in figures and tables within the main body of the report, and any calculations or text within the appendices, may be in either English or SI units.

Writing and Typing Instructions

Paper. Use good quality white bond paper of 20 lb. weight. The senior project is to be printed on the front side of paper only. A high quality word processor printer output (e.g., laser-printer or equivalent) is acceptable with single sheets of paper. Standard paper size is considered to be 8-1/2 in. x 11 in.

Type Style. Only one font shall be used throughout the text. Letter spacing should be approximately 5 characters per cm (12 per in.). Use a standard font style such as Times New Roman, Century Schoolbook or Arial.

Margins. The margins must be a minimum of 3.8 cm (1-1/2 in.) on the left, and 2.5 cm (1 in.) on the right, top, and bottom (see Figure 10).

Line Spacing. Single space throughout the report except between paragraphs and before and after some headings, as defined below.

Paragraphs. There is no indentation at the beginning of paragraphs. Double space between paragraphs (one blank line between paragraphs).

Section Headings. Section headings should be in full capitals and centered at the top of the page. A triple space follows section headings (two blank lines after the section heading, see Figure 10).

Subsection Headings. Subsection headings have the first letter of all major words capitalized. The headings are underlined without a period following. A double space is used before and after the subsection headings (one blank line before and after the subsection heading, see Figure 10).

Sub-subsection Headings. Sub-subsection headings have the first letter of all major words capitalized. The headings are underlined and followed by a period (don't underline the period). The text begins immediately afterward on the same line (as in this paragraph, for example). A double space precedes the sub-subsection headings (one blank line precedes the sub-subsection heading, see Figure 10).

Appendices. Each appendix is preceded by a single page having the appendix identification (e.g., Appendix A), followed by a blank line, and followed by the title of the appendix (e.g., Design Calculations). These lines are centered, half way down the page. This page is numbered in sequence and in the same fashion as all the other pages of the main body of the report. All pages of the appendices must be numbered.

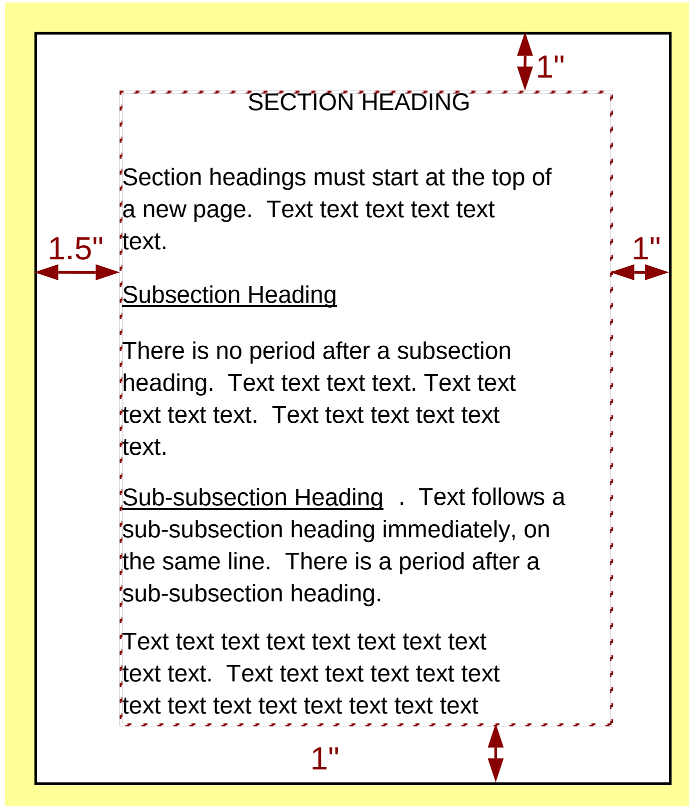

Figure 10. Page layout showing proper format for headings and margins.

Equations. Equations should be indented at least five spaces (or one tab stop [0.5 in.]) from the left hand margin. The equation margin on the left hand side must be uniform throughout the text. Double space prior to and following an equation (one blank line before and after the equation). Equations should be numbered consecutively, with the number shown in parenthesis at the right hand margin. Complex equations will have a more professional appearance if prepared with an equation editor. The example below illustrates the placement and format of an equation.

text text text text text text text text text text text text text text text text text text text text text text text text text text text text .

$$s = \frac{M\,c}{I} = \frac{(14{,}926\ \text{in-lb})\,(1.25\ \text{in})}{(1.42\ \text{in}^4)} = 13{,}140\ \text{psi} \qquad (1)$$

Text text text text text text text text text text text text text text text text text text text text text text text text text text text text

Pagination. All pages are numbered, except the report Title Page. The Table of Contents, List of Tables, and List of Figures are assigned lower-case Roman numerals (e.g. ii, iii, iv, v, etc.). These numbers are centered, one-half inch from the bottom of the page. Note that the Title Page is page i, but is not numbered. All subsequent page numbers (including the Appendices) should be Arabic numerals and appear at the upper right hand corner, 2.5 cm (1 in.) from the right edge and 1.3 cm (1/2 in.) below the top (see Figure 11). There is no special numbering in the appendices (i.e., numbers such as 60a are not used).

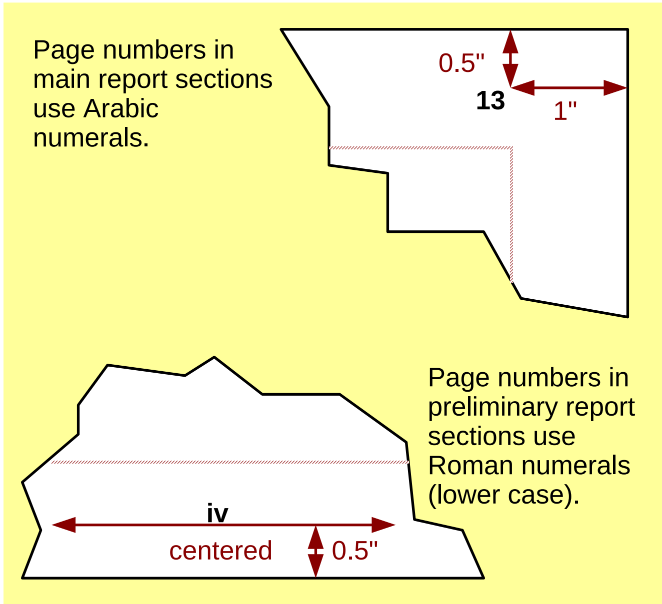

Figure 11. Proper positions for page numbers in preliminary and main report sections.

Reference Citing. ASABE format should be used when citing a reference within the report (http://www.asabe.org/pubs/29_References.html). The authors' name(s) and date of publication should be given. Two common examples are given below.

Example #1: Jones and Hawthorne (1984) found that …

Example #2: Previous work showed that in sub-zero weather the device would operate as designed (Bartles and Jaymes, 1971).

For a dual authored reference, such as those above, both of the last names are provided. For more than two authors of one reference an example would be Brown et al. (1983).

Numerals. Zero through nine should be spelled out except in the cases of:

- Fractions less than one-ninth (e.g., 3/47, not three-forty sevenths),
- Mixed fractions (1-3/8, not one and three-eighths),
- Decimal fractions (0.89, not zero point eight nine), and
- When accompanied by units (3 ft-lb, not three ft-lb).

Any decimal less than one should have the numeral zero precede the decimal point. A number at the beginning of a sentence is always spelled out.

Calculations. All calculations, with few exceptions, should be shown in the appendices, not in the main body of the report.

Units. It is important to use units in showing calculations. Complete units must be shown with all calculations. Where there is enough room to show all numbers and their units on one line, the units may be presented as shown in the following example:

$$V = 8 \text{ mm/day} \times 31 \text{ days} \times 50 \text{ ha} \div 1000 \text{ mm/m} = 12.4 \text{ ha-m} \qquad (2)$$

When there is not enough room to get all numbers and their units on one line, the units should be presented as follows:

$$V = 12 \text{ acre-ft} \times \frac{43{,}560 \text{ ft}^2}{\text{acre}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} = 3.91 \text{ million gallons} \qquad (3)$$

Abbreviations. Standard abbreviations are used without periods unless the abbreviation forms another word (e.g., inches are shown as in.). Other abbreviations can be used, provided they are spelled out and explained to the reader on first use. Some examples of commonly used inch-pound system of units and SI units are shown in Table 2. For those units not listed below, refer to the ASABE Yearbook of Standards.

Table 2. Abbreviations for commonly used units.

Quantity	**Unit**	**Name**
Length	in.	inch
	ft	foot
	yd	yard
	mm	millimeter
	cm	centimeter
	m	meter
	km	kilometer
Area	$in.^2$	sq. inch
	ft^2	sq. foot
	acre	acre
	m^2	sq. meter
	ha	hectare
Volume	gal	gallon
	$in.^3$	cu. inch
	ft^3	cu. foot
	yd^3	cu. yard
	acre-ft	acre-foot
	m^3	cu. meter
	L	liter

Table 2. Abbreviations for commonly used units (continued).

Quantity	**Unit**	**Name**
Time	s min h	second minute hour
Temperature	°F °R °C °K	Fahrenheit Rankine Centigrade Kelvin
Force	lb N	pound Newton
Pressure	psi Pa kPa	pound per sq. in. Pascal kiloPascal

APPENDIX A

SAMPLE CONTRACTS

California Polytechnic State University	December 1, 2009	
BioResource and Agricultural Engineering Department	Smith, Pat	
ASM Senior Project Contract	0123456789	ASM

Project Title

Design, Construction and Evaluation of an Almond Brush Module Cutter

Background Information

A new method of handling orchard tree prunings involves loading them into a modified cotton module maker, compacting them into a 2.1 m by 2.1 m by 5.5 m bale, transporting the bale to a central location, cutting the module into two or three sections and tub grinding the sections. The result is a product which can be used as an alternate energy source. All of the equipment used in this process is currently available with the exception of the module cutting device. A need exists to design and construct a machine capable of cutting through these modules of prunings.

Statement of Work

The first phase of this senior project will be to design and size the components of the machine previously conceptualized by the California Almond Board. The second phase will involve acquiring the necessary materials for the construction of the prototype. The third phase will be the construction of the machine. The fourth phase will involve the testing and evaluation of the machine.

How Project Meets Requirements for the ASM Major

ASM Project Requirements - The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving.

Application of agricultural technology	The project will involve the application of mechanical systems, power transmission, and fabrication technologies.
Application of business and/or management skills	The project will involve business/management skills in the areas of machinery management, cost and productivity analyses, and labor considerations.
Quantitative, analytical problem solving	Quantitative problem solving will include the cost analysis and the bending stress calculations.

Capstone Project Experience - The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses).

Incorporates knowledge/ skills from these key courses	129 Lab Skills/Safety, 133 Engineering Graphics, 151 AutoCAD, 142 Machinery Management, 301 Hydraulic/Mechanical Power Systems, 321 Ag Safety, 343/344 Mechanical & Fabrication Systems, 402 Ag Materials, 418/419 Ag Systems Management, Technical Writing

ASM Approach - Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. (insert N/A for any area not applicable to this project)

Systems approach	The project involves the integration of multiple functions (lifting, cutting, main & auxiliary hydraulic systems, safety guards), and the integration of machine/operator/crop husbandry systems to provide an improved waste management solution for almond growers.
Interdisciplinary features	The project touches on aspects of mechanical systems, agricultural safety and waste management.
Specialized agricultural knowledge	The project applies specialized knowledge in the areas of mechanical and fabrication systems, and agricultural safety.

Project Parameters

1. The machine must be able to make two cuts per module.
2. The machine can not reduce the integrity of the module.
3. The machine must be capable of cutting about 6 modules per hour.
4. The cost of operation must not greatly exceed $3.00/ton.
5. A team of two workers will be sufficient to attach/operate the machine.

List of Tasks and Time Estimate

TASK	Hours
Research in library on brush handling and cutting processes	8
Visitation to brush handling operations	10
Consultation with Almond Board Researcher and advisor	4
Prepare working drawing of design	30
Materials procurement	8
Machine fabrication in shop	80
Field testing	20
Modification to design	6
Final evaluation	4
Preparation of written report	30
TOTAL	200

Financial Responsibility

Preliminary estimate of project costs: $ *[insert dollar amount]*

Finances approved by (signature of Project Sponsor): *[signature of sponsor]*

Final Report Due: June 4, 2010 **Number of Copies**: 3

Approval Signatures		**Date**
Student:	*[student's signature]*	*[date signed]*
Proj. Supervisor:	*[supervisor's signature]*	*[date signed]*
Department Head:	*[department head's signature]*	*[date signed]*

California Polytechnic State University	December 1, 2009
BioResource and Agricultural Engineering Department	Smith, Pat
BRAE Senior Project Contract	0123456789 BRAE

Project Title

Design, Construction and Evaluation of an Almond Brush Module Cutter

Background Information

A new method of handling orchard tree prunings involves loading them into a modified cotton module maker, compacting them into a 2.1 m by 2.1 m by 5.5 m bale, transporting the bale to a central location, cutting the module into two or three sections and tub grinding the sections. The result is a product which can be used as an alternate energy source. All of the equipment used in this process is currently available with the exception of the module cutting device. A need exists to design and construct a machine capable of cutting through these modules of prunings.

Statement of Work

The first phase of this senior project will be to design and size the components of the machine previously conceptualized by the California Almond Board. The second phase will involve acquiring the necessary materials for the construction of the prototype. The third phase will be the construction of the machine. The fourth phase will involve the testing and evaluation of the machine.

How Project Meets Requirements for the BRAE Major

Major Design Experience - The project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes the following fundamental elements. Explain how this project will address these issues. (Insert N/A for any item not applicable to this project.)

Establishment of objectives and criteria	Project objectives and criteria are established to meet the needs and expectations of the California Almond Board. See "Design Parameters and Constraints" section below for specific objectives and criteria for the project.
Synthesis and analysis	The project will incorporate bending stress calculations, almond wood shear testing and analysis, and the consideration of alternate cutting methodologies.
Construction, testing and evaluation	The almond brush module cutter will be designed, constructed, tested and evaluated.
Incorporation of applicable engineering standards	The project will utilize AISC standards for allowable bending stresses, ISO standards for hydraulic circuit schematics, and ANSI standards for impact resistant safety glass.

Capstone Design Experience - The engineering design project must be based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses).	
Incorporates knowledge/ skills from these key courses	129 Lab Skills/Safety, 133 Engineering Graphics, 151 AutoCAD, 234 Mechanical Systems, 421/422 Equipment Engineering, Engineering Statics/Dynamics, Strength of Materials, Technical Writing
Design Parameters and Constraints - The project should address a significant number of the categories of constraints listed below. (Insert N/A for any area not applicable to this project.)	
Physical	The bale size was 8 ft x 8 ft, with an indeterminate length. The Module cutter must fit on a low-bed trailer for highway-legal transport.
Economic	The cost of operation must not exceed $3/ton. A team of two workers will be sufficient to attach and operate the machine.
Environmental	A benefit of the project will be to reduce field burning of orchard prunings. This will reduce air pollution. The module cutter will convert the prunings into a form suitable for use as a renewable energy supply.
Sustainability	The module cutter will convert the prunings into a form suitable for use as a renewable energy supply.
Manufacturability	N/A (the project will produce a one-of-a-kind machine)
Health and Safety	The module cutter will utilize strategically placed safety glass to shield the operator from flying chips, and a chain guard that will keep the cutting chain covered when not buried in the module being cut.
Ethical	N/A
Social	N/A
Political	Reduced air pollution.
Aesthetic	The finished machine will be spray painted with high quality automotive paint to provide a professional appearance. A two-tone color scheme will be used to provide contrast and high visibility.
Other - Productivity	The machine must be able to make two cuts per module. The machine must be capable of cutting about 6 modules per hour. The machine cannot reduce the integrity of the module.
Other	

List of Tasks and Time Estimate

TASK	Hours
Research in library on brush handling and cutting processes	8
Visitation to brush handling operations	10
Consultation with Almond Board Researcher and advisor	4
Prepare working drawing of design	30
Materials procurement	8
Machine fabrication in shop	80
Field testing	20
Modification to design	6
Final evaluation	4
Preparation of written report	30
TOTAL	200

Financial Responsibility

Preliminary estimate of project costs: $ *[insert dollar amount]*

Finances approved by (signature of Project Sponsor): *[signature of sponsor]*

Final Report Due: June 4, 2010 | **Number of Copies**: 3

Approval Signatures

		Date
Student:	*[student's signature]*	*[date signed]*
Project Supervisor:	*[supervisor's signature]*	*[date signed]*
Department Head:	*[department head's signature]*	*[date signed]*

APPENDIX B

SAMPLE SCHEDULE OF PROGRESS

Schedule of Progress | *[student's name]* | *[supervisor's signature]* | *[date]*

Key — **Task/Activity** (shaded) — **Milestone** +

Mon/Yr	month 1				month 2				mon			6	month 7				month 8				month 9			
Week	1	2	3	4	1	2	3	4	1	2		4	1	2	3	4	1	2	3	4	1	2	3	4
BRAE 460																								
Brainstorm for ideas																								
Proj background/justification																								
Consult w proj supervisor																								
Initial literature review																								
Consult w proj sponsor																								
Draft contract & schedule																								
Final contract & schedule										+														
BRAE 461																								
Weekly mtgs w supervisor											+	+	+	+	+	+								
Intro & Lit Review																								
Draft																								
Review by proj supervisor																								
Make corrections																								
Final draft due																+								
Poster																								
Photos/drawings																								
Design/prepare																								
Poster session																+								
BRAE 462																								
Weekly mtgs w supervisor																	+	+	+	+	+	+	+	+
Report & Appendices																								
Draft																								
Review by proj supervisor																								
Make corrections																								
Final draft																								+
Poster																								
Photos/drawings																								
Design/prepare																								
Poster session																								+
Design phase																								
Review design parameters																								
Set tank mount pattern																								
Size components																								
Design critical welds																								
Design tank mounts																								
Determine water pipe routing																								
Prepare working drawings																								
Materials Procurement																								
Order all parts/materials																								
Lag time for delivery																								
Construction Phase																								
Cutting																								
Welding																								
Machining																								
Assembly																								
Progress photos																								
Testing & Evaluation																								
Physical tests																								
Operational tests																								
Modifications																								
Final evaluation																								
Progress photos																								

APPENDIX C

BRAE LAB POLICIES

BRAE LABORATORY POLICIES/PROCEDURES
October, 2003

1. Priority for laboratory/facility usage is as follows:
   a. Regularly scheduled classes (including BRAE 240, etc.).
   b. Supervision courses (Senior project, special problems).
   c. Club/extracurricular activities.
   d. Professional development/research activities, unless directly related to a specific course.

2. A student working in a lab must be accompanied by another individual at all times. Note: lab 6 and 7 are considered to function as a single laboratory. See Note 3 regarding qualifications of individuals.

3. Laboratory activity/usage shall only take place under the responsible charge/supervision of a qualified individual. That individual will be present and available during all activity. At the conclusion of the work period, this individual will oversee all clean-up procedures. Qualified individuals may include:
   a. Instructor
   b. Departmental technician
   c. Staff personnel
   d. Assigned student assistant
   e. Approved student

   An information board will post the names of all qualified individuals, with a provision for posting the name of the person in responsible charge for a particular work period.

4. Insufficient clean up/organization may result in the loss of laboratory use privileges.

5. No tools/equipment from the tool boards and associated storage areas are to be removed from the shop area.

6. Reserve (backup) tools/specialty equipment may be checked out for short term (one day) usage. Check out tags or clipboards must be used to record equipment loans.

7. All damaged/faulty equipment will be reported to the department technician(s) at the earliest opportunity.

8. All laboratory projects and materials must be directly related to a class, BRAE Dept. Club, or professional development (Faculty/staff) activity. A signed work permit is required for each project, and must be on file in the lab 6/7 technician's office.

9. Repair costs resulting from equipment misuse are the responsibility of the user or project sponsor.

10. Each project sponsor (student or otherwise) is financially responsible for consumables used.

11. Only materials designated as “scrap” are available for project use at no charge. Departmental supplies (nuts, bolts, etc) and remnants are only available on an exchange basis. Any exchange will be overseen by the person in responsible charge, and documented.

12. Each individual must provide his/her own personal equipment (safety glasses, welding gloves, leathers, tape measures, etc).

13. Individuals working in the shop area must wear appropriate clothing. No shorts or open-toed shoes are allowed.

14. Students must be “checked out” prior to the usage of each piece of equipment. Set-ups on equipment including the plate shear, press brake, lathes and milling machines must be approved by the person in responsible charge.

15. Projects of large size or scope that might affect shop use or accessibility must be approved by the department head.

16. Vehicle parking on the shop apron is prohibited, with the exception of 1) project material loading and unloading purposes, 2) ITRC vehicles in designated spots, 3) BRAE faculty/staff in designated spots.

17. Anyone in violation of safety rules may be asked to leave the premises until the insufficiency or violation is corrected.

18. Faculty members and staff will immediately stop any work that is considered unauthorized or which appears to be unsafe.

Other General Items

1. Technician will be available for student assistance during regular posted hours. Shops and associated tool boards will remain fully secured otherwise.

APPENDIX D

CHECKLISTS FOR SENIOR PROJECT POSTERS AND REPORTS

CHECKLIST FOR SENIOR PROJECT POSTER DESIGN

Identification

[ ] **Author**: Prominently displayed? Easy to identify who did the work?

[ ] **Title**: Prominently displayed? Easy to see what the project is about?

[ ] **Major**: Prominently displayed? Easy to tell if this is an BRAE or ASM project?

[ ] **461/462**: Is this poster about a project plan (461), or a project completed (462)? Is it easy to determine this information?

[ ] **Author's Photo**: Does the author 's photo help identify the person to talk to?

[ ] **Title**: Prominently displayed? Easy to see what the project is about? Is it easy to determine this information?

Visual Arrangement

[ ] **Overall Appearance**: Is the poster visually appealing? Professional?

[ ] **Flow**: Does the information flow logically? Is the logical path easy to follow?

[ ] **Results**: Are the objectives and conclusions clearly and quickly grasped?

[ ] **Sections**: Are individual sections (methods, results, etc.) placed on separate panels, with headings?

[ ] **Headings**: Do headings stand out from the body of text?

[ ] **Illustrations**: Do illustrations, photos and charts use a horizontal format? Are these clearly labeled? Are the key elements somehow identified or highlighted? Do they each illustrate just a single theme, or are they too complex?

[ ] **Author's Photo**: Does the author 's photo help identify the person to talk to?

Readability of Text

[ ] **Sentences**: Are sentences short, using simple sentence structure? Would a bulleted list of key phrases serve better than sentences?

[ ] **Words**: Are common words used, avoiding "jargon"? Is the wording to-the-point, or too abstract?

[ ] **Font**: Is a sans serif font used? Is the type large and easy to read? Is the smallest type used at least 1/4 inch high?

[ ] **Case**: Does the text use both upper and lower case letters? Are words and titles in all-caps avoided?

Display Notebook

[ ] **Available**: Is the display notebook available for more detailed discussions with interested viewers?

[ ] **Content**: Does the display notebook contain additional photos, drawings, data to help explain the project in more detail to the interested visitor? [The display notebook is not just a copy of the project report - no one has time to read that during a poster presentation.]

[ ] **Used**: Is it used by the author to present material not displayed on the poster?

[ ] **Professional**: Is the display notebook organized, neat, complete?

CHECKLIST FOR SENIOR PROJECT REPORTS

Structure: are required sections present, in the proper order, and in the proper format?

[ ] Black pressboard binder
[ ] Cover label showing Title, Author, Date, Major
[ ] Title and Signature Pages: major, date
[ ] Preface or Acknowledgments (optional)
[ ] Abstract
[ ] Disclaimer Statement
[ ] Table of Contents
[ ] List of Figures
[ ] List of Tables
[ ] Introduction
[ ] Literature Review
[ ] Procedures and Methods
[ ] Results
[ ] Discussion
[ ] Recommendations
[ ] References
[ ] Appendices

Format

[ ] **Figures**: single space before, centered, figure number/title centered, single blank line after
[ ] **Photographs**: digitally inserted or dry mounted, numbered and formatted as a figure
[ ] **Tables**: number and title centered and at top
[ ] **Drawings**: numbered and formatted as a figure, title block, self explanatory, CAD
[ ] **Paper**: white bond, 20 lb. weight
[ ] **Type Style**: single font throughout, approximately 12 characters per inch
[ ] **Margins**: 1.5 inch on left, 1 inch on top, right, bottom
[ ] **Paragraphs**: single spaced text, not indented, single blank line between
[ ] **Section Headings**: full caps, centered at top of page
[ ] **Subsection Headings**: left justify, capitalize major words, underlined, no period, blank line before and after
[ ] **Sub-subsection Headings**: left justify, capitalize major words, underlined, period follows, blank space before, text follows immediately after (on same line)
[ ] **Equations**: indented 5 spaces from left, blank line before and after, numbered consecutively with number between parentheses at right margin
[ ] **Page Numbering** (prelim. pages): lower case Roman numerals, title page is page i, but is not numbered, numbers are centered, 1/2 inch above bottom of page
[ ] **Page Numbering** (main text pages): number all pages, including appendices, Arabic numerals, in upper right hand corner, 1 inch in from right margin, 1/2 inch down from top of paper
[ ] **References** (reference section): ASABE format, as shown in text.
[ ] **References** (cited in text): ASABE format: (Author, year)
[ ] **Writing Style**: usually 3rd person, past tense in early sections, present tense OK for Conclusions and Recommendations sections, professional tone (no slang or jargon)

Content

[ ] **Title**:

- Does it well represent the report's contents?

[ ] **Introduction**:

- Is the background information sufficient?
- Will the reader understand the need for this project?
- Are the objectives, criteria and constraints clear?

[ ] **Literature Review**:

- Did you make a serious effort to identify relevant information, data or standards?
- Have different facets of the project been explored?
- Does the Literature Review summarize what you have learned, with proper citation of sources? [A literature review that is just a summary of the search activities is inadequate.]

[ ] **Procedures and Methods**:

- Are the procedures presented clearly and in a logical order (chronological order is not always the easiest to follow)?
- Could someone else duplicate your project from the information in your report?
- Are discussion of results, evaluations and interpretations excluded from this section? [They should be placed in later sections.]

[ ] **Results**:

- Are the results of your project summarized?
- Are the tables and illustrations clear and well organized?
- Do the results presented match the objectives stated earlier
- Are discussions of results, evaluations and recommendations excluded? [These should be placed in later sections.]

[ ] **Discussion/Recommendations**:

- Does the discussion evaluate or interpret the results, or merely repeat the results?
- Do the results justify the conclusions?
- If objectives were not met, why?
- Are suggestions made for future work to meet them?

[ ] **Overview**:

- Does the abstract summarize the report?
- Check the format of the report.
- Check the structure (headings and paragraph topics) of the report.
- Is the organization clear?
- Does the report seem complete, or are you left wondering about some things?

APPENDIX E

TECHNICAL WRITING TIPS

[This section is still under preparation]

APPENDIX F

SAMPLE SENIOR PROJECT REPORT

[The following is an abbreviated sample senior project. Each section is limited to a minimal example of proper format and context. It is by no means inclusive.]

DESIGN, CONSTRUCTION, AND EVALUATION OF AN

ALMOND BRUSH MODULE CUTTER

by

Pat Smith

BioResource and Agricultural Engineering
(or)
Agricultural Systems Management

BioResource and Agricultural Engineering Department

California Polytechnic State University

San Luis Obispo

2009

TITLE	:	Design, Construction, and Evaluation of an Almond Brush Module Cutter
AUTHOR	:	Pat Smith
DATE SUBMITTED	:	May 31, 2009

Mark A. Zohns
Senior Project Advisor

Signature

Date

Richard A. Cavaletto
Department Head

Signature

Date

ACKNOWLEDGEMENTS

First, I would like to express my appreciation to the California Almond Board whose funding made this project possible.

Second, I would like to thank by advisor, Dr. Mark A. Zohns, who offered extensive guidance in many times of need.

Third, I would like to give special thanks to the Lab 7 technician, Virgil Threlkel, who was always there to give practical advice.

Fourth, I would like to thank Kathy Daniels for putting up with me during my many visits to the departmental office.

Fifth, but most important, I would like to thank my parents for giving me courage and support throughout my educational career.

ABSTRACT

This senior project discusses the design, construction, and evaluation of an almond brush module cutter. The module cutter was one part of a system to process tree prunings for fuel and fiber. This system included a modified cotton module builder, a module mover, the cutter, and a tub grinder.

Field tests with the prototype indicated that an operational rate of 10 module cuts per hour was possible with minimal effort.

DISCLAIMER STATEMENT

The university makes it clear that the information forwarded herewith is a project resulting from a class assignment and has been graded and accepted only as a fulfillment of a course requirement. Acceptance by the university does not imply technical accuracy or reliability. Any use of the information in this report is made by the user(s) at his/her own risk, which may include catastrophic failure of the device or infringement of patent or copyright laws.

Therefore, the recipient and/or user of the information contained in this report agrees to indemnify, defend and save harmless the State its officers, agents and employees from any and all claims and losses accruing or resulting to any person, firm, or corporation who may be injured or damaged as a result of the use of this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

INTRODUCTION

Production of tree prunings from fruit and nut tree crops in California was about one million tonnes (350,000 tons) per year (Knutson, 1982). The principal method of disposal was to buckrake the prunings to the edge of the field and burn them on an assigned burn day. With increasing concern for the conservation of energy and pollution of the atmosphere, a new method for the handling and disposal of tree prunings had to be formulated.

One such method was under investigation in California. This concept involved moving the prunings to the edge of the orchard, loading them into a modified cotton module maker, and compacting them into a 2.1 m by 2.1 m by 5.5 m bale. The module could then be transported by a cotton module mover to a location where it could be cut into two or three small sections. The sections could be loaded into a tub grinder to produce marketable products, such as fuel chips, mushroom compost, and others.

The moduling process had three major advantages. First, it allowed the prunings to be compacted into a package that could be easily transported and stored. Second, the compactness of the module sections increased the throughput of the tub grinder. Average throughput rates for loosely piled prunings ranged from 2.7 t/h (3 tons/h) to 5.4 t/h (6 tons/h). Throughput rates on moduled prunings were increased to 13.6 t/h (15 tons/h) to 18.1 t/h (20 tons/h) (Jenkins, et al. 1985). The third advantage was that each activity, with the exception of the module cutting process, was performed by currently available equipment. A large scale module cutting machine had not yet been developed.

A number of conceptual ideas for cutting modules were developed on paper. In addition to those ideas gathered from the review of literature, other cutting schemes considered included band saws, circular saws, flail cutting saws, reciprocating saws, and shearing mechanisms.

Preliminary feasibility analyses of the initial design concepts led to the decision that a large bow type chain saw would be simplest to construct and operate. Preliminary estimates also indicated it would be low in cost.

Figure 1 illustrates the geometry of the proposed bow chain saw.

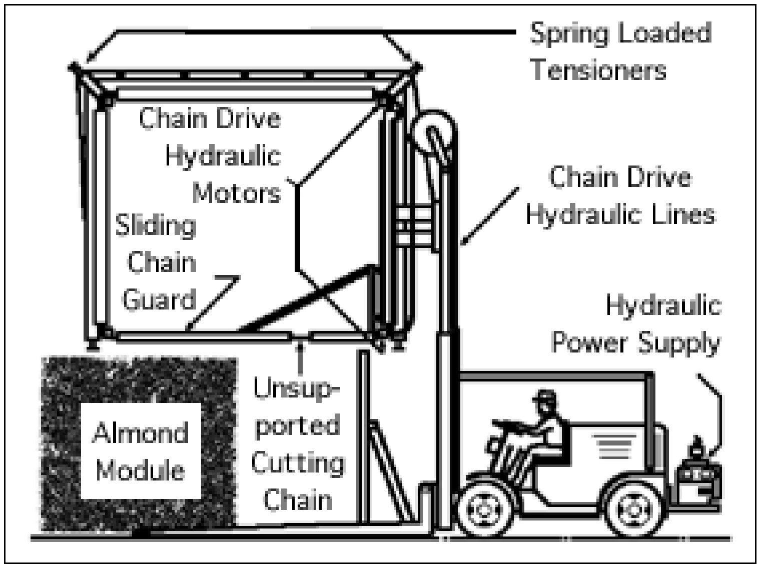

Figure 1. Proposed module cutting machine.

The machine consisted of a large "C" shaped frame measuring approximately 2.4 m (8 ft) in height and 3 m (10 ft) in length mounted on a forklift. A tensioned chain saw chain traveled around the inside perimeter of the frame and was unsupported across the lower, cutting span of the frame. A module lifting device was also included to aid in separating the module as the cut was proceeding.

The objective of this senior project was to design, construct, and test the device described above while considering the following constraints:

1. The machine had to be able to make two cuts per module.
2. The machine could not reduce the integrity of the module.
3. The machine had to be capable of cutting about 6 modules per hour.
4. The operational cost was not to greatly exceed $3.50/Mg ($3.00/ton).
5. The anticipated module mass was 2.3 Mg (5000 lb).
6. The machine had to be easy and safe to operate.

LITERATURE REVIEW

A search was initiated to identify any currently produced machine that would satisfy the module cutting requirements.

Currie Manufacturing Co. of Lumberton, North Carolina, produced a large bow type chain saw for cutting full loads of logs while on the bed of the truck. This machine consisted of 1.9 cm (3/4 in.) pitch saw chain which traveled across a curved saw bar, where the cutting took place, then up around a large reinforced frame. The main frame traveled up and down on a vertical mast. This machine was capable of cutting a 259 cm (8 ft, 6 in.) width. An 18.7 kW (25 hp) motor powered the cutting chain (Currie Manufacturing Co., 1983).

Another device developed by ARMEF (1975) in France was used for crosscutting bundles of 2 m logs into 1 m shortwood. This machine consisted of a sliding frame situated between two jaws, all mounted on the front of a cross country lift truck. The two jaws were used to position and clamp the logs. The sliding frame supported a saw chain which traveled around its perimeter. The chain was unsupported along the cutting span.

An oversized mower bar cutter designed by Monroe and Peterson (1977) was also thought to have potential for cutting modules but could not be obtained for testing. Monroe and Peterson used a large cutter bar with knife sections similar to those on commercial equipment for cutting sugarcane stalks. After grinding the knives to create nearly parallel shearing edges, Monroe and Peterson found that this machine was capable of cutting 90 mm diameter branches on 50 year old Pecan trees. For this particular device to succeed in cutting almond modules, any branches larger than 90 mm would have had to be separated out prior to moduling.

-
-
-

PROCEDURES AND METHODS

Design Procedure

Main Frame. • • • • (discussion) • • • •

Module Lifting Forks. The module lifting forks had to be designed to accommodate the anticipated module mass of 2.3 kg (5000 lb) at a distance of approximately 1.5 m (5 ft) from the auxiliary forklift mast. Calculations (shown in the Appendix A) indicated that for adequate strength each fork could be constructed of 4" x 6" x 1/4" rectangular tubing. Since the forks were cantilevered, they could be tapered to allow for easier positioning under the module prior to the cutting process.

•

•

(other items)

•

•

Construction Procedure

Main Frame. • • • • (discussion) • • • •

Module Lifting Forks. Figure 2 shows the completed module lifting fork assembly. In order to taper each fork, a pie shaped piece was removed from the 4" x 6" tubing, the two sides were clamped together, and a weld was placed near the neutral axis. The end of the fork and short upright were cut on a 45° angle, beveled, and joined together to form the "L" shaped member, as can be seen in the Figure.

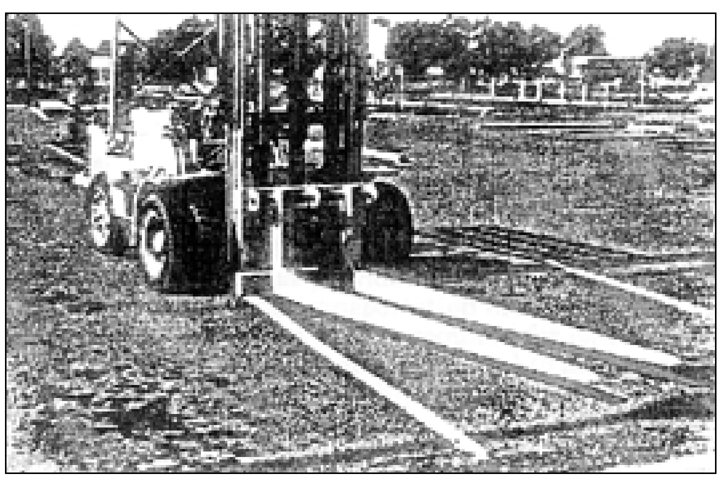

Figure 2. Completed module lifting fork assembly.

Outrigger Cylinder Pivot. The outrigger cylinder pivot consisted of a piece of 1-1/2" x 2-1/2" x 3-1/3" steel attached to a 4" x 5" x 3/4" plate with a 3/8" fillet weld. Figure 3 in Appendix B illustrates the geometry of the outrigger cylinder pivot.

-
-

(other items)

-
-

General. Figure 4 shows the completely assembled module cutter. The saw frame was mounted directly on the lift carriage of the forklift. The module lifting forks were attached to the auxiliary mast system. A large wheel was located on top of the forklift mast in order to manage the hydraulic hoses when the saw was raised and lowered. The hydraulic power supply was attached to the rear of the forklift.

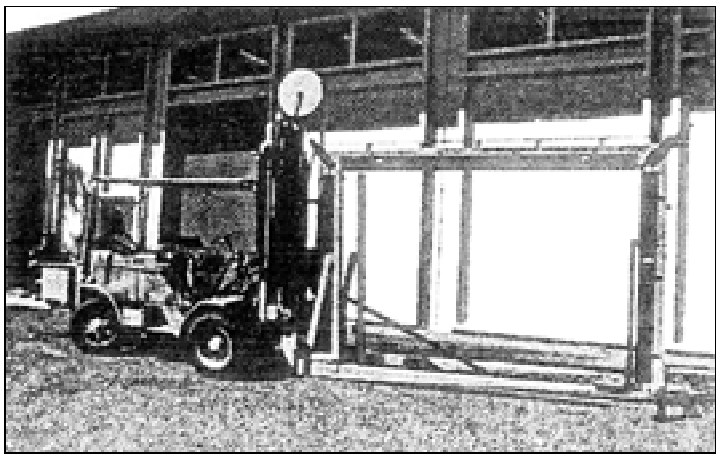

Figure 4. Assembled module cutting machine.

Testing Procedure

The prototype module cutter was transported to Fresno, California for a series of tests during the 1984 and 1985 pruning seasons. An operator was trained during a one day session and was provided with a detailed manual describing the operation, maintenance, and transportation of the machine. The operator was asked to measure the amount of time required for each full module cut, to keep a record of the total number of cuts made, and to note any problems or difficulties with the function of the machine.

RESULTS

During the field tests, the average time per cut, including machine approach and withdrawal from the module, was 4 minutes. Cutting times of less than 2 minutes were obtained on occasion. After the first 50 cuts, the chain was sharpened and shortened by approximately 10 cm (4 in.) to account for stretching. The time required for one man to remove, service, and reinstall the chain was about 1 hour. These figures represent an operating rate of about 11 cuts/hour at 75% field efficiency.

-
-
-

DISCUSSION

Initially, only one hydraulic drive motor was used. After approximately 100 module cuts, the chain drive links exhibited extensive wear. "Mushrooming" of the drive links was caused by excessive bearing stress exerted by the sprockets. After dulling, the chain was deflected excessively during cutting. Large deflections caused the tensioning devices to reach their travel limit. Beyond this point, further deflection of the chain caused the chain tension to increase, resulting in deformation of the drive links. A second drive motor was added to relieve bearing stress by increasing chain contact area on the sprockets. This modification prolonged the chain life, but did not eliminate the problem.

Module Cutter Cost Analysis

To determine whether the cutter met the design constraint for cost, an economic analysis based on the field test data and the following assumptions were performed.

Assumptions:

1. Module cutter to be used 1000 hours per year.
2. Machine wearout life = 10000 hours (10 yr).
3. New forklift cost = $20,000.
   Because the forklift was not restricted to the cutting operation, only 1/2 of its cost was allocated to the cutter.
4. Estimated cutting chain life = 200 module cuts.
5. Price of gasoline = $0.34/L ($1.30/gal).
6. Price of soluble coolant oil for the chain = $0.80/L ($3.00/gal).
7. Cost of labor = $8.00/h.
8. Cost of repairs = (0.02% x machine cost)/h.
9. Interest rate = 10%.
10. Salvage value = 10% of original.
11. Taxes, insurance, shelter = 2% of original price/year.

Machine cost and performance parameters:

1. Module cutter cost (without forklift but with auxiliary power supply) = $22,500.
2. Cutter performance @ 75% field efficiency = 11 cuts/h.
3. New saw chain cost = $125.
4. Forklift fuel consumption = 7.5 L/h (2 gal/h).
5. Hydraulic power supply fuel consumption = 7.5 L/h (2 gal/h).
6. Chain coolant/oil consumption = 0.09 L/cut (0.1 qt/cut).

The economic analysis was done according to the method outlined by Kepner, Bainer, and Barger (1972), except for the use of capital recovery depreciation to compute capital charges.

Annual Fixed Charges

Capital recovery depreciation:

Forklift cost	=	$10,000 (1/2 allocation)
Cutter cost	=	$22,500
Total machine cost	=	$32,500

Annual cost = (P - S)(A/P, i%, n) + (i)(S) (1)

Annual cost = (32,500 - 3,250)(0.1627) + 0.10(3,250) = $5,084 (2)

P	=	acquisition cost
S	=	salvage value
(A/P, i%, n)	=	capital recovery factor
i	=	effective interest rate
n	=	life in years

Taxes, insurance, shelter: 0.02 (32,500) = $ 650 (3)

Total fixed costs per year = $5,734

Costs Per hour

Fixed costs $\frac{\$5,734}{1,000\ h}$ = $5.74 (4)

Repairs $(\frac{0.02}{100} \times \$32,500)$ = $6.50 (5)

Fuel 15L/h x $0.34/L = $5.20 (6)

Oil and filters (15% of fuel) $5.20 x 0.15 = $0.78 (7)

Chain oil/coolant $\frac{\$0.09\ L}{cut} \times \frac{11\ cuts}{h} \times \frac{\$0.80}{L}$ = $6.87 (8)

Labor = $8.00

Total cost per hour = $33.88/h

Total cost per cut @ 11 cuts/h = $3.08/cut

Costs per module weight

Average module weight = 2,225 kg (2.5 tons)

Number of cuts per module = 2

$$\text{Cutting cost/module weight} = \frac{\$3.08}{\text{cut}} \times \frac{2\text{ cuts}}{\text{module}} \times \frac{1\text{ module}}{2.225\text{ t}} \quad (9)$$

$$= \$2.77/\text{t}\ (\$2.51/\text{ton})$$

The economic analysis indicates that the cost of cutting is within the design constraint of \$3.50/Mg (\$3.00/ton).

RECOMMENDATIONS

The main improvement in the design of this module cutter is the decrease in cost of materials and components.

Instead of using two hydraulic motors and sprockets to drive the cutting chain, perhaps one motor could be utilized with a larger diameter drive sprocket. The larger sprocket would increase the chain contact area and thus alleviate the problem of excessive bearing stress on the chain drive links. For the same chain speed, a slower speed hydraulic motor could be utilized which would be less expensive than the two high speed motors that were used. In addition, a higher pressure, lower flow combination in the chain drive motor hydraulic system would decrease the size and cost of the hydraulic lines, valves, filter, and oil reservoir.

By using the module lifting device, the beginning of the cut can be opened approximately 7 to 10 cm (3 to 4 in.) after the saw has reached a cutting depth of about 1.3 m (50 in.). Since the width of the top of the saw frame is less than 7 cm (3 in.), the frame could conceivably enter the module at this point in time. Therefore, the actual height of the saw could be decreased significantly, decreasing material and cutting chain costs. However, with this arrangement, the sliding chain guard would have to be modified somewhat.

The use of this module cutting machine is not limited to forklift implementation. Future designs should investigate the possibility of mounting the saw frame on a trailer. The trailer could include conveyor chains that would move the modules under the saw for cutting and then transport the module sections up a ramp to be dropped directly into the tub grinder.

-
-
-

REFERENCES

1. ARMEF. 1975. Experimentation d'un tracteur prototype de manutention et de decoupe de billions de 2 metres en rodins de 1 metre. Experimenting with a prototype tractor for handling and crosscutting 2 m long blocks into 1 m shortwood. ARMEF, Paris, France.

2. Currie Manufacturing Co. 1983. Currie cost cutter model 860 specifications. Lumberton, NC.

3. Jenkins, B. M., G. E. Miller, D. Morrison and M. Magaletti. 1985. A module system for harvesting tree prunings. APPLIED ENGINEERING in AGRICULTURE 1(1):32-34.

4. Kepner, R. A., R. Bainer and E. L. Barger. 1972. Principles of farm machinery. AVI Publishing Co., Inc., Westport, CT. 486 p.

5. Knutson, J. and G. E. Miller. 1982. Agricultural residues (biomass) in California . . . . factors affecting utilization. Leaflet 21303, Cooperative Extension, University of California, Berkeley, CA 94720.

6. Monroe, G. E. and D. L. Peterson. 1977. Oversize mower cutterbar for pruning trees. TRANSACTIONS of the ASAE 20(4):606-608.

-
-

(other items)

-
-

APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM (or BRAE) MAJOR

[Note: This example Appendix A contains typical material and wording for both an ASM and a BRAE version of this project. In an actual senior project report, Appendix A would contain only material appropriate to the major of the student doing the project.]

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

ASM Project Requirements

The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving. This project addresses these issues as follows.

Application of Agricultural Technology. The project involves the application of mechanical systems, power transmission, and fabrication technologies.

Application of Business and/or Management Skills. The project involves business/management skills in the areas of machinery management, cost and productivity analyses, and labor considerations.

Quantitative, Analytical Problem Solving. Quantitative problem solving techniques include the cost analysis and the bending stress calculations.

Capstone Project Experience

The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge/ skills from these key courses.

- BRAE 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics
- BRAE 151 AutoCAD
- BRAE 142 Machinery Management
- BRAE 301 Hydraulic/Mechanical Power Systems
- BRAE 321 Ag Safety
- BRAE 343/344 Mechanical & Fabrication Systems
- BRAE 402 Ag Materials
- BRAE 418/419 Ag Systems Management
- ENGL 148 Technical Writing

ASM Approach

Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. This project addresses these issues as follows.

Systems Approach. The project involves the integration of multiple functions (lifting, cutting, main & auxiliary hydraulic systems, safety guards), and the integration of machine/operator/crop husbandry systems to provide an improved waste management solution for almond growers.

<u>Interdisciplinary Features</u>. The project touches on aspects of mechanical systems, agricultural safety and waste management.

<u>Specialized Agricultural Knowledge</u>. The project applies specialized knowledge in the areas of mechanical and fabrication systems, and agricultural safety.

HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

Major Design Experience

The BRAE senior project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes fundamental elements as outlined below. This project addresses these issues as follows.

Establishment of Objectives and Criteria. Project objectives and criteria are established to meet the needs and expectations of the California Almond Board. See *Design Parameters and Constraints* below for specific objectives and criteria for the project.

Synthesis and Analysis. The project incorporates bending stress calculations, almond wood shear testing and analysis, and the consideration of alternate cutting methodologies.

Construction, Testing and Evaluation. The almond brush module cutter was designed, constructed, tested and evaluated.

Incorporation of Applicable Engineering Standards. The project utilizes AISC standards for allowable bending stresses, ISO standards for hydraulic circuit schematics, and ANSI standards for impact resistant safety glass.

Capstone Design Experience

The BRAE senior project is an engineering design project based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge/ skills from these key courses.

- BRAE 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics
- BRAE 151 AutoCAD
- BRAE 234 Mechanical Systems
- BRAE 421/422 Equipment Engineering
- ME 211/212 Engineering Statics/Dynamics
- CE 201/204/206 Strength of Materials
- ENGL 149 Technical Writing

Design Parameters and Constraints

This project addresses a significant number of the categories of constraints listed below.

Physical. The bale size is 8 ft x 8 ft, with an indeterminate length. The Module cutter must fit on a low-bed trailer for highway-legal transport.

Economic. The cost of operation must not exceed $3/ton. A team of two workers will be sufficient to attach and operate the machine. The project successfully met these goals.

Environmental. A benefit of the project is a reduction in field burning of orchard prunings, which reduces air pollution. The module cutter converts the prunings into a form suitable for use as a renewable energy supply.

Sustainability. The module cutter converts the prunings into a form suitable for use as a renewable energy supply.

Manufacturability. N/A (the project produced a one-of-a-kind machine)

Health and Safety. The module cutter utilizes strategically placed safety glass to shield the operator from flying chips, and a chain guard to keep the cutting chain covered when not buried in the module being cut.

Ethical. N/A

Social. N/A

Political. Reduced air pollution.

Aesthetic. The finished machine was spray painted with high quality automotive paint to provide a professional appearance. A two-tone color scheme was used to provide contrast and high visibility.

Other - Productivity. The machine must be able to make two cuts per module. The machine must be capable of cutting about 6 modules per hour. The machine cannot reduce the integrity of the module. The project successfully met these goals.

APPENDIX B

DESIGN CALCULATIONS

(Include Design Calculations Here)

APPENDIX C

CONSTRUCTION DRAWINGS

(Include Construction Drawings Here)