Call for Project Proposal

From:
McCracken Industry, Inc.
2106 Wayland Boulevard
Prairie Land, Minnesota 57666
ATTN: Dr. Sarah Wang

Name of Project Proposal: Design, Build and Test a Compact Heat Exchanger

Introduction: The McCracken Industry, Inc. produces methanol from corn using a fermentation procedure. The ethanol is separated from the cellulose mixture by distillation. The company is planning to install a pilot plant to determine the feasibility of using switch grass as an alternative source of cellulose for the production of ethanol. This requires the addition/modification of several unit operations that have to be tested before installation in the main plant.

The existing production plant is very compact and Management does not want to increase the size of the production plant to build the pilot plant. The area in the plant Management has determined that can be used to set up a pilot plant is fairly small; therefore, the planning team has to minimize the size of all the unit operations. Management has also requested that the costs be kept to a minimum. The company is very safety conscious so everything in the pilot plant has to be designed and built to meet all safety and building codes.

Details of the project: The project entails the design, building and testing of a compact heat exchanger that can be used to cool the hot water from one of the unit operations before the water is used in another part of the operation. The design of the heat exchanger should include minimizing the cost (assumed to be directly proportional to the dry weight) and size (taken as the largest dimension, e.g., length of heat exchanger [measured from the ends of the copper tube fittings]) while maintaining the safety of the operation of the unit.

The pressure of the cold water in the plant will be in the range of 65 to 70 PSI and the hot process water will be at 45 PSI. The plant water pressure is a lot higher than the pressure that the test apparatus will produce because both outlet streams in the test apparatus will be at atmospheric pressure.

The Company's planning team is asking each University of Minnesota Duluth, Department of Chemical Engineering, Unit Operations Laboratory (CHE 3211) student team to design, build and test a compact heat exchanger. This is beneficial to both parties since it gives you, the student, experience in designing and building a heat exchanger and it gives the company planning team a number of heat exchanger designs to pick from.

The Company requests each team assigned by the Faculty instructor in CHE 3211, Unit Operations Laboratory to submit a project proposal to McCracken Industry, Inc. Their address is shown above. The project proposal should be submitted to the laboratory faculty instructor(s) (found on the ATTN: line in the address above) for review, comments, and approval by the planning team prior to any work being started. A written and electronic copy shall be submitted to the faculty instructor(s) and an electronic copy shall be submitted to the Lab Services Coordinator so sufficient material will be available for the building of the heat exchangers.

The Company will not allow anything less than schedule 40 pipe for the shell of the heat exchanger for safety reasons. The Company has a contract with Minnesota Fluid System Technologies in Chanhassen, MN so all tube fittings used in the heat exchanger will be Swagelok fittings. All connections to the heat exchanger must accommodate ¼ in compression fittings so the heat exchanger can be connected to the test apparatus.

Schedule 40 PVC pipe in 1", 1-1/2", 2", 3" and 4" sizes with end caps to match and up to 20 ft of ¼ in OD soft copper tubing (3/16" in. ID) and ¼" OD polyethylene tubing will be supplied by the Company free of charge. The Company may be able to supply other materials if they are addressed in the project proposal. Any extra materials the Company may be able to supply are limited to those available from the local hardware or home improvement stores. Please specify the type of material and size needed (including thickness, length, width or diameter etc.). If the Company cannot supply these materials you will be informed of this fact before construction begins and they will be your responsibility to purchase.

The specifications for the compact heat exchanger are given below.

1. The unit operation that the warm water discharge from this heat exchanger enters can handle a temperature of 20°C to 30°C without causing a problem. The heat exchanger you design must maintain a ΔT of hot water between 20°C to 26°C.
2. All fluid streams are water. Base your heat exchanger design on the following stream parameters for flow rate and temperature found in Table 1.

Table I. Fluid Stream Parameters

Stream	Temperature in (°C)	Flow Rate (L/min)
Cold	15 ± 2	0.60 ± 0.02
Hot	50 ± 3	0.20 ± 0.02
Room Air	21 ± 2	-
Hot Water ΔT	20 - 26	

Project Proposal

A project proposal will be written by your group in lieu of the Pre-lab form. The preferred written structure of a project proposal can be found later in this document. The proposal will be addressed to the company but sent to the attention of the faculty instructor. See information later in this document on due dates and where to send the proposal. The project proposal will request that you be allowed to design and build a compact heat exchanger to be used in their pilot plant to cool the hot water using the specifications and materials listed above. Included in the proposal should be the amount, type and size (length and diameter) of pipe and tubing you will be using in your heat exchanger based on your design calculations.

The proposal should include:

1. Assumptions used in the design of your heat exchanger.
2. The safety factor used in the design of your heat exchanger.
3. The type of compact heat exchanger (shell and tube, multiple tubes, multiple shell or tube passes, cross-flow, or other configurations).
4. The equations used in the design of your heat exchanger. The actual calculations should be included in the Appendix of this proposal as part of the document. Do not send an individual MathCad or Excel file containing these calculations.
5. The results of a preliminary uncertainty analysis of your calculations. A set of uncertainty calculations should be included in the appendix.
6. The results for the heat transfer rate for the hot stream, the Reynolds number for both streams, the Nusselt number for each stream, the heat transfer coefficient for each stream and the overall heat transfer coefficient in a format that is easily viewed (A table in the discussion section of the report).
7. If you ran any simulations you should compare the results of your simulations and state the reasons you picked this one to build.
8. The type and size (length and diameter) of pipe and tubing you will be using in your heat exchanger based on your selected design parameters. A table in the discussion section is encouraged.
9. If you are planning on installing baffles or other materials inside the heat exchanger to change the flow pattern, the type of material you will be using and the diameter (or length and width), and thickness of each individual baffle and the total amount of material needed should be included. The Company may not be able to supply this material, but it should be included in your proposal.
10. The number and type of Swagelok fittings you will need.
11. Safety and environmental issues of concern with this project.
12. Include a detailed schematic of the heat exchanger design using Visio or other drawing software. The schematic should be annotated to include dimensions and locations for feed and effluent streams. Note that the schematic may be used as a graphic in your full/memo report and oral presentation. If the schematic is to be used in an oral presentation, ensure that the text font is large enough so it is visible at the back of a presentation room.

In order to give you an incentive to be innovative in your design and help the Company planning team determine which heat exchanger will be installed in the pilot plant they will use four criteria to select the heat exchanger to be installed in the pilot plant. Depending on the state of the economy a prize may be given to the best heat exchanger design from each section based on these four criteria.

1. The heat exchanger must meet the ΔT requirements for the hot stream to produce a hot water outlet temperature between 20°C to 26°C using the test rig designed by the planning team. The fluid stream parameters used in the test rig are found in Table I.

2. The heat exchanger must meet all safety requirements as stated in this call for project proposal.
3. The heat exchanger must have minimal water leakage. Excessive leakage will decrease the economic rating.
4. A heat exchanger economic rating has been developed by the planning team that will be used to determine which is the smallest and the most economically feasible heat exchanger. The team with the highest economic rating in each section will be awarded the design to be used in the pilot plant. The economic rating, *E*, for this project is calculated using the following empirical formula (Equation 1).

$$E = \frac{\varepsilon}{\left(\frac{L}{\overline{L}} + \frac{W}{\overline{W}}\right)} x\,100 \qquad (1)$$

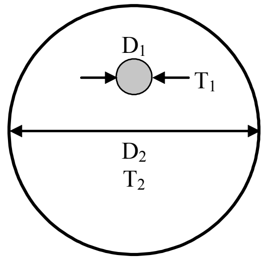
Where ε is the effectiveness factor, L is the length (cm) [end of copper tube to end of copper tube] and W is the dry weight (kg). The weight used in this calculation is an estimate for the total cost of the heat exchanger. $\overline{L}, \overline{W}$ are the class average values for the length and weight. Assume a typical value for the length to weight ratio of $\overline{L}/\overline{W} \cong 30 cm/gm$. The final values for $\overline{L}$ and $\overline{W}$ are calculated by the instructor after all of the team compact heat exchangers are built and tested.

The effectiveness factor ε is determined by the use of equation 2.

$$\varepsilon = \frac{(T_{hi} - T_{ho})}{(T_{hi} - T_{ci})} \qquad (2)$$

T_{hi} is the temperature of the hot water entering the tube side of the heat exchanger. T_{ho} is the temperature of the hot water exiting the tube side of the heat exchanger. T_{ci} is the temperature of the cold water entering the shell side of the heat exchanger.

Laminar Annular (Concentric Tube) Flow[1]



$$\bar{N}u_{D_e} = \frac{\bar{h}_1 D_e}{k_f} = 1.02\,\mathrm{Re}_{D_e}^{0.4}\left(\frac{D_2}{D_1}\right)^{0.8}\left(\frac{\mu_2}{\mu_1}\right)^{0.14} Gr^{0.05} \tag{3}$$

where

$$D_e = D_2 - D_1 \tag{4}$$

[1] Example of a correlation for a heat transfer coefficient from Perry's Chemical Engineer's Handbook, 7th ed., p. 5-15.

Material Specifications

PVC Pipe

Nominal Diameter/in	gm/cm
1.5	7.6
2	10.6
3	21.9
4	30.4

¼" Tubing

Material	gm/cm
Polyethylene (PE)	0.2
Copper (Cu)	0.8

PVC End Caps

Nominal Pipe Size/in	Gm
1.5	52.0
2	76.0
3	210.4
4	358.8

Brass Pipe Fittings

¼" Tube Connectors	gm
MNPT Bored Through	31.6
MNPT Standard	36.0
Union (Cu to PE)	33.5
Union (Cu to Cu)	36.5
Tee	69.6

Bending Copper Tubing

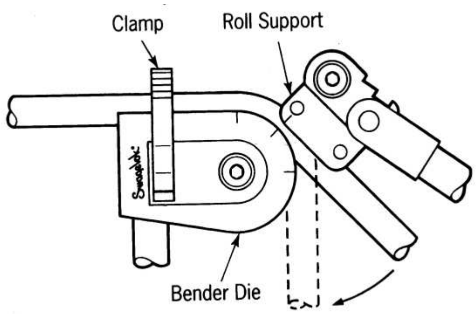


FIGURE 11.20 Tube Benders. (Reproduced with permission of Swagelok Marketing Co.)

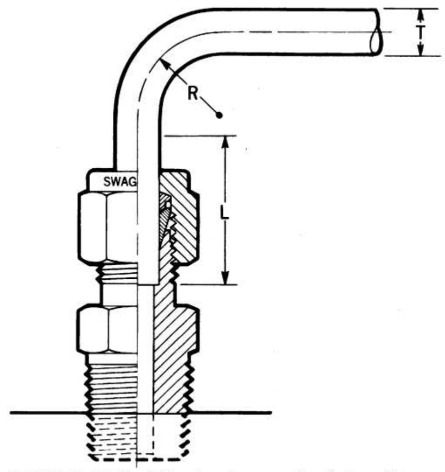


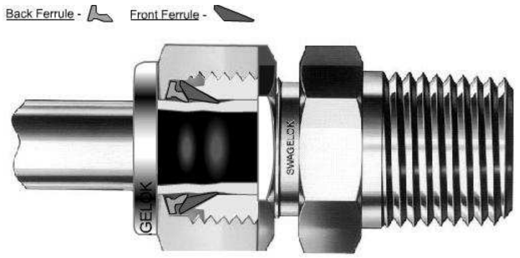
FIGURE 11.21 Tube bend near tube fitting. (Reproduced with permission of Swagelok Marketing Co.)

Hazardous Materials

PVC Primer and Cement: Methyl Ethyl Ketone, Cyclohexanone, Tetrahydrofuran, Acetone

Silicone Rubber Sealant: Methyltriacetoxysilane, Ethyltriacetoxysilane

Compression Fittings



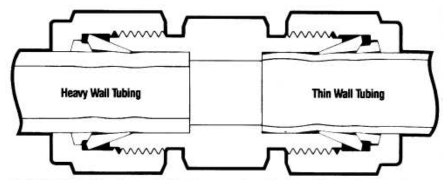


FIGURE 11.25 Swagelok® Compression Fitting. (Reproduced with permission from Swagelok Marketing Co.)

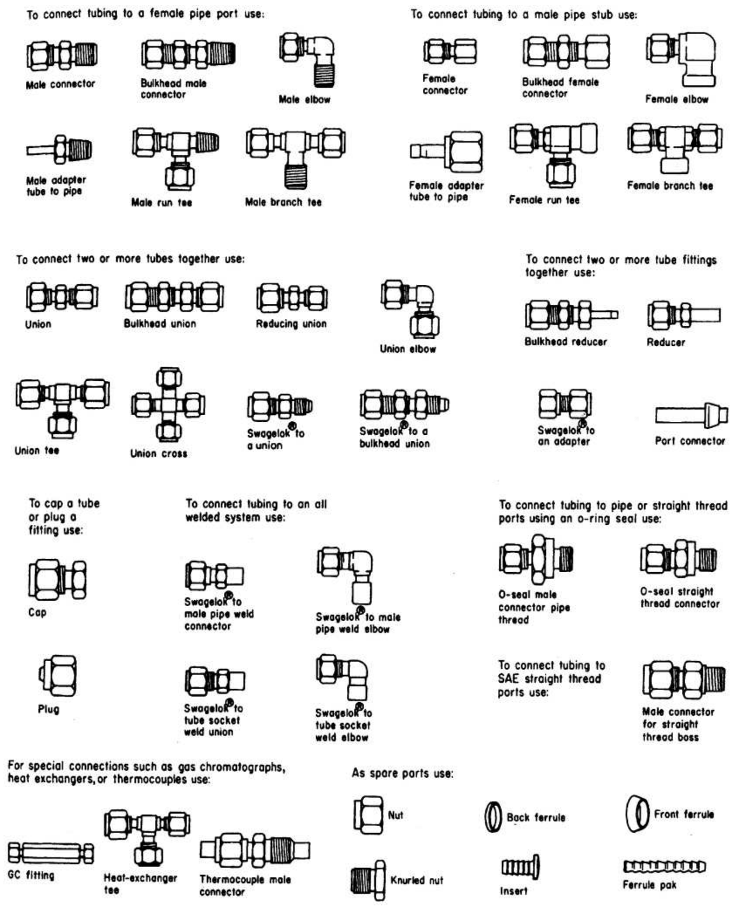
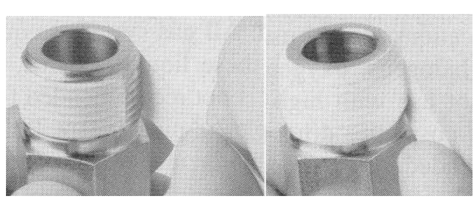


FIGURE 11.24 Compression Fittings and Configurations.

Application of Teflon Tape



The due date for this project proposal is listed below

Tuesday Lab (Section 1) – October 29, 2012, at 4:30 PM
Thursday Lab (Section 2) – October 31, 2010 at 4:30 PM

Please address the project proposal to:

ATTN: Faculty Advisor
McCracken Industry, Inc.
2106 Wayland Boulevard
Prairie Land, Minnesota 57666

In order to save time and postage charges, please deliver a written copy of the project proposal to:

Dr. Sarah Wang
ChE 3211 Laboratory Instructor
University of Minnesota Duluth
Department of Chemical Engineering
Engr 238

Also send by email an electronic copy to Dr. Sarah Wang - wang4060@d.umn.edu and Duane Long - dlong@d.umn.edu

Structure of the Project Proposal

Components of a Project Proposal

1. Title Page
2. Table of Contents
3. Abstract
4. Introduction
5. Discussion (the body of the proposal)
6. Conclusion/recommendation
7. Glossary
8. Works cited information (optional; only needed if you are documenting research)
9. Appendix

Title Page

1. Title of Proposal
2. Name of the company, organization, or reader of the proposal
3. Name of the company or writer(s) submitting the proposal
4. Date on which the proposal was completed.

Table of Contents

1. The table of contents should be a complete and accurate listing of the main headings and subheadings covered in the proposal.

Abstract

1. The abstract is a brief overview of the proposal's key points geared toward decision makers.
2. Abstracts often focus on but are not limited to the following;
    a. The problem this proposal is addressing.
    b. The suggested solutions to the problem.
    c. The benefits that will result if the suggestions in this proposal are implemented.

Introduction – The introduction should include two components

1. Purpose statement – in one to three sentences tell the reader the purpose of your proposal. This statement informs your readers why you are submitting this proposal (response to a Call for Project Proposal) and what you hope to achieve.
2. Problem (Needs Analysis) – Your discussion of the problem or the reader's needs must be more detailed. Your introduction is important for two reasons.
    a. First, it highlights the importance of your proposal. You persuade the reader(s) that a problem truly exists and needs immediate attention.
    b. Second, by clearly stating the problem, you reveal your knowledge of the situation. The problem section reveals your expertise

Discussion (body of the proposal)

1. In this section you sell your product, service or suggested solution.
2. The discussion section represents the major portion of the text.
    a. Include in this section your analysis of the problem (specifications from the Call for Project Proposal, assumptions made, equations used, calculation results)
    b. Include in this section the results of a preliminary uncertainty analysis.
    c. Include your solution(s) to the problem based on the equations and calculations you used (in a Table format).
    d. Include in the discussion the proposed diameter and length of the shell, the proposed length of the copper tubing, the Swagelok fittings you will need and any other material you will need to construct a working heat exchanger (in a Table format).
    e. Include in the discussion section a schematic of your heat exchanger with the dimensions and the inlet/outlet of the hot and cold streams labeled.
    f. Include an implementation schedule with the use of a gantt chart.
    g. Include a cost analysis based on the economic rating you calculate. Use as an average length, 54.4 cm, and the average weight, 1.8 Kg, in your calculation. This is the average length and weight of all the heat exchangers built to date. You can use the weights found in the document "Exchanger Design Project Info" to estimate the weight of your heat exchanger.
    h. Include a discussion of safety and environmental issues.
    i. Include any other information you think will be important to the planning team in their evaluation of your proposal.

Conclusion/Recommendations

1. Sum up your proposal.
2. Restate the problem
3. Restate your solutions
4. State the benefits to be derived by allowing your project to proceed.
5. Your recommendation will suggest the next course of action. Specify when this project will or should occur and why that date is important.

Glossary

1. Define your terms such as abbreviations, acronyms, equation variables and specialized terms.
2. Place after your conclusion/recommendation section.

References

1. This page documents the sources such as books, periodicals, computer software and online sources you have used, quoted or paraphrased.
2. Placed after the Glossary.

Appendix

1. Include your design calculations.
2. Include your preliminary uncertainty calculations.

Release Form

I have read the safety documents and received training on the safe use and operation of the following tools in the Department of Chemical Engineering (signature and date for all that apply):

- Band Saw: ______________________________
- Disk/Belt Sander: ______________________________
- Miter Saw: ______________________________
- Hand Drill: ______________________________
- Drill Press: ______________________________
- Saber Saw: ______________________________
- High Speed Cutting Tool: ______________________________
- Other (Specify): ______________________________
- Other (Specify): ______________________________
- Other (Specify): ______________________________

I will use these tools only under the direct supervision of the instructor or laboratory services coordinator. I agree to wear safety glasses and follow safe operating procedures at all times in the laboratory and while using tools. I will use hearing protection when using power tools.

I agree to use these tools at my own risk and will not hold the Department of Chemical Engineering liable for any injury resulting from the improper use of these tools.

Name (Print): ______________________________

Signature: ______________________________

Date: ______________________________

Turn this sheet in to the instructor.

University of Minnesota Duluth

Department of Chemical Engineering

Student Built Heat Exchanger Data Sheet

Team

Student Name:____

Student Name:____

Student Name:____

Heat Exchanger

Heat Exchanger Nick-Name: ____________________________________

Length (cm): _________________________

Weight (gm):_________________________

Steady State Performance Data

Water Streams	Flow Rate (L/min)	Inlet T/ ^{o}C	Outlet T/ ^{o}C	ΔT/^{o}C
Hot (~0.2 L/min)				
Cold (~0.6 L/min)				

Room Air Temperature (^{o}C): _______________

Provide the instructor with a copy of this sheet after your test.