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RESERVE DESK

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1999

Design
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

Please **p r I n t** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

Question #1 - Reverse Vending Machine Design

In many states and countries, deposits are collected on containers (typically beverage bottles and cans) to encourage recycling. These containers can be made from aluminum, steel, plastic (only one type of plastic, polyethylene terepthalate (PET), is collected, and it might be green or clear), and glass (clear, green and brown). You have been given the job of designing a "reverse vending machine". This is a machine that takes in empty bottles and cans from a consumer, and refunds the correct deposit.

The machine you are to design is to take in the various size cans and bottles from 12 oz cans and bottles to three-liter bottles. The machine should identify the bottle or can material type; determine the appropriate refund and give it to the customer in the form of coins; and reject unacceptable plastic bottles and return them to the customer.

Many of the bottles and cans have bar codes on them that allow their identification. This identification does not always contain information concerning the color of the glass or of the type of metal. Some bottles and cans have distinctive shapes and sizes, also.

The machine should sort the containers by material type (glass, aluminum, plastic, steel), and color (green, brown, clear) if glass or plastic. It should densify or otherwise reduce the volume of the containers. It should store them in separate bins for collection at a later time. The containers do not need to be in their original shapes. Labels on the containers do not need to be removed.

Your job is to:

1 Determine the main functions and sub-functions of the machine.

2) Place those functions and sub-functions into a function tree.

3) Develop a Functional Diagram which shows the flow of energy, materials, information) for the machine. Be explicit as to the machine's boundary, and flows across it. Either the Functional Diagram presented in Ullman (the 3110 text) or the EMI diagram from Pahl and Beitz (the 6170 text) are acceptable.

Problem #2 – Pressure Regulator/Control Valve Assembly

In Figure 1 (below), a cross-sectional drawing of an AVA ("Aktiebolaget vapor ackumulator") pressure regulator/control valve assembly for steam systems is given. Basically, steam is flowing through the pipes as indicated in Figure 1, and turning the hand wheel at the top will open or close the valve labeled K. If K is closed, the steam flow is blocked. Right now, the valve is shown in the closed position.

As you can see in Figure 1, there are a number of studs keeping the main sections of the assembly clamped together. The studs labeled "1" are placed in a circle with a 125 mm radius. The studs labeled "2" are placed in a circle with a 100 mm radius.

In Figure 2, a close-up of one of the stud labeled "1" and the flanges/members to be clamped is given. *Figure 2 is not drawn to scale, so do not derive any dimensions directly from the drawing.*

The studs labeled "1" are M16, coarse pitch, rolled thread. Tensile stress area is 157 mm^2. Each stud consists of three parts labeled a, b, and c. Parts a and c are threaded. Part b is slightly wider in diameter because it is used for centering the top flange. The length of part b is 20 mm, its diameter is 18 mm (equal to the diameter of the hole), and it is unthreaded.

The length L of the grip is 60 mm. The thickness T1 of the top flange is 30 mm. There is a hardened washer being used under the nut with a diameter of 25 mm (not shown in Figure 2). Both flanges are made out of gray cast iron.

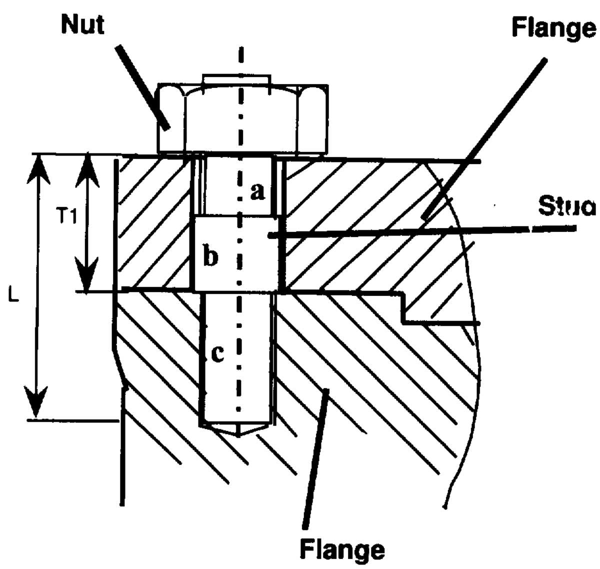


Figure 2 – Schematic of Flanges and Stud-Nut Combination for Situation "1"

The steam pressure is 13 MPa. It acts on a circular area with a radius of 80 mm. The modulus of elasticity E for carbon steel is 207 GPa. The modulus of elasticity E for cast iron is 100 GPa.

a) Which set of studs ("1" or "2") do you expect to take a higher load and why?

b) Calculate the stiffness of the stud in Figure 2, which represents the studs labeled "1"..

Assume a joint constant of $C = 0.30$ for the **two** next questions which concern Figure 2.

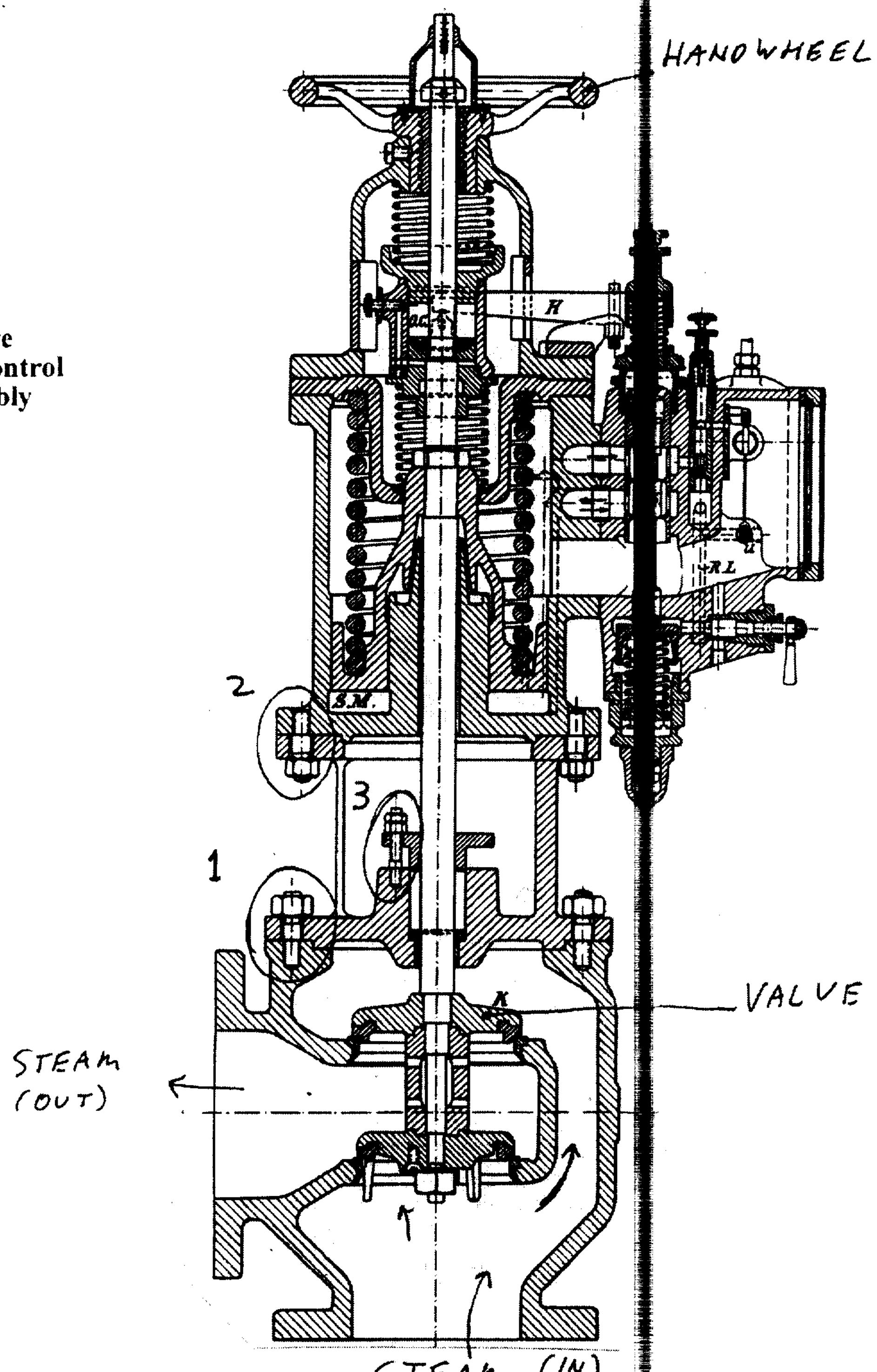
c) If there are four studs, what is the minimum required torque to avoid joint separation?

d) If there were a gasket present, would you (in general) recommend four studs for this type of application? Why or why not?

e) Why are two nuts used in situation "3"?

f) Why do you always have to check for yielding if you use the Goodman criteria for fatigue failure?

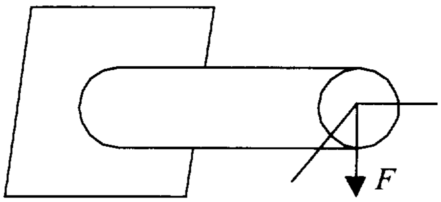
Figure 1 – AVA Pressure Regulator/Control Valve Assembly



Question #3 - Spring Design

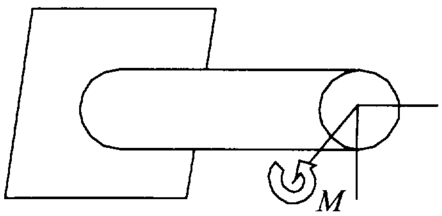
For your reference, a cantilever beam of radius r is shown for three types of loading:

Force - F



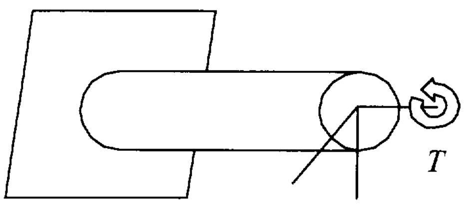
$$\tau_{max} = \frac{F}{A}, \qquad A = \pi r^2$$

Bending moment - M



$$\sigma_{max} = \frac{Mr}{I}, \qquad I = \frac{\pi r^4}{4}$$

Torsion - T



$$\tau_{max} = \frac{Tr}{J}, \qquad J = \frac{\pi r^4}{2}$$

Consider a portion of a coil spring that is not close to the ends. Determine a formula for the factor of safety against yielding in terms of the applied load and the spring parameters. Please simplify the equation using the ratio $C = D/d$.