GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2001

Design
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

DESIGN QUALIFING EXAM

Spring 2001

We are interested in learning what you know and your ability to reason in the formulation and solution of design problems. If you find any question or part of this exam confusing, please adjust the question, explicitly rephrase it, and state your assumptions.

Read the entire exam first. Allocate your time carefully so that you cover all three parts of the exam: Realizability, Analysis, and Methods.

ORALS

We will conduct the oral exam by first giving you the opportunity to state how design fits into your research activities. If you do not do an adequate job on this written exam, we may ask you to discuss it during the oral exam.

1 –Squirrel Removal System

In many cities it is illegal to kill squirrels, even if they are destroying your home by chewing holes in the eaves or other parts of the house. Thus, the only legal option to deal with this problem is to catch the squirrels, without harming them, and then turn them loose in the yards of the mayor or other city officials. This exercise requires the design of a means of apprehending the squirrels, a system for transporting the squirrels to a recommended release location, and a means for releasing the squirrels without harming either the squirrels or the home owner/operator.

Your goal is to develop a system to apprehend common squirrels and transport them to an approved release location. Your task is to design a system that has the following qualities:

1. The device must effectively catch squirrels without endangering the health and well being of the squirrels.
2. The device and all associated components must be easily deployed, operated and removed by a home owner.
3. The device and any associated components and systems must provide a means to transport the captured squirrels to an acceptable location and safely release the relocated squirrels.
4. The device must be light weight.
5. The device must be inexpensive.

Deliverables

A short report containing the following:

1. A statement defining the overall function of your system.
2. The steps (including a specification list and functional diagrams/decompositions) for transforming your overall function into (at least) three alternative design solutions.
3. Sketches of your design, showing its parts and how it operates.
4. Written explanation of why you chose your design from the three alternatives.
5. Written explanation of the way your design works, referencing the sketches.
6. Discussion of the advantages and disadvantages of your design.

2 – "Fast Runner" Steam Engine

In Figure 1, a cross-sectional drawing of a so-called "fast-runner" three-cylinder steam engine is given (it was taken from a Dutch 1920 engineering textbook). The three pistons drive a crankshaft through the connecting rods. In the picture, one of the cylinders and its piston is also shown in a cross-section. As you can see, the piston is in its top-most position. The two other cylinders and pistons are not fully shown due to their angle with respect to the drawing view. Note that the cylinders are horizontal (see also top view).

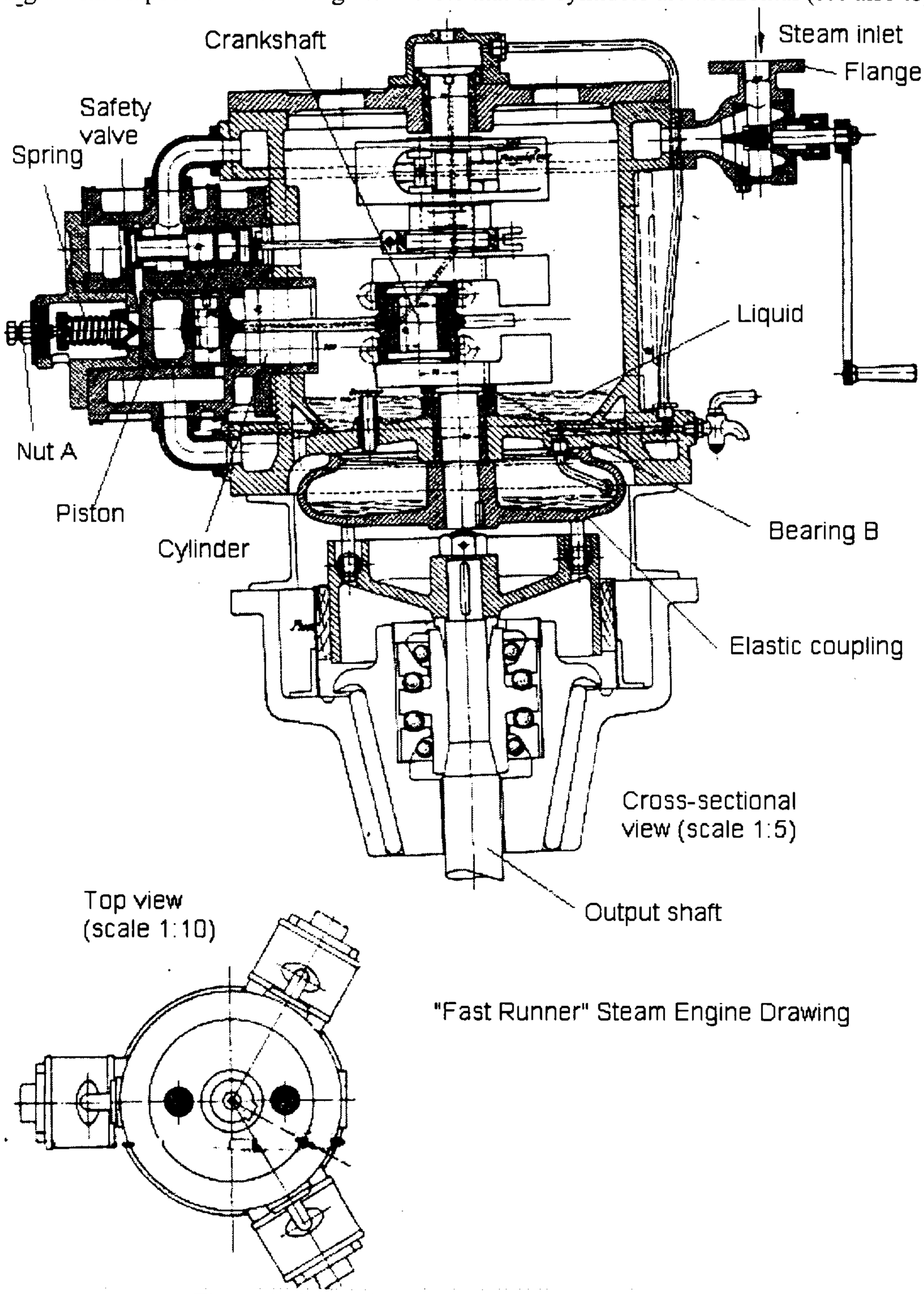


Figure 1 - Three Cylinder "Fast Runner" Steam Engine.

In Figure 1, a spring operated pressure relief valve is shown which opens if the pressure in the cylinder exceeds the safety limit. The area of the valve on which the steam pressure acts is 950 mm^2. The dimensions for the spring are wire diameter d = 5 mm, mean coil diameter D = 25 mm, total number of coils N_{total} = 12, free length Lf = 80 mm. The spring is made of A228 music wire with a modulus of rigidity G=79.3 Gpa. The modulus of elasticity E for carbon steel is 207 GPa. The modulus of elasticity E for cast iron is 100 GPa.

a) At what steam pressure will all coils of the safety valve spring be touching?

b) What is the purpose of the nut A?

c) What kind of load do you think the primary load on bearing B is?

d) Assuming that the total load on bearing B is 1000 N and the bearing's basic load rating is 30000 N, what is the L_{10} life of the bearing?

e) What would be the L_{10} life if a roller bearing was used with the same basic load rating of 30,000 N?

f) What are the advantages and disadvantages of using journal bearings instead of roller bearings?

g) What do you think the liquid (see label in Figure 1) is inside the steam engine, and why?

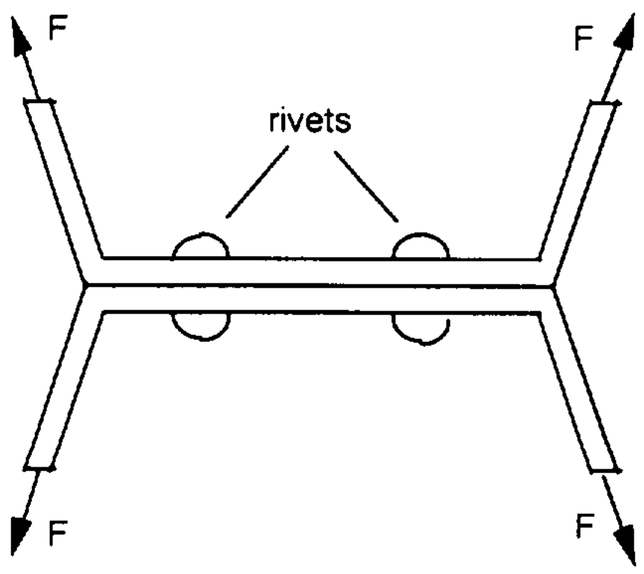
h) A flexible coupling is used to connect the crankshaft to the output shaft (see Figure 1). Why do you think this kind of coupling was used? What are some other types of couplings?

As shown in Figure 1, the steam inlet contains a flange, which is made of carbon steel. The plan is to bolt this flange to a flanged steam pipe (not shown, but also carbon steel) by four fully threaded M12 bolts and nuts. Both flanges are 10 mm thick each. Assume that the total load on the flanged joint (caused by the steam pressure) is 1,500 N and that the tensile stress area of an M12 bolt is 84 mm^2.

i) If the joint constant C = 0.2, what is the stiffness of both flanges? Assume that no gaskets are present.

j) Assuming a pre-load of 1,000 N, what is the minimum required proof strength to avoid bolt failure in the described flanged steam inlet joint if we assume the load is static and not dynamic?

k) What is wrong with the following structure?



Useful equations: $k = d^4 G / (8D^3Na)$