# ME 356 Pressure Vessel Project



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## 1.0 Objectives.

The objectives for ME356 adopted by faculty last year state that by the end of this course, the student should be able to

1. analyse and design a mechanical component for both steady and time-varying loads, and account for the presence of stress concentrations.

2. Specify and where appropriate select from a catalog common mechanical elements such as fasteners, springs, bearings, etc.

Thus, towards fulfilment of the course objectives, the objectives for this project are:

1. Apply the principles for static and fatigue design to the components of a pressure vessel.

2. Compare the results of analysis to the ASME code design rules.
3. Specify standard components (e.g. bolts, washers, flanges, etc.) where possible.

## 2.0 Background.

Pressure vessels are used in a variety of industrial processes. Due to early accidents involving steam boilers, ASME set up a committee in 1911 to formulate rules for construction of steam boilers and other pressure vessels. Today this committee is called the Boiler and Pressure Vessel Committee and it meets regularly to revise the rules as needed in light of new experience, and technology development. The ASME B&PV code is required by law in the USA, and in many countries around the world.

Apart from boiling to make superheated steam for power generation, pressure vessels are needed in a variety of applications. In chemical process industries they are called "reactors" where the contents can undergo a chemical reaction at some temperature and pressure. In composite materials industry, one speaks of "Autoclaves" used to cure parts at some pressure and temperature. The submarine is a pressure vessel loaded externally. And in our Microcellular Plastics lab, we use pressure vessels to impregnate plastics with gases such as $CO_2$ or $N_2$ at various pressures. Typical pressure ranges of interest are 100–1000 psi for $CO_2$, and 500–2500 psi for nitrogen. Recently, in an effort to make open-cell, porous structures in biodegradable polymers for tissue engineering applications, we used supercritical $CO_2$ in the range 2000–4000 psi. The higher pressures are obtained by "pumping" $CO_2$ from a standard tank (or cylinder – which is another example of a pressure vessel!) using a positive displacement pump.

3. Problem Statement.

Design a cylindrical pressure vessel rated for a maximum pressure of 1500 psi and a maximum service temperature of 150 °F.

Nominal internal diameter = 11 inch.
Nominal depth (or length) = 24 inch.

You can adjust the ID to go with the nearest standard flange that you can find.

Do your design calculations for

A. Static load. ( assume vessel will be used only once)

B. Infinite fatigue life.

Again, the objective is to do the <u>analysis</u> on various components in <u>support of the design decisions</u>.

A sketch showing dimensions of components, and specifications etc. is all that is needed.

Manufacturing drawings are NOT required.

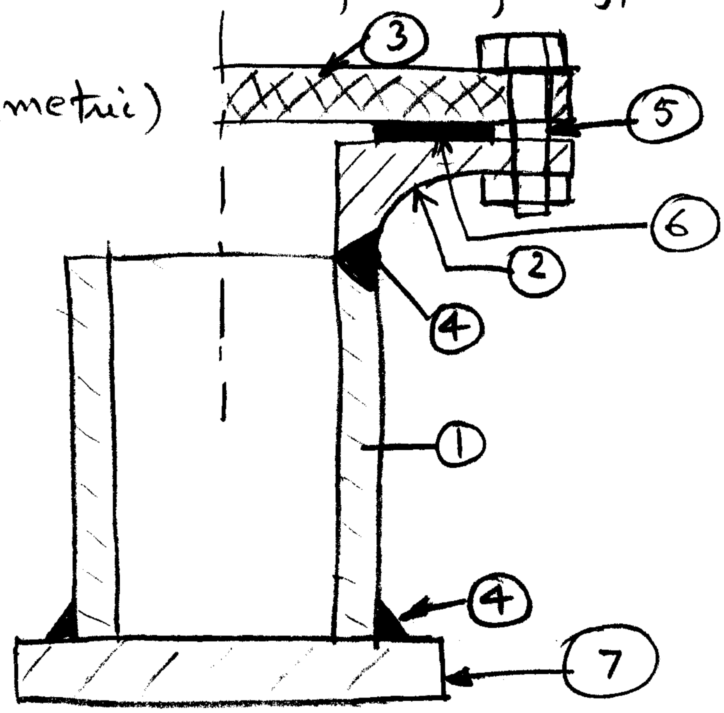
OTHER INFORMATION

- Assume no corrosion.
- Shell has one 1/4" hole to which appropriate tubes/ fittings will be connected in order to attach to a source of pressurized gas.
- for static design use the distortion energy theory.
- Vessel will NOT be used below 32 °F
- Use a design factor of safety $n = 3.5$

## 4.0 Design guidelines / suggestions.

Consider the following typical design:

(Symmetric)




(Schematic) Fig 1.

① Shell

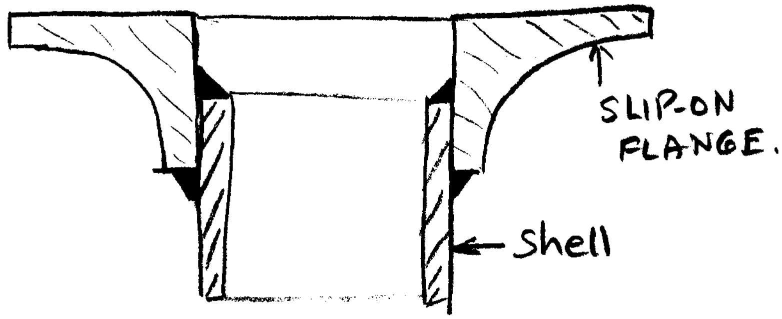
This can be made from steel plate, rolled up and welded, for example. OR one may use pressure-rated seamless pipe. [Look up KILSBY steel tubes/pipe, for example]

Calculate the minimum thickness needed, then see if the use of thin-walled cylinder equations is justified. If not, use the thick-walled cylinder equations to calculate the principal stresses.

② Flange

You can look up Flange manufacturers. The kind shown in Fig 1. will be butt-welded to the shell. (weld-neck flange)

Another design you might consider is one that "SLIPS-ON" the shell:



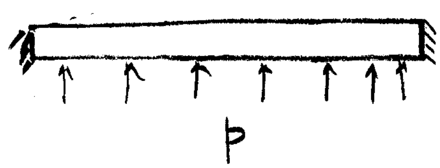

note the location of the welds. Both welds can be made without having to reach inside the shell (which may be a problem for small shell diameters).

For the weld-neck flange, the code may stipulate on the weld specification — with respect to achieving full penetration.

Do not design the flange. Try to find one you can use off the shelf.

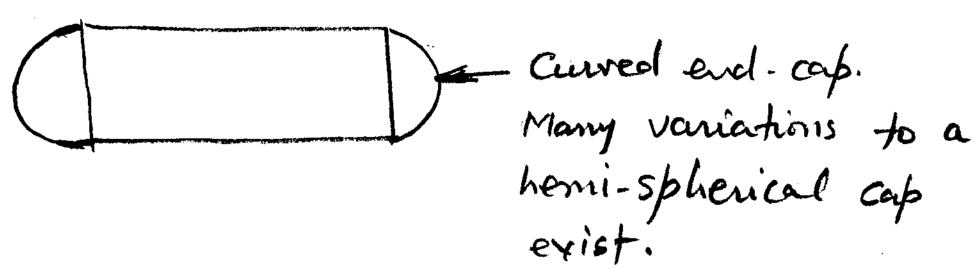
③ cover plate. (also ⑦, Bottom plate)

Consider a flat cover plate design. You will have to consider stresses induced due to internal pressure. You may consider it fixed at the circumference.




Look for a solution for stress (and strain if needed) distribution in ROARK, for example.

The pressure puts the plate in bending. As you know the material carries a load most efficiently in direct tension. For this reason, larger vessels (such as for boilers, for example, have a curved cover to induce stresses that look 'axial' to the material.

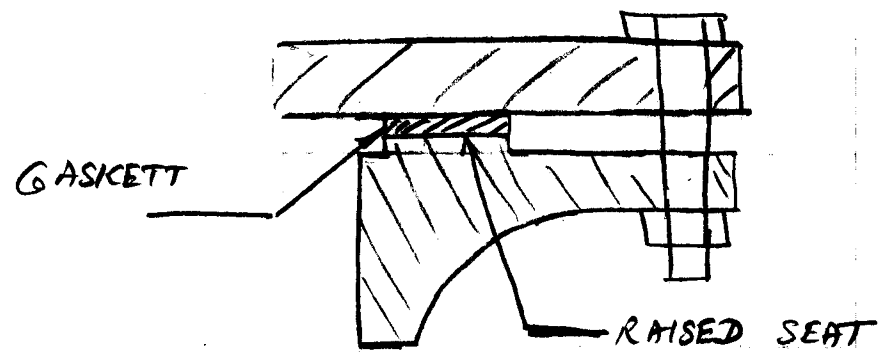


④ Analyze / specify the needed welds

⑤ Analyse / specify needed bolts, washers, etc.

⑥ Gaskett. ( Look-up manufacturers / Specify a gaskett )

often a flange will have a raised seat on which the gaskett is placed.




O-RINGS are quite common on small vessels. O-RING Grooves need to be precision-machined to create an effective seal.

## 5.0 Materials

Allowable materials are given in Section II of the ASME Code.
Material properties are given in part D.

For this project limit material choices to the following:

PLATE

SA 516 GRADE 70

SA 285 GRADE B

SA 283 GRADE D

PIPE

SA 106 GR B

SA 53 GR S/A

SA 672 GR C 65

FORGING

SA 105 ( Flange is

SA 181 often forged)

BOLTS ?

## DELIVERABLES

YOUR REPORT is DUE Thursday Dec. 6.

- All calculations should be initialed "done by ____" and "Checked by ____"
- Organize all calculations in the appendix.

## NAVIGATING THE CODE

I do not have specific recommendations about how to go about this at this time.

My goal is not to beome an expert at using the ASME code for pressure vessel design; rather, it is to gain an appreciation for what the Code is, how it is organized, and the kind of rules it contains.