University of Salford

BEng(Hons) Mechanical Engineering

Report on the design , manufacture and marketing of a standardised beer keg

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Abstract

This technical report was written by the Salford University Mechanical engineering design team comprising Joshua Jones , Neelsanth Ghoorun, Fubin Ou, Mudassir Amin, Mohammed Shah and Herve Tshiyombo.
The aim of this report is to provide the technical, manufacturing and marketing details of a typical beer keg, based on the research that was conducted.
Therefore the result of this excercise should be a document containing all the necessary details to, with the right resources and capital , begin manufacturing beer kegs based on this specification.

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0.1 Introduction

During the Medieval times, beer was brewed to meet the needs of small groups of people and was usually consumed at the production site, but as the time passed demand for beer grew and beer had to be transported to different locations. Wooden barrels were used to do this job for a long period of time until the Industrial Revolution. The industrial revolution led to the discovery of new metals and with the discovery of new metals, industry started using metals for the storing beer. Metals were selected essentially for their strength and cost, but more information about metals is discussed later. In the present day, beer is thought to be a everyday necessity. It is a massive market to be exploited, and hence the primary reason to work on a beer keg design. A beer keg should be of appropriate size, not too big so that it consumes a lot of space and not to small that the consumer has to refill it again and again, the keg should also be easy to store and transport. Furthermore, the material used to produce the beer keg should be food grade material and should not in any way pose any health risks. Keeping all of these design constraints in mind, a design plan of beer keg along with manufacture and marketing is produced.

0.1.1 Objective

The history of storing beer can be traced back to Roman times; our ancestors used to store beer in wooden barrels but as the technology progressed wooden barrels changed into metal containers. The Design, Manufacture and Marketing of these modern metal beer containers are discussed.

0.2 Materials analysis

overview This section will describe the material selection process and subsequently the properties of the material to be used.

0.2.1 Discussion of purpose material selection process

Selecting the correct material is paramount to the functionality and economical viability of a product, therefore the properties of the ideal material must be defined, and then an appropriate real world material must be chosen that fits the technical specification and the economic contraints.

Through this process a suitable material can be found which meets the needs of the user and is a marketable and profitable product for the manufacturer.

0.2.2 Specification

The ideal material would exhibit these properties and characteristics:

- Resistant to liquid(Beer) and gas(Carbon Dioxide) corrosion.
- Able to withstand high internal pressures.
- Lightweight
- Cheap to source and manufacture - this also implies reasonably workable and machinable
- Commonly rolled into sheets of variable thicknesses
- Ability to retain strength at small thicknesses

These material properties most obviously resemble sheet metals. Therefore a comparison of different metals yields that the most suitable metal to use is AISI 304 Stainless Steel [1].

Reasons to use AISI304 Stainless Steel

- most widely used stainless steel therefore it is cheap.[1]
- corrosion resistance, 304 steel exhibits high resistance to a wide range of atmospheric and food industry exposures.[2]
- good mechanical properties : UTS 505 MPa ,0.2% YS 215 MPa , Rockwell Hardness of B82.[2]
- good strength to weight ratio.
- commonly worked and machined by standard (cheap) equipment.
- Easily rolled into sheet metal of most common thicknesses.

0.2.3 Properties of AISI 304 Stainless Steel

Stainless steel is widely used in the food and medical industries because it is easily cleaned and sanitized.[3]
This stainless steel is widely used in food industry, particularly in beer brew, milk processing and wine making. [4]
AISI 304 Complete Composition Table: [2]

Element	% by weight
Carbon	0.08 max
Manganese	2.00 max
Phosphorus	0.045 max
Sulfur	0.030 max
Silicon	0.75 max
Chromium	18.00-20.00
Nickel	l8.00-12.00
Nitrogen	0.10 max
Iron	64.995

Material Notes:

Austenitic Cr-Ni stainless steel. Better corrosion resistance than Type 302. High ductility, excellent drawing, forming, and spinning properties. Essentially non-magnetic, becomes slightly magnetic when cold worked. Low carbon content means less carbide precipitation in the heat-affected zone during welding and a lower susceptibility to intergranular corrosion.

Applications: beer kegs, bellows, chemical equipment, coal hopper linings, cooking equipment, cooling coils, cryogenic vessels, dairy equipment, evaporators, flatware utensils, feedwater tubing, flexible metal hose, food processing equipment, hospital surgical equipment, hypodermic needles, kitchen sinks, marine equipment and fasteners, nuclear vessels, oil well filter screens, refrigeration equipment, paper industry, pots and pans, pressure vessels, sanitary fittings, valves, shipping drums, spinning, still tubes, textile dyeing equipment, tubing.

Corrosion Resistance: resists most oxidizing acids and salt spray.
[5]

AISI 304Steel Physical and Mechanical Properties Table:

Density	$8000\frac{kg}{m^3}$
Melting point	1400°C
UTS	505 MPa
YS	215 MPa
Elongation at Break	70%
Modulus of Elasticity	193-200 GPa
Poisons's Ratio	0.29
Charpy Impact	325j
Shear Modulus	86 GPa
Rockwell Hardness	70
Vickers Hardness	129

0.3 Technical analysis

Overview This section will describe the geometry and technical specification of the barrel, where possible standardised dimensions have been used in accordance with international codes and specifications.

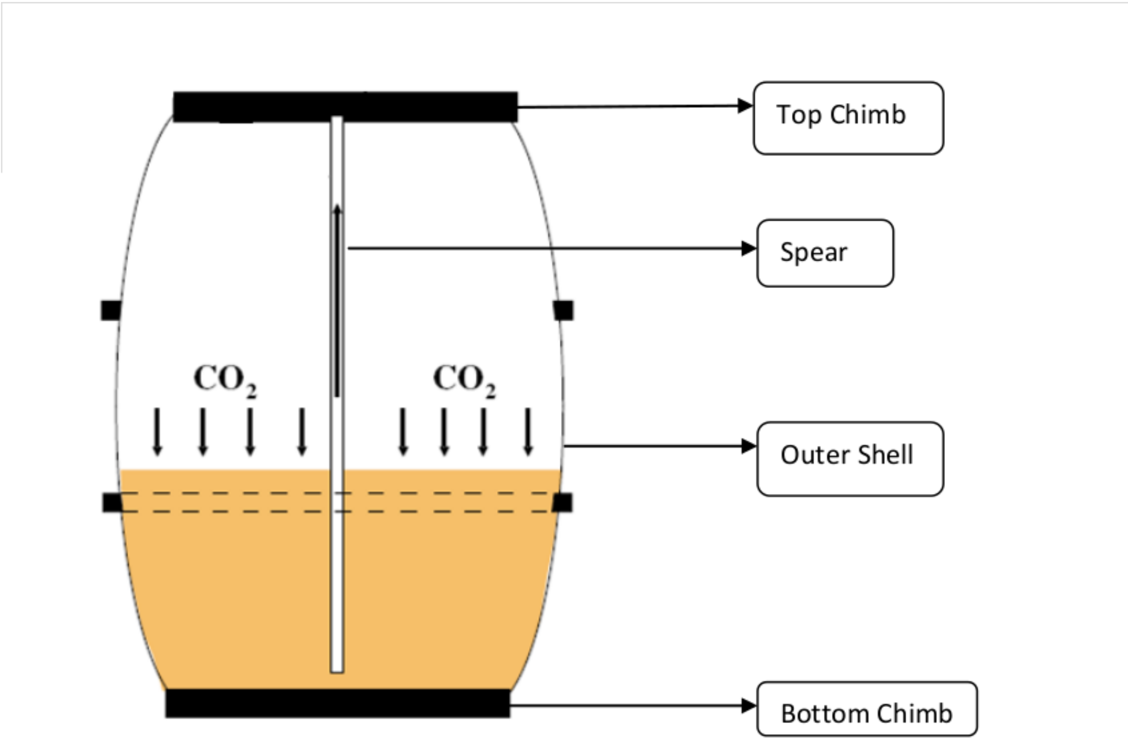


Figure 1: beer keg fluid diagram

0.3.1 Material and Technical Specifications ofthe keg:

- Capacity of the keg to be 72.91 liters (50 liters of beer and 22.9kg of Carbon Dioxide).
- Outer Shell and Chimbs shall be made of AISI 304 Stainless steel of thickness 1.70mm.
- Empty weight of keg 11.8 kg (approximate)
- Full weight of keg 65-70 kg, depending on the liquid (approximate)

Dimensions of Keg:

- Diameter of 395mm
- Height of 600mm
- Thickness of 1.70mm

Keg Volume to ensure projected capacity:

Assume keg is a simple cylinder we can calculate the volume using the given formula.
Volume of a Cylinder V (m^3):
$V = \pi \frac{D^2}{4} \times h$
• $h = 600mm, D = 395mm$
$\therefore$
$V = \pi \frac{(395 \times 10^-3)^2}{4} \times 600 \times 10^-3 = 72912340.32mm^3 = 72.91L$

So, the total capacity of the keg is 72.91 Liters and in that capacity we have 50 Liters of Beer and 22.91 Liters of CO_2.

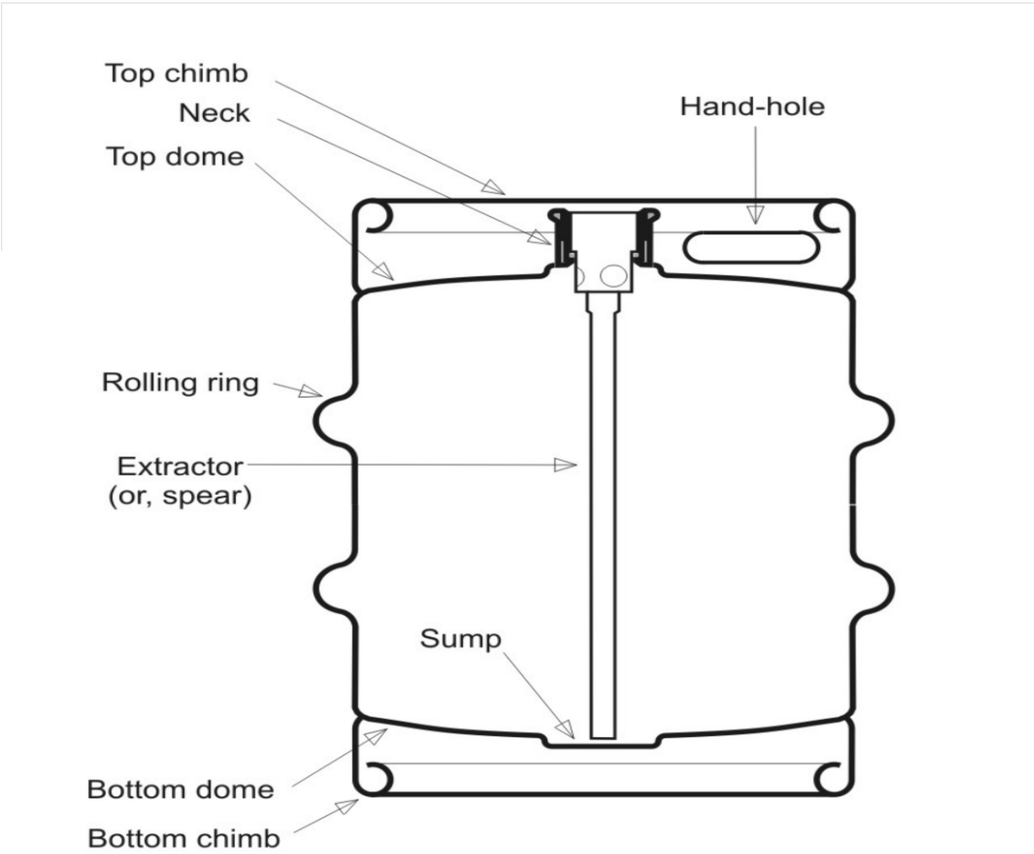


Figure 2: Typical keg schematic

Height of Carbon Dioxide and Beer in the keg:

Height of CO_2 :
$22.91 \times 10^6 = \pi \frac{395^2}{4} \times h$
$\therefore$
$h = 190.8mm$

Height of Beer:
$50 \times 10^6 = \pi \frac{395^2}{4} \times h$
$\therefore h = 408.02mm$

Pressure inside the keg

Pressure of a static incompressible fluid: Pressure $P = \rho g h (pa)$

Density of CO2 = $1.98\frac{kg}{m3}$

So, Pressure of CO2 = $1.98 \times 9.81 \times (190.8^3) = 3.706Pa$

Density of Beer= $1060\frac{kg}{m3}$

Hence, Pressure of Beer= $1060 \times 9.81 \times (408.02 \times 10^3) = 4242.87Pa$

Total unpressurized pressure in keg = 4242.87+3.706 = 4246.576 Pa or 0.0424 bars

Keg has to be tapped before using and recommended pressure for tapping is 10psi
1psi = 0.069bars

So at 10psi:
Pressure of CO2= $10 \times 0.069 = 0.69 bars$
$11 Liter = 1Mmmor1 \times 10^6 mm$
Pressure of Beer= $10 \times 0.069 = 0.69 bars$

Total Pressure = Pressure of unpressurized keg + Tapped CO2 pressure + Tapped Beer
$\therefore$
Pressure = 0.0424+0.69+.069 = 1.42 bars

Stresses

Using the Hoop Stress Equation we can calculate the maximum safe working pressure for the keg:
Hoop stress : $\sigma = \frac{P \times R}{T}$

Ultimate Tensile Strength of 304 Stainless Steel is 580MPa, using this information we can find out the maximum pressure that the keg can bear.

Hence,

$580 \times 10^6 = \frac{P \times 197.5 \times 10^-3}{1.70 \times 10-3}$
$\therefore$

P $= 580\frac{\times 10^6 \times 1.70 \times 10^-3)}{197.5 \times 10^-3}$

=4992405.063 or 4.99 bars or 724psi.

Although the keg will be operated at a pressure of 10psi and using hoop stress equation that pressure comes out to be 8MPa which is within the safe working limit of the keg.

0.4 Manufacturing analysis

0.4.1 Cost and supply

To keep the price of the beer keg as low as possible it was absolutely vital to get raw materials at cheap prices. After conducting market research it was found out that the cheapest option was to import raw materials from China and after contacting a lot of different manufacturers in China, the best price we got for sheet metal was 1800 per ton without shipping costs and import duty.
The cost of importing is mainly divided into; import duty, V.A.T and shipping costs. The import duty for raw sheet metal is 4.5% and the V.A.T is 20% of the value of the materials The best possible shipping cost from China to UK is about 80 per cubic meter via sea freight.
For example, the price for importing 1 ton of AISI 304 stainless steel from china would be worked out as following:

- Cost of the steel: £1800
- Import duty: £81
- Shipping cost: £640
- Other costs: £100
- V.A.T: £360
- Total cost: £2981

Although apart from raw material, we need to separately buy Neck and Extractor for the beer keg. The basic function of the neck and extractor is to transfer the beer in and out of the barrel.
After conducting some market research and discussing with the design team, decision was made to purchase the Neck and Extractors from within United Kingdom.
The best price for the Neck and Extractor came out to be £2 per unit and £6 per unit, respectively. Keeping all the costs and market competition in mind it was decided by the design team to sell the 50 liter beer keg for £100 per unit.
(To work out the final beer keg price we had to bear in the mind the cost of labor, factory running expenses, energy bills and lot of other things but as this was not the requirement of the exercise we worked out the final beer

keg price similar to the prices that they are been sold for in United Kingdom)

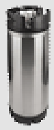
In the UK around 50 million Hectolitres of beer is consumed a year. A report in The Daily Telegraph states that 51% of beer in the UK is consumed in pubs. This beer is kept and transported in kegs. Kegs are the ideal option for pubs and breweries to store and transport beer as they are strong, relatively lightweight, and comply with food hygiene standards (and can hold beer for long periods of time). The Vast majority of Pubs and Breweries use the keg size we have chosen, 50 litres. Spread across the largest beer companies in the UK approximately 50 million kegs are used every year.

The market leader up until 2009 with the most market share and was Heineken. The largest manufacturers of beer in the UK

Market volume in % by company for 2005-2009 in the UK

%	2005	2006	2007	2008	2009
Heineken	2	2	2	29	29
Molson Coors	21	21	21	21	22
Anheuser-Busch InBev	–	–	–	21	21
Carlsberg	14	14	14	15	15
SAB Miller	1	1	1	4	4
Diageo	5	5	5	5	3
Private label	3	3	3	3	3
Other	5	4	4	1	1
Greene King	1	1	1	1	1
C&C	–	–	–	–	1

Figure 3: Market Volume

	 Mini Keg	 Cornelius Keg	 Sixth Barrel	 Quarter Barrel	 Slim Quarter	 Half Barrel
Keg Type:	**Mini Keg**	**Cornelius Keg**	**Sixth Barrel**	**Quarter Barrel**	**Slim Quarter**	**Half Barrel**
Compatible with:	EdgeStar Mini Kegerator	EdgeStar Full Size Kegerator	EdgeStar Full Size Kegerator	EdgeStar Full Size Kegerator	EdgeStar Full Size Kegerator	EdgeStar Full Size Kegerator
Also Called:	- Bubba	- Corny Keg - Pepsi Keg - Home Brew Keg	- Sixtel - Log	- Pony Keg - Stubby Quarter	- Slim 1/4 - Tall Quarter	- Full Size Keg - Full Keg
Most Common Uses:	- Individual Use - Portable Applications	- Home Brewing - Micro Brews	- Home Brewing - Micro Brews - Dual Tap Kegerators	- Small Parties	- Dual Tap Kegerator Applications	- Residential - Home Bar - Commercial - Large Events
Capacity (gal/L):	1.32 / 5	5 / 18.9	5.16 / 19.8	7.75 / 29.3	7.75 / 29.3	15.5 / 58.7
Ounces:	169	640	661	992	992	1984
Beer Mugs (12 oz.):	14	53	56	82	82	165
Pint Servings (16 oz.):	10.6	40	42	62	62	124
Filled Weight (US pounds):	13	49	58	87	87	161
Keg Height:	9-7/8"	23"	23-3/8"	13-7/8"	23-3/8"	23-3/8"
Keg Diameter:	6-3/4"	9"	9-1/4"	16-1/8"	11-1/8"	16-1/8"

After conducting market research it came to our attention that the most commonly used size keg by pubs was half barrel with a capacity of 50 litres. This keg size could also be used for home brewing purposes and for any large events that served beer, making it a worthwhile to manufacture financially due to the high demand for the product.

Figure 4: Typical stacking methods

0.4.2 Machining of raw materials and processing

The fabrication of a beer keg from Steel sheet metal consists of cutting strips of sheet metal to size and welding them together to form a cylinder, then welding chimbs (circular plates) onto the top and bottom, therefore forming a closed cylinder, however the top cylinder is machined with a hole in it the spear and extractor system to be fitted.Typical keg schematic

A multitude of machines are needed to produce a keg, from a roll of sheet metal. The process is as follows:

- The sheet is rolled on a straightener machine which consists of a bed of rollers.

- Then the straightened metal is fed into a shearing machine that cuts the sheet metal priodically to create the desired length.
- The cut pieces are then cleaned and bent in a bending machine into a cylindrical shape.
- The newly bent cylinder is placed on a spot welding machine and welded at the seams.
- then the top and bottom are flanged by a compressing machine to create a lip on the circumference of the barrel.
- The barrel is placed over a vacuum forming machine and reinforced ridges are created in the walls of the barrel.
- Finally the top and bottom chimbs are fitted and the barrel neck and spear is added.

The machines used are A De-Coiler, Power Guillotine Shear, Four Edge Sheet Grinder, Body Rolling Machine, Spot Welder , Seam Welder, Vertical Bottom Seamer, Barrel Degreasing Machine, 200 Ton Pillar Type Power Press, Hydraulic Double End Barrel Flanger, Hydraulic Bead Expander, Air Compressor.

The output of these machines are; central section, top and bottom dome/plate , top chimb with hand hole and bottom chimb.
All parts are bonded together using gas tungsten arc welding, after manufacture all kegs are pickled in 3% hydrofluoric acid, 10% nitric acid solution to descale the welds, then the keg is immersed in water and leak tested at 40Psig with air and then pressure tested to 90Psig hydraulically.

0.4.3 Conclusion

In conclusion our design team has researched the subject of this report thouroughly and comprehensively in order to determine the technical and economical feasibility of the manufacturing of beer kegs, we have found that the processing required and the materials used fit our specification and we reccomend that it be put into production.

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