Introduction to Steam, Boilers, and Thermodynamics

An Online Continuing Education Course for Engineers

Course Number: M-2086

Credit: 2 Hours / 2 PDH / 2 CPD

Contents

Before Getting Started

This course is distributed globally so units are quoted in both ***imperial*** and ***metric*** wherever possible. A list of common units and conversions (metric to imperial or vice versa.) is given in the ***Appendix***. or ***Resources*** section of this course.

The course is split into ***Chapters*** and ***Lessons***.

ⓘ *Indicates a useful tip that can be used to remember or understand the subject matter.*

Text highlighted like this, indicates fundamental knowledge that should be learnt and understood.

The term '***a.k.a.***' means 'also known as' and is often used within the course.

If you are reading this course in PDF format and have a saVRee account, you may click on images of many of the 3D models to load the associated model.

Enjoy the course!

Introduction

The ***industrial revolution (circa. 1760-1820)*** may have been fired by coal, but it was powered by steam. Humans have been harnessing the power of steam for thousands of years, but it is only in the past 200 years that we have started to rely on it for countless industrial applications. This course looks at the origins of steam, its theory (thermodynamics), generation and applications.

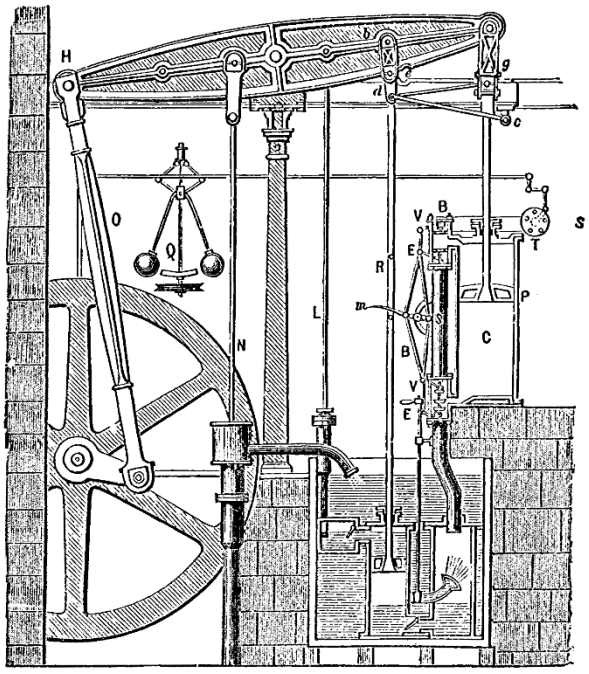
Fire Tube Boilers

History

The first usage of steam was recorded several thousand years ago. ***Hero of Alexandria*** created one of the first steam turbines in the 1st century, but the concept saw little application until much later in the 1800s.

Aeolipile (Hero Engine)

At the start of the industrial revolution, ***James Watt*** designed a reciprocating piston engine that was driven by steam; the design was referred to as a ***steam engine***. The steam engine was widely adopted and became one of the most iconic prime movers of the age.



Boulton and Watt Steam Engine Drawing

But James Watt was not the only person to use the power of steam to complete useful work. Other engineers soon realised that steam engines could be used for a wide range of applications. Some applications included powering railway locomotives, tractors and ships.

Steam Powered Automobile

At about the same time as steam's applications were growing, rapid advances in electrical engineering led to a surge in demand for prime movers that could be used to generate the newest wonder of the age…electricity!

Steam turbines were found to be ideal prime movers for the new power generation industry. Today, over 80% of the world's electricity is provided from steam turbine prime movers.

Almost all industrial revolution prime movers were powered by steam, and it was ***boilers*** that provided that steam. As the applications of steam have grown, so too have the quantity and design variations of steam boilers. Advances in technology and materials have allowed for ever larger prime movers, which has led to a corresponding increase in the size and power of steam boilers.

Steam is used in almost all modern industrial processes, either in the process directly, or for secondary services such as water heating, or space heating. The next lesson discusses the main uses of steam.

Uses of Steam

Steam is used for ***four*** main purposes:

- ***Heating*** – closed loop. Simple design. Low pressures and temperatures.
- ***Power Generation*** – system designs vary from simple to sophisticated. Wide range of pressures and temperatures. May produce medium to very large amounts of steam.
- ***Industrial Processes*** – much like power generation steam systems although much tighter tolerances concerning steam quality may exist. Steam systems are often critical for the plant/factory production process i.e. no steam = no production.
- ***Mechanical Work*** – steam can -and is- used to drive pumps, compressors and other machinery items that may not be well suited for an electrical drive, or other drive type.

It is rare to visit an industrial plant that does not have a boiler on site. Although the uses of steam are numerous, they generally belong to one of the four categories mentioned above.

Why Steam?

Human civilisation requires ***energy*** to function, lots of it. Without energy, it would not be possible to pump water to cities, provide electricity to homes, drive automobiles, or heat buildings. Prior to being used by end consumers, all energy must first be generated and conveyed to the point of use.
Electricity is an example of conveyed energy. Power stations generate electricity by converting heat, pressure, and/or kinetic energy, into electrical current. Converting the original energy source into electrical energy allows it to be conveyed easily across vast distances to the point of use.

Steam can -and is- also used to convey energy, but unlike electricity, steam conveys ***heat energy***, and is a ***fluid***. Because steam is a fluid, and is used to convey energy, it is termed an ***energy fluid***.

*A **fluid** has no fixed shape and yields when external pressure is applied i.e. fluids flow easily. Fluids may be a liquid, or a gas. An **energy fluid** is a fluid used to convey energy, usually in the form of **heat (thermal energy)**, **pressure (pressure energy)** and/or **speed (kinetic energy)**.*

Although other energy fluids are available, steam is considered 'the energy fluid' and is by far the most common energy fluid in use today. The reasons for steam's popularity are closely linked to the properties of the water from which it is made. Water is:

- Plentiful.
- Easy to access (geographical location dependent).
- Cheap compared to other energy fluids.
- Non-toxic.
- Easily conveyed i.e. can be pumped.
- Easily controlled i.e. with valves etc.

After water is converted to steam, it becomes an energy fluid with many advantageous properties:

- A given mass of steam can hold ***five to six times more energy*** than an equivalent mass of water.
- It can be generated efficiently; many boilers operate with ***>80% thermal efficiency***.
- It can be distributed easily by creating a pressure difference in the steam system.
- It is non-toxic and does not damage the environment.
- It will not spark, ignite, or combust (intrinsically safe).
- The amount of energy within the system can be regulated easily by regulating the steam pressure.
- Steam's heat transfer properties are high.

Other energy fluids are usually only undesirable. For example, thermal oils (mineral oil) are used to which steam may not be suitable. For safety reasons, buildings he lower pressures and temperatures also place less stress upon service life.

The Steam System

The purpose of steam is to equired, whilst minimising the energy loses associated with ur main parts.

- ***Fuel System*** – provi heat recovery steam generator ***(HRSG)*** is used).
- ***Boiler*** – converts the
- ***Distribution*** – conve
- ***Collection/Recovery*** turns it to the boiler.

The systems mentioned above

1. ***Generation***
2. ***Distribution***
3. ***Recovery***
4. ***Repeat***