STEAMING SYSTEMS

ENGINE-UITY EXPRESS

LEVEL

Year 11

VCE: Systems Engineering

ACTIVITY DESCRIPTION

Puffing Billy Railway relies on engineers to keep the 120+ year old steam locomotives working. Many of these engineers have a Mechanical engineering background to give them the skills required to work with the equipment and technology needed to fix a steam train.

Students will learn about the role and importance of the engineers at Puffing Billy Railway. They will discuss the engineering decision making process and why they choose some materials over others. Students will identify factors that affect the railway workshops team in their design and building processes.

SUBJECT AREA

Systems Engineering Unit 1: Mechanical Systems

Area of Study 1 – Mechanical Systems Design

MATERIALS REQUIRED

- “Engine-uity Express” Worksheet
- Devices with access to the internet to conduct research
- Pens/Pencils/textas

INSTRUCTIONS

1. As a whole class watch the Puffing Billy Railway Video – *https://www.youtube.com/watch?v=gv-V2R82FHXw&list=PL444521E4F9548C9F&index=11*

   Discuss the importance of an engineer at Puffing Billy Railway. What does their day look like? What type of work would they be doing?
2. Discuss how David talked about the use of oil rather than coal to fire a steam train. What is the reasoning for this? Why would it be a more effective selection in the future?
3. Allow students time to research the difference between coal fired and oil-fired steam engines, determining their own conclusions around the advantages and disadvantages of both. Students add any thoughts to the “Engine-uity Express” Worksheet.
4. In the past Puffing Billy Railway used a lot of outdated materials such as cast iron, asbestos, and lead, etc. Discuss factors that would influence Puffing Billy Railway’s engineering team to change to modern materials in their design and building processes at the railway. Have students brainstorm any other factors that might influence the design and build of a steam train. Complete the “Engine-uity Express” Worksheet. (Remember: Puffing Billy Railway no longer uses these outdated materials.)

EXTENSION: Discuss the skills required for a mechanical engineer to work effectively in the team at Puffing Billy Railway.
Optional: Watch the extension of the first video: *https://www.youtube.com/watch?v=7dtLB-18d2_8&list=PL444521E4F9548C9F&index=12*

SUGGESTIONS FOR ASSESSMENT

Contribution to class discussions. Successful completion of "Engine-uity Express" Worksheet to outline the factors that influence engineering decisions at Puffing Billy Railway.

CURRICULUM LINKS

SYSTEMS ENGINEERING

Unit 1: Mechanical Systems

Area of Study 2

Producing and evaluating mechanical systems.

On completion of this unit the student should be able to produce, test, diagnose and evaluate a mechanical system using the systems engineering process.

BACKGROUND INFORMATION

WHAT DO MECHANICAL ENGINEERS DO?

Professional Engineers hold a four-year professional engineering degree that's accredited or recognised by Engineers Australia.

Professional Engineers also hold comparable overseas qualifications or a degree that's accredited by a signatory to the Washington Accord.

As a professional engineer you have the skills to:

- Focus on overall systems
- Develop and apply new engineering practices
- Apply leadership and management skills
- Pursue engineering opportunities in a holistic way, talking environmental, community and social issues into consideration
- Solve diverse problems.

According to Engineers Australia "Engineering is a career for problem solvers. It's a wide and diverse field that touches every part of human life. The vehicles we drive, the electronic devices we use, the buildings we work in and the medicines we take are all products of engineering."

Mechanical Engineers design power-producing machines, such as electric generators, internal combustion engines, and steam and gas turbines, as well as power using machines, such as refrigeration and air conditioning systems.

Mechanical Engineers design other machines inside buildings, such as elevators and escalators. They also design material-handling systems, such as conveyor systems and automated transfer stations.

Like other engineers, Mechanical Engineers use computers extensively. Mechanical Engineers are routinely responsible for the integration of sensors, controllers, and machinery. Computer technology helps Mechanical Engineers create and analyse designs, run simulations and test how a machine is likely to work, interact with connected systems, and generate specifications for parts.

Reference: www.engineersaustralia.org.au

PUFFING BILLY RAILWAY

As the second steam railway in the world to be preserved, Puffing Billy Railway continues to build on a wealth of experience spanning more than five decades. For Puffing Billy Railway, operating and maintaining locomotives and rolling stock from all periods of its 120-year history has been integral to the preservation of traditional practices and machinery, which would otherwise have faded from the modern world.

With a dedicated team of tradesmen from a variety of backgrounds in industry, the workshops branch combines traditional practices with ongoing innovation to care for historic assets in a cotemporary environment. From design, construction and fabrication at the Belgrave Locomotive workshop, to maintenance, repairs and restoration at the Emerald carriage and wagon workshop, Puffing Billy Railway's Rolling stock branch have the skills, equipment and opportunity to assist other tourist and heritage organisations in keeping the tradition of historic rail travel alive.

Reference: https://puffingbilly.com.au/about/engineering-services/

THE RISE OF THE STEAM ENGINE

A question that might be posed is 'who invented the steam engine?' The answer is that it wasn't a single person but an accumulation of ideas and discoveries over a long period of time. It was known as far back as the ancient Greeks that steam could produce movement. This was shown by directing steam across a model windmill, which began to turn. But it was only when the coal mining industry had started to develop that steam was looked at as a viable power.

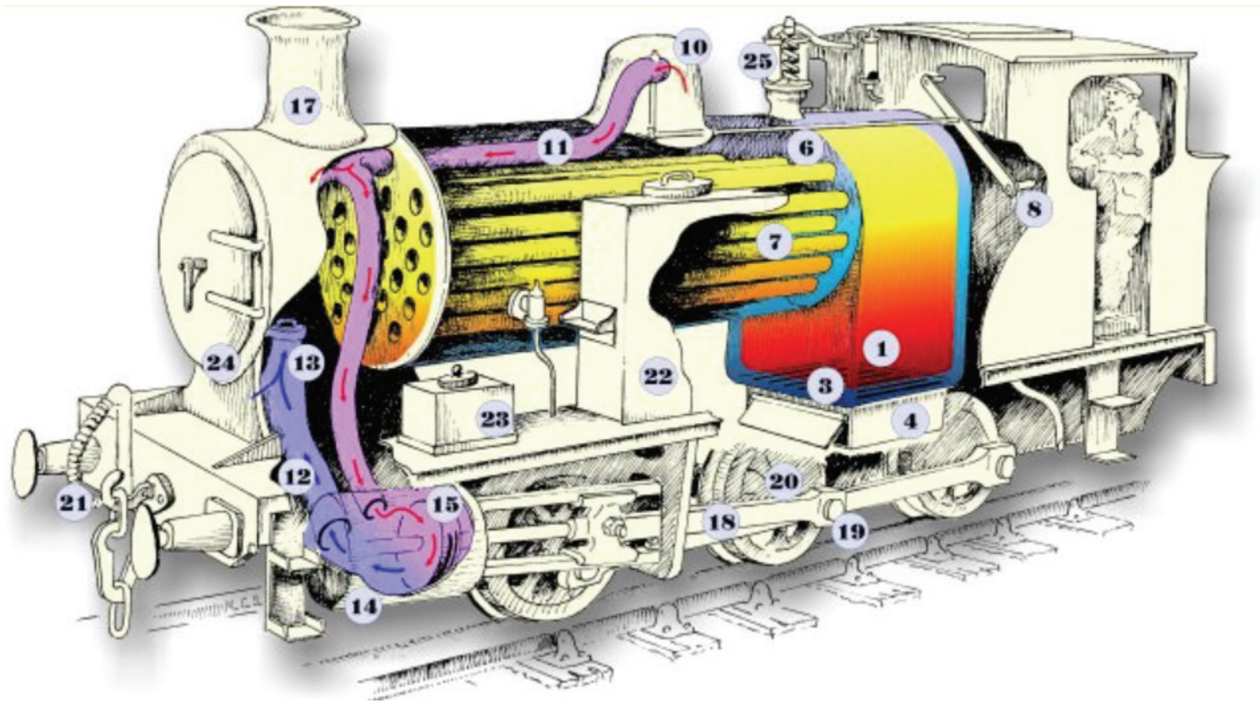
The first useful application of steam power was patented in 1698 by Thomas Savery. He described it in a book using the title 'the miner's friend' because it was intended to raise water and so could be used to drain mines.

The first successful steam engine involving a piston was developed by Thomas Newcomen. The first of these was installed in a mine in or just before 1712. Again, its purpose was to pump water. Newcomen's engine was very inefficient. It used a lot of coal to raise a small amount of water. Spraying water on the main cylinder cooled it so it had to be reheated by the steam in each cycle. James Watt made significant advances in the technology between 1763 and 1776. First, he added a separate condensation chamber which remained cold while the main cylinder remained hot. The next improvement was the addition of an insulating jacket for the main cylinder. The third improvement was a better boiler so that the steam pressure could be raised enough to use the expansion of the steam to provide power which had been wasted in the Newcomen engine. These improvements reduced coal consumption by about 75%. The early Watt engines are still used for pumping.

As soon as Watt's patent expired there was an acceleration in the development of steam power. In 1800 William Trevithick developed a high-pressure steam engine. Now all the power came from the expansion of the steam and the condensation phase was not needed. His engines could run at much higher speeds and generate more power for a given size and weight. In fact, he built the first self-propelled steam engine that ran on roads in 1801 but this was destroyed when the driver left the fire burning with insufficient water. Only three years later in 1804 he built a steam rail locomotive that did work but it was very heavy and frequently bent the rails, so that technically it worked but was in practice of little use.

Reference: https://www.ncm.org.uk/news/the-rise-of-the-steam-engine/

HOW A COAL FIRED STEAM ENGINE WORKS



Reference: https://www.lakesiderailway.co.uk/how-a-loco-works/

1. Firebox
2. Firebox Door
3. Firebars / Grate
4. Ashpan
5. Coal
6. Water
7. Firetubes
8. Regulator
9. Manifold for other steam equipment (ie. whistle, breakes, blower, etc)
10. Steam dome
11. Main Steam Pipe
12. Exhaust Pipe
13. Blast Pipe
14. Cylinder
15. Piston
16. Slide valve
17. Chimney
18. Connecting Rod
19. Crank
20. Driving Wheels
21. Steam pipe for train brakes
22. Side water tanks
23. Sand Box, for traction on wet rails
24. Smoke Box
25. Safety Valve

A steam engine uses a coal fire as its source of energy to boil water and make steam. The hot gases from the burning coal in the firebox are passed through the boiler in “Fire tubes” before leaving the engine via the smoke box and chimney.

As the water boils, the hot “wet” steam rises, and is collected from the steam dome on top of the boiler through the regulator valve, which the driver uses to control the locomotive speed.

From the regular, steam is piped to the cylinders, and is admitted alternatively via the valve-chests, pushing the piston in the cylinder back and forth as the piston is connected to the driving wheels via the “connecting rod” and crank, the to and for motion of the piston turns the driving wheels.

HOW DOES PUFFING BILLY RAILWAYS OIL FIRING STEAM ENGINE WORK?

The light oil firing system described herein was developed in 1990 by the Swiss Locomotive & Machine Works (SLM) of Winterthur for their newly designed rack steam locomotives. Eight of these one-man operated all-new steam locomotives were built in 1992 and 1996, successfully operating since then on the Swiss Brienz-Rothorn Railway and the Austrian Schafberg Railway.

When SLM terminated its business in the year 2000, their modern steam activities were continued by the newly formed Dampflokomotiv und Maschinenfabrik (DLM AG).

Since then, this proven system has also been used for the conversion of existing old steam locomotives from coal to oil firing, be it for environmental reasons to avoid smoke, to prevent spark throwing that can cause lineside fires, or both.

Similar oil firing systems are in use on a narrow-gauge steam locomotive of the German Borkumer Kleinbahn, the metre-gauge rack and adhesion steam locomotive HG 2/3 No. 7 of the Swiss BVZ Brig-Visp-Zermatt Railway, and the metre-gauge steam locomotive G 3/4 No. 11 “Heidi” of the Swiss Rhaetian Railway. These steam locomotives received new all-welded boilers with newly designed all-welded superheaters.

DESCRIPTION AND FUNCTION OF THE OIL FIRING SYSTEM

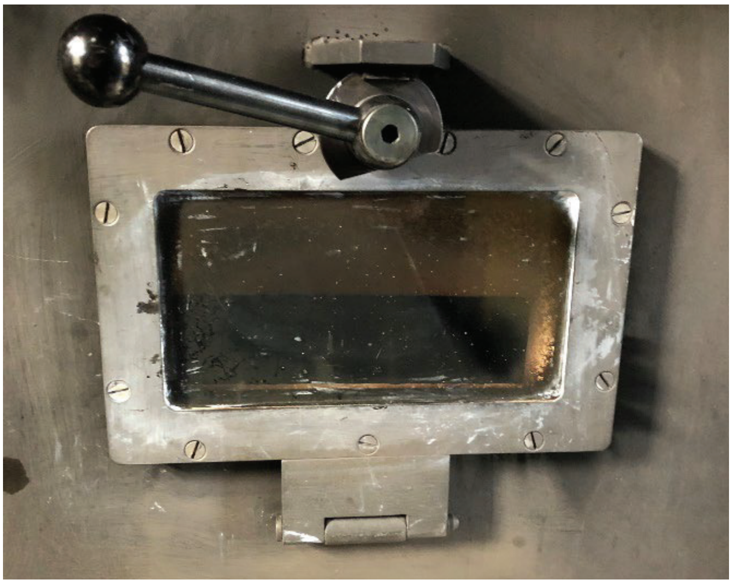
The function of the light oil firing system can best be seen by studying the figures on the following pages:

- Figure 1: Sectional view of the steam locomotive G 3/4 No. 11 “Heidi”
- Figure 2: Schematic of the light oil firing system
- Figure 3: Sectional view of the burner

The principal function of the steam locomotive remains unchanged. As with coal-fired engines, the combustion air is drawn through the boiler by the drafting system, whereby the blast pipe creates a vacuum in the smokebox. The smokebox and the smokebox door must be air-tight to ensure a good vacuum in order that there is a sufficient flow of combustion air.

Instead of the grate there is a burner plate mounted on the foundation ring, containing a central pilot burner and four load burners arranged in a square around it. The burner plate is closed-in by an airbox underneath which has holes in the base to restrict air flow at low power outputs, and a damper which can be used to increase air flow for higher power outputs as required.

View of the burners through the firedoor.



Firebox viewing window .

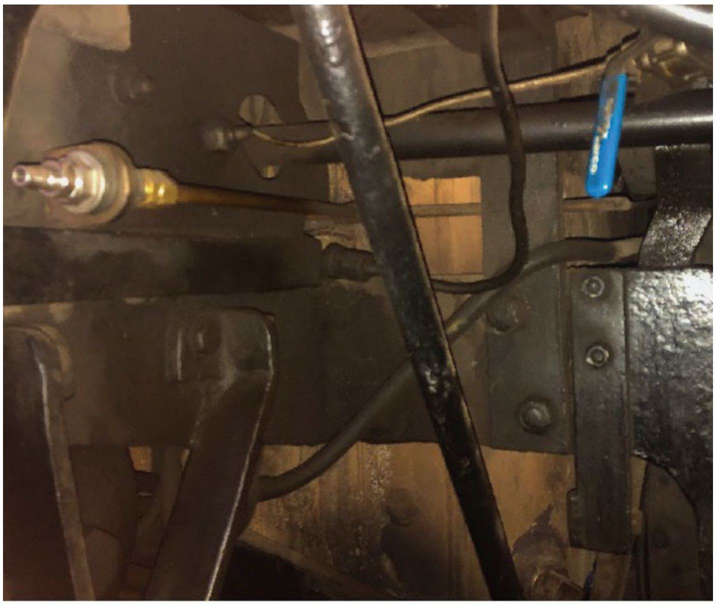
All burners are centrally placed in air deflector devices.

Pilot and main burners are of the same size. The only difference is the rotational direction of the swirl. The oil flow to the burners is by gravity when lighting up and shunting. The oil flow can be increased by pressurizing the fuel tank. The oil is atomised by superheated steam. If there is no steam available or the boiler pressure is below 20 psi, the pilot burner can be operated using compressed air.

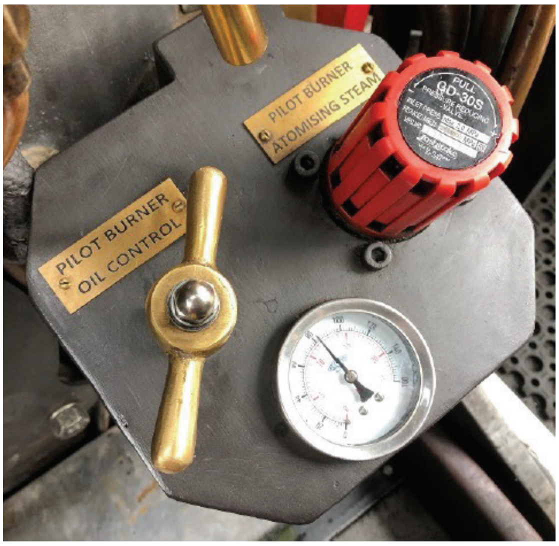
To ensure that consistent clean combustion is achieved with this oil firing system, the burners are of a high-precision standard, more comparable with a Swiss watch than burners of the old oil firing systems for heavy fuel, and therefore must be treated with extreme care.

To prevent the burners from being contaminated by dirt, the steam and oil pipes are equipped with fine mesh filters. A separator drain is provided with stop valve under the drivers-side water tank. The drain is connected to the water tank, and the valve should be open when steam is used for atomising.

Turret with atomising steam valve and steam separator.



Shed air connection and steam separator drain valve (blue handle) under drivers-side tank.



Pilot burner controls.

Load burner controls.

All superheater coils of the oil firing system are made of high-quality heat resistant stainless steel. The steam pipes between the superheater coils and the burners have a hole of approximately 1 mm diameter to drain condensed water.

The pressure of the atomizing steam is regulated by pressure reducing valves. Once set, it is not normally necessary to adjust them again. The set pressure is maintained independent of the boiler pressure and independent of the atomizing media, be it steam or compressed air.

The oil flow of the pilot burner is regulated by a simple hand valve. Once set, it usually remains unchanged for the entire trip. If the combined power of the pilot burner and the four main burners is insufficient, the power of the pilot burner can be temporarily set to the same level as that of the main burners.

The oil flow of the 4 main burners is regulated by a hand valve and, to ease operation, it is equipped with a graduated scale.

The burner plate is manufactured from ordinary stainless steel, not heat-resistant material, and is therefore insulated on top against radiation.

The fire arch in the firebox is made of high-quality heat-resistant stainless steel. It lengthens the flame path, thereby giving better combustion and reducing the stress on the tubeplate.

The firedoor is fixed to the boiler by means of four screws. These must always be tight when the system is in operation, to protect the crew from possible blow-backs. The firedoor has a widow with heat-resistant glass to check the fire. This window can be opened to ignite the pilot burner by means of the lighting gas torch.

A damper is provided to allow for increased air flow when the locomotive is working at high power outputs. This should be closed when the locomotive is stationary.

Air box damper control (shown closed).

Figure 1: Sectional view of the steam locomotive G 3/4 No. 11 “Heidi”

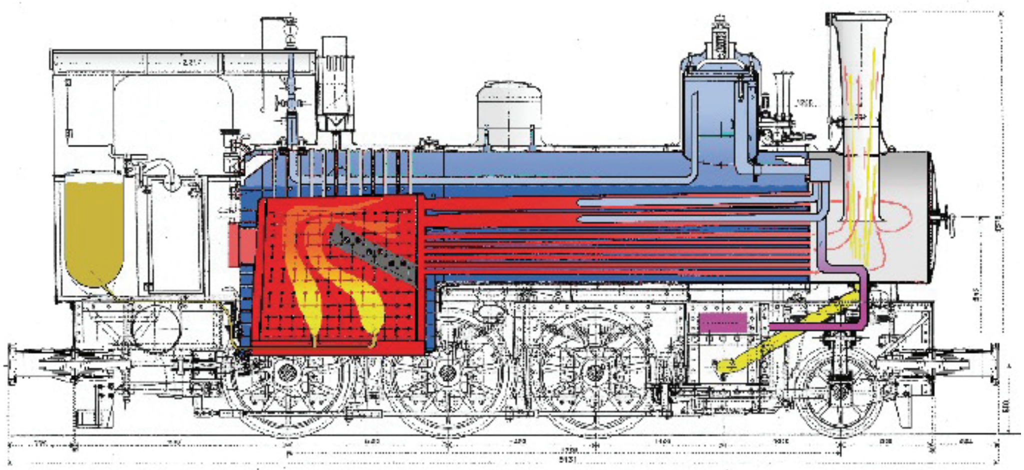


Figure 2: Schematic of the light oil firing system

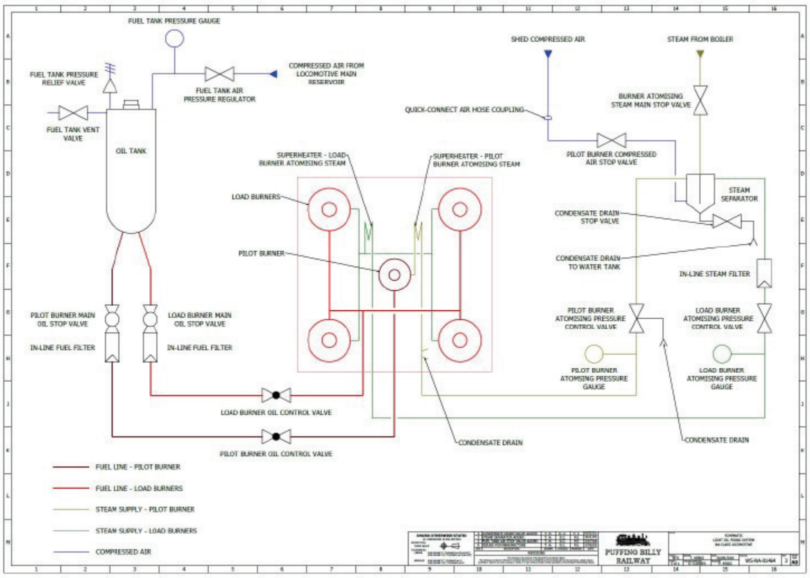
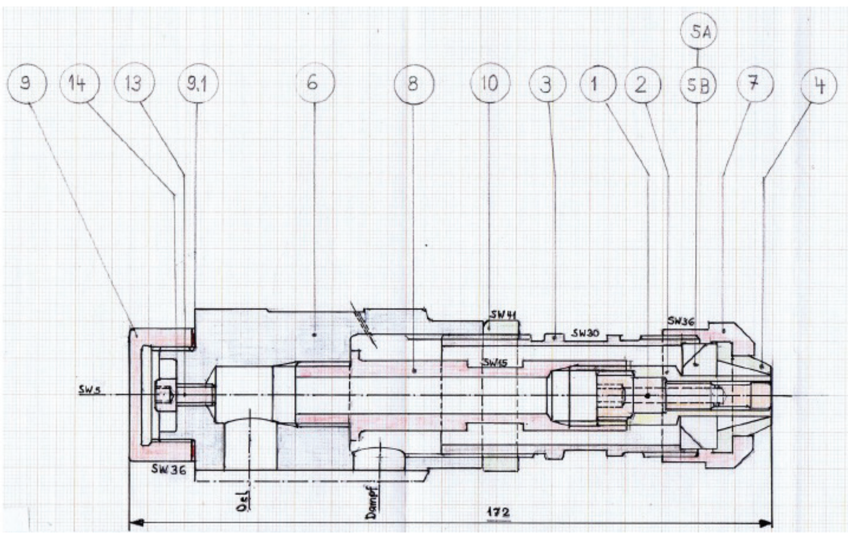


Figure 3: Sectional view of the burner



Reference: Puffing Billy Raiwlay- NA Class Oil Firing- Training and Operation Manual LRM013
Project: WS-EPM-00015

OTHER TYPES OF ENGINES

Coal was a cheap and abundant fuel during the early Industrial Revolution, but the invention of the gasoline engine (petrol engine) in the mid-19th century heralded a new era: during the 20th century, oil overtook coal as the world's favourite fuel. Steam engines are extremely inefficient, wasting around 80–90 percent of all the energy they produce from coal. That means they have to burn enormous amounts of coal to produce useful amounts of power.

A steam engine is so inefficient because the fire that burns the coal is totally separate (and often some distance from) the cylinder that turns the heat energy in the steam into mechanical energy that powers the machine. This design is called an external combustion engine because the fire and boiler are outside the cylinder. It's inefficient because energy is wasted as the heat and steam travel from the fire, via the boiler, to the cylinder. Gasoline- and diesel-powered engines are based on a totally different design called an internal combustion engine. The gasoline or diesel fuel is burned inside the cylinder, not outside it, and this makes internal combustion engines considerably more efficient. Oil has many other advantages too: it's cleaner than coal, makes less air pollution, and is much easier to transport in pipes.

That's largely why steam locomotives disappeared from our railroads—diesel locomotives were altogether more convenient. It takes hours to fire up a steam engine before you can use it; you can get a diesel engine running in less than a minute. Steam engines disappeared from factories when electricity became a more convenient way of powering buildings. Who wants to load coal into a factory every day when they can just flick on switches to make things work?

Reference: https://www.explainthatstuff.com/steamengines.html

FIRST TO LIGHT UP OIL

Wednesday the 31st of January 2018 marked a momentous day for Puffing Billy, as 14A's new oil burning system was ignited for the first time; the culmination of significant work by the railways engineering team.

Reference: https://puffingbilly.com.au/news/workshop-blog/would-you-rather/

REFERENCES

- Teachers can watch the below videos to get an understanding of how Engineers work in a team with different tasks and requirements than Puffing Billy Railway:

  https://www.abc.net.au/education/the-role-of-a-mechanical-engineer/13896090

  https://www.abc.net.au/education/how-to-design-and-build-a-robot-in-six-weeks/13896106

- Teachers can extend their learning about Puffing Billy Railway by watching this video:

  https://www.youtube.com/watch?v=PyWq8MEIGeU&t=57s

- Coal fired steam- can it last?

  https://csrail.org/newsroom/2016/3/29/coal-fired-steam-can-it-last

- If speaking about the various roles of a Mechanical Engineer, teachers can show students the below video:

  https://neonfutures.org.uk/case-study/mechanical-engineer-angela-malynn/

WORKSHEET – ENGINE-UITY EXPRESS

Puffing Billy Railway relies on engineers to keep the 120+ year old steam locomotives working. Many of these engineers have a mechanical engineering background to give them the skills required to work with the equipment and technology needed to fix a steam train.

After watching the Puffing Billy Railway's Virtual Tour #4 on YouTube (*https://www.youtube.com/watch?v=gvV2R82FHXw*). Complete the following questions regarding the engineers and their decision making at the Railway.

1. What is the importance of keeping old heritage assets in today's modern society?

2. What is the benefit of having larger locomotives (Eg. Garratts) or diesel engines?

3. Puffing Billy Railway's steam locomotive 14A is oil fired rather than coal fired.
   a. What does this mean?

   b. What would be the advantages of using oil instead of coal? What would be the disadvantages of using oil instead of coal?

ADVANTAGES	DISADVANTAGES

4. Discuss factors that would influence the team to change to modern materials in their design and building processes at the railway. Have students think of anything else that might influence the design and build of a steam train.