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Te Whare Wānanga o Tāmaki Makaurau
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ENGINEERING

Practical Work Portal

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Employment at Victoria University Wellington

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Report Submitted : 2024-03-24 PASSED

Assigned Marks : 25 / 25 (Grade : A)
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Student : [redacted]
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Student Group : [redacted]

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Scoring Rubric

Section One	**Passed Section** If you pass Section One you still need to pass Section Two.			**Failed Section** If you fail Section One you will be asked to resubmit the report.			5/5
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Section Three Part A : Structure of the Report	Excellent	Above Average	Satisfactory	Room for Improvement	Below Average	No Marks	5/5
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Practical Work Report

Department of Mechanical Engineering

Name: [redacted]
Date: 24 March 2024
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Employer: Victoria University Wellington
Supervisor: [redacted]
Address: [redacted]

Work Period Start: 16 November 2023
Work Period End: 16 February 2024

Summary

During the summer period spanning from mid-November 2023 to mid-February 2024, I undertook a research scholarship internship at Victoria University of Wellington's Kelburn campus, focusing on Geothermal low-enthalpy heat sources for optimal power generation employing Organic Rankine Cycles (ORCs) and integrating waste heat recovery systems within the ORC system. Commencing with an extensive literature review, I delved into global low-enthalpy geothermal reserves, devising initial system drafts grounded in fundamental mass transfer, fluid, and thermodynamic principles gleaned from university coursework. Consultation with GNS New Zealand's head geothermal modeller informed subsequent iterations of system designs on DWSIM process simulation software.

Throughout the internship, my duties encompassed diverse tasks such as research capabilities, numerical analysis utilizing Excel, MATLAB, and DWSIM, rapid prototyping, and system simulation, alongside meticulous documentation and regular progress presentations. Employing advanced thermodynamic property tables, mass and heat transfer analyses, and fluid dynamics tools, I honed my engineering skills portfolio.

This experience cultivated vital skills, including research proficiency, holistic system design, effective communication across disciplines, time management, and meeting deadlines. Moreover, mastery of DWSIM software expanded my technical repertoire, enhancing my ability to tackle complex engineering challenges.

With the current climate change crisis and the dire need for decarbonisation, this enabled me to envision the huge potential and countless possibilities in design for delivering sustainable, innovative and environmentally friendly solutions as an engineer.

In retrospect, this internship proved to be immensely valuable, equipping me with skills and insights pivotal for my academic and professional trajectory. I am deeply appreciative of my supervisor and Victoria University Wellington for this enriching opportunity, which will undoubtedly shape my future endeavours in engineering.

Acknowledgement

I would like to thank Victoria University Wellington Te Herenga Waka for allowing me to undertake this summer research scholarship internship and providing me with the resources and office facilities in order to ensure that my summer research progressed smoothly. I had the privilege of working under the supervision of [redacted], who selected me to undertake this project on geothermal systems for power generation. I gained a lot of valuable insights under his supervision, and he was also open to suggestions I had in my research. I would lastly like to thank [redacted] who co-supervised this project and enabled me to test out various ideas and theories. These research meetings were quite valuable to the project and ensured that I did a better job. I am very grateful for the opportunity I got this summer, as I was able to successfully complete this work with all of their support and guidance.

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1 Introduction

During the summer period between 16th November 2023 to 16th February 2024, I undertook a summer research scholarship internship at Victoria University Wellington. I was tasked with developing, modelling and simulating a geothermal power system to generate as much power as possible from a low-enthalpy geothermal reserve (low-temperature heat sink) and also incorporate a waste heat recovery system.

This report shall document my professional experience by describing the institute and working environment, the tasks I worked on and reflect on the relevant lessons learned.

2 Company Information

2.1 History

Victoria University of Wellington (Māori: Te Herenga Waka) is a public research university in Wellington, New Zealand. It was established in 1897 by an Act of Parliament and was a constituent college of the University of New Zealand. The university is well known for its programmes in engineering, law, the humanities, and some scientific disciplines, and it offers a broad range of other courses. Victoria had the highest average research grade in the New Zealand Government's Performance Based Research Fund exercise in both 2012 and 2018, having been ranked 4th in 2006 and 3rd in 2003.[9] Victoria has been ranked 215th in the World's Top 500 universities by the QS World University Rankings (2020).

Victoria University of Wellington (originally known as Victoria University College) was founded in 1897 and named after Queen Victoria on the 60th anniversary of her coronation. The original name was Victoria University College, but on the dissolution of the University of New Zealand in 1961, Victoria or "Vic" became the Victoria University of Wellington, conferring its own degrees **[1]**.

2.2 Campuses and Facilities

Victoria University of Wellington has three campuses spread out over the city of Wellington. I was based in the main campus in Kelburn (Alan MacDiarmid building).

- The main campus is located in the suburb of Kelburn, New Zealand, overlooking Wellington CBD, where the Faculties of Engineering, Humanities and Social Sciences, Science, Education and Health are based. Additionally, it is the location of the university's Central Library and the site of its administrative offices. The campus has a range of amenities, including cafes, the university bookstore VicBooks, a pharmacy and health services, childcare facilities, and a sports and recreation centre. The Victoria University of Wellington Students' Association is based here.

- The Pipitea campus consists of the Wellington School of Business and Government, which includes the School of Accounting and Commercial Law, School of Economics and Finance, School of Government, School of Information Management, School of Management, School of Marketing and International Business, and the Faculty of Law.[44] The Campus is located near the New Zealand Parliament Buildings, consisting of Rutherford House, the Old Government Buildings and the West Wing of the Wellington railway station. It is the location of the Commerce and Law libraries. Student services available at the Pipitea campus include Student Health and Well-being, the Recreation Centre and VicBooks.

- The Wellington Faculty of Architecture and Design Innovation is located in the Te Aro Campus, in Te Aro - right in the heart of the CBD. The campus contains an Architecture and Design library ***[1]***.

[redacted]

Figure 1: Kelburn parade, Alan MacDiarmid building quad

2.3 Staff Organisation

As with every university and research institute, VUW has a summer research scholarship office/team, who are responsible for the administrative side of things related to summer research internships. They work in conjunction with the university's admissions team and professors who have advertised summer research projects to foresee student internship intakes and determine whether a candidate is successful or not, as well as any further administrative tasks after a student has been given a project.

My supervisor also happened to be the deputy head of the school of engineering at VUW, and hence, a lot of academic staff report directly to him. He had quite a few PhD students and a couple of summer research intern students, including myself, whom he supervised simultaneously.

[redacted]

Figure 2: Employee organisational structure at VUW - Summer research + PhD

The post-graduate, masters and PhD students are students of Victoria University Wellington completing their research and qualifications in their relevant fields of study. In addition to these students, every summer, a number of summer research interns undertake a short-term role (3 months) carrying out research as part of the projects advertised by the relevant supervisors and academics.

2.4 Workplace Layout and Facilities

My office space was based on [redacted] This spacious office space consisted of individual workstations occupied by some of the PhD students and myself. The floor plan of the research office space is shown below.

[redacted]

Figure 3: Floor plan of the postgraduate and research office space on level 2 AM building

As can be seen in the floor plan, there were 12 individual workstations, and I occupied workstation number 6.

[redacted]

Figure 4: Workstation used during research work

[redacted]

Figure 5: Workstation used during research work

As can be seen, we had access to a double monitor workstation in room [redacted]. My supervisor's office was in [redacted], so it was quite easy for me to go up to him for meetings. [redacted]. At times when more than a weekly meeting was required, I would report to him directly in his office.

3 Project Brief

Brief initial conditions and requirements of the system have been provided in the figure below.

[redacted]

Figure 6: Draft Cycle 1

It is impossible to achieve a temperature of 20°C with the geothermal fluid starting at 80°C in a single heat exchange process, as this would result in a negative pinch point and an extremely unrealistic heat exchanger.

Figure 7: Draft Cycle 1

Hence, a multistage heating process needs to be employed in order to ensure that the temperature drop can be achieved realistically from about 80°C to about 20 - 30°C. A typical temperature-entropy diagram of this process is shown below.

Figure 8: Temperature-Entropy diagram of the cycle

The organic working fluid's process line is denoted in green and begins at point ***a***. Upon constant heat exchange with the hot fluid in a heat exchanger, the organic fluid's temperature and pressure rises until it reaches it's boiling/vaporization point at ***c***. Further heating at this point does not increase its temperature; however, it contributes more to its phase change from a pure liquid to a mixture and then to a full vapour state at point ***d*** (the latent heat of vaporization). Upon becoming vapour, further heating causes it to become a super-heated vapour. A second heat exchange process using cold water in a condenser brings the organic working fluid's temperature down to point ***g***. Further cooling from this point reduces its entropy back to its inlet starting point at ***a***, and the cycle continues.

It would also be advantageous to inculcate a heat pump of some sort in the system, which is able to heat the geothermal fluid to a temperature above 100°C.

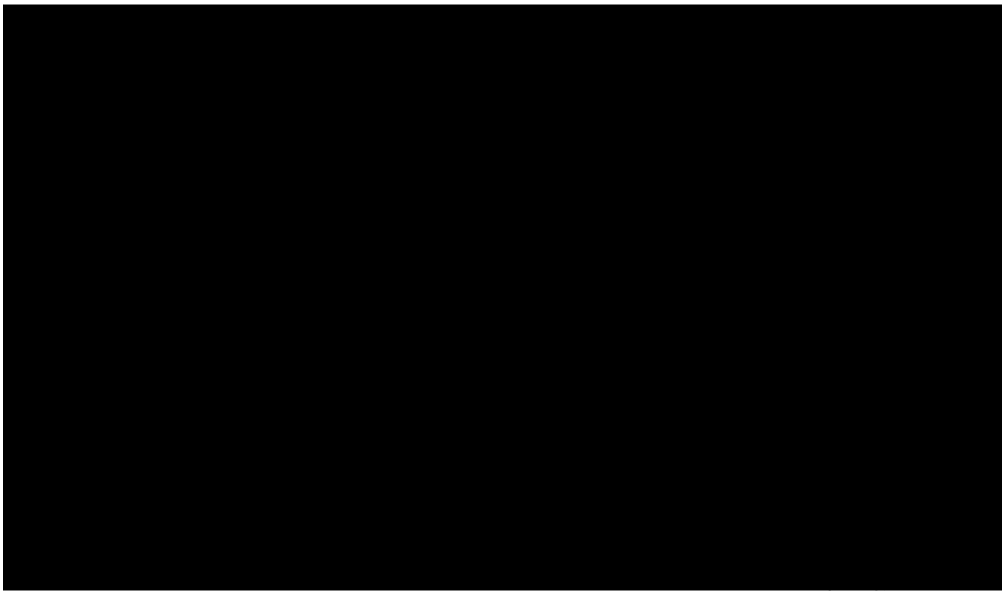


Figure 9: Heat Pump Technology powered by the ORC

Over the last few years, industries have been interested and are looking into heat pumps delivering heat from various processes. At present, heat pump systems are limited to supplying heat within the range of 70°C to 80°C **[2]**. Many industrial processes are designed to operate with heat supply temperatures of 100°C to 200°C and beyond. Hence the concept of using a heat pump system using the same geothermal fluid in the ORC and heating it to this temperature range while simultaneously employing a multi-stage compression to further raise the temperature is quite intriguing and could poise as a viable solution.

3.1 Objectives

- Design a continuously operating ORC
- Use 80°C Geothermal water as the heat source
- Use an appropriate organic working fluid, which is also easily available and store-able
- System must generate as close to 1MW as possible whilst operating efficiently
- Can use nearby cold river water for the Condenser stage
- Must use a heat pump system to heat the geothermal water above 100°C
- Can inculcate other components as part of the system
- System must be practical and solution-viable

4 Geothermal Power Systems

4.1 Introduction

In recent years, abundant consumption of fossil fuels has resulted in serious environmental issues such as global warming, ozone layer depletion, and pollution of the atmosphere **[3]**. It has been studied and demonstrated that more than half of the industrial waste heat generated is from low-temperature/low-enthalpy systems **[4]** and is difficult to recover and reuse using conventional Rankine steam cycles.

It was hence desired to model a small Organic Rankine Cycle power system that could utilize a low-enthalpy geothermal fluid in conjunction with an organic working fluid that could power a Turbine, generating sufficient power. The working fluid would then be condensed and re-heated using the geothermal fluid, ensuring the cycle runs continuously, thereby constantly generating power - with minimal greenhouse emissions.

4.2 Geothermal Electricity Generation

Geothermal power plants can generate about 1 to 40 MWe, depending on the heat source temperature, type, depth, and application. These systems are available and operate 24 hours a day, every day of the year, in order to match consumer and industrial demands **[5]**.

Figure 10: Typical Geothermal Reserve for industrial and household heating

Moderate to high-temperature geothermal fluid found in abundance in deep reservoirs is required as the primary heat source in order for the geothermal power plants to generate electricity. The temperature and depth of the reservoir can drastically vary depending on the geographic location and other characteristics of the system and site. Similarly, the temperature requirements depend on the applications, i.e., whether for household commercial use or other industrial processes. The temperature can be manipulated by adjusting the depth and the overall heat exchange area. Geothermal reserves can be accessed via wells drilled/bored into the earth's surface. Hot water and steam can then be pumped up to the surface to power a turbine and generate electricity. Alternatively, this hot source of water/steam can be used for heat exchange processes for thermodynamic cycles ***[5]***.

4.3 Low-Enthalpy vs High-Enthalpy Systems

All geothermal power systems can be classified based on the temperature or enthalpy (heat content) of the operating/reservoir fluid **[6]**.

4.3.1 Low-Enthalpy Systems

- **Temperature:** Ranges from 30°C to 150°C (86°F to 302°F).
- **Fluid:** Hot water, steam or Brine
- **Heat Source:** Underground sedimentary rocks and other hot aquifers significantly away from the magma region.
- **Applications:**
  - Direct usage for household heating and cooling purposes
  - Aquaculture and Greenhouse heating
  - Industrial processes and power systems
  - District heating and other commercial applications
- **Example Locations:** New Zealand, Japan, Philippines, Hungary.

4.3.2 High Enthalpy Systems

- **Temperature:** Exceeds 150°C and can go up to 400°C (86°F to 752°F).
- **Fluid:** Super-heated vapour steam, liquid-vapour mixture.
- **Heat Source:** Hot magma rocks and rock bed.
- **Application:** Electricity generation using flash power systems.
- **Example Locations:** Yellowstone National Park (USA), The Geysers (USA), Iceland.

The distinction between the two systems would be the fluids' temperature range and enthalpy content, with low-enthalpy systems operating at relatively lower temperature ranges and high-enthalpy systems at a much higher range. Due to their higher energy/enthalpy content, high-enthalpy systems primarily operate to generate large amounts of electricity. On the other hand, low-enthalpy systems offer more versatility in applications as they can be used directly for heating applications and generate moderate amounts of electricity, often, both can be achieved simultaneously. With regards to technology, ease of operation, and machine requirements, low-enthalpy systems can operate using simple components such as standard heat exchangers as boilers and condensers, vapor compressors, turbines, and pumps. High-enthalpy systems, on the other hand, require specialized and more complicated flash components, such as flash turbines and flash pumps, in order to deal with extremely high temperatures and pressures ***[6]***.

Low-enthalpy systems are gaining more popularity nowadays and have immense potential when it comes to electricity generation, as these resources are much more abundantly available and widespread compared to high-enthalpy resources, with minimal greenhouse emissions.

4.4 The Organic Rankine Cycle

Organic Rankine Cycles (ORCs) power systems and power plants have emerged as a viable and practical alternative solution for recovering and converting low to moderate-grade heat to electricity ***[3]***. An ORC involves the utilization of clean energy sources such as solar energy **[7]**, geothermal water/steam **[8, 9]**, and biomass.

4.4.1 Working Principle of an ORC

The basic components of an ORC include:

1. An organic working fluid (hydrocarbons)
2. A hot working fluid as the heating source (Geothermal water/steam)
3. An Evaporator/Boiler (heat exchanger)
4. An expander (Turbine)
5. A condenser
6. A pump

There are a few other components, such as a droplet separator, compressor, and pre-heater, which can be installed as per the system's needs and characteristics.

The process first begins at the evaporator/boiler, where hot geothermal water is the heat source and the organic working fluid is the cold fluid. Organic working fluids are selected such that their boiling points are quite low, and hence, the heat content of the hot geothermal water is sufficient to vaporize it. The evaporator is usually a shell & tube heat exchanger, ensuring maximum heat exchange takes place between the two fluid streams.

[redacted]

Figure 11: Shell & Tube HEX as the Boiler/Evaporator

The hot geothermal water is pumped up from the underground geothermal reserve. As it is pumped up, it loses some heat to the surrounding pipe walls and soil; however, at the surface, its temperature is still quite hot enough to ensure sufficient heat exchange. The organic working fluid has a very low boiling point; hence, this heat exchange process ensures that it gains sufficient heat to vaporize it. Now that the organic fluid is vaporized, it exists at a much higher pressure, which can now pass through an expander (turbine) to relieve the pressure, and this pressure drop generates power, as the mechanical energy to spin the turbine is converted to electrical energy via a generator. The electricity generated is then fed to the electricity grid.

[redacted]

Figure 12: Pressure drop across a turbine to generate power

The fluid then proceeds to a condenser, where it is further cooled down back to its supply inlet conditions. The condenser is once again a Shell & Tube heat exchanger, which draws cold water from a nearby river or water source in order to further cool down the Isopentane back to its liquid supply temperature at the inlet of the cycle.

[redacted]

Figure 13: Condenser in the ORC

The fluid now needs to be recirculated throughout the system and hence a pump is used which will bring it up to its operating pressure, ensuring constant flow in the cycle.

[redacted]

Figure 14: Pump to recirculate fluid at supply pressure

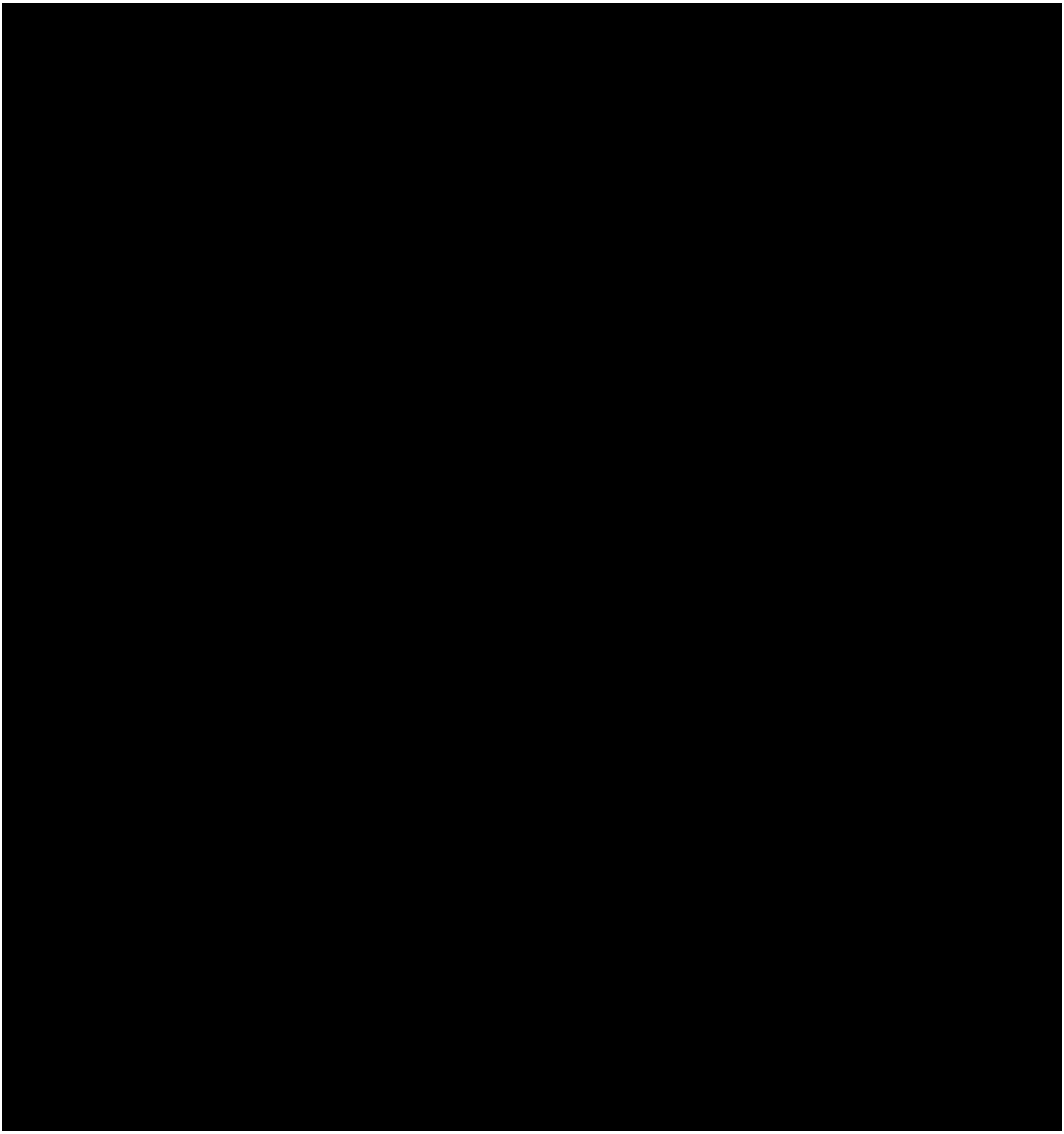
The fluid now goes back to the inlet and the cycle starts over again and keeps running continuously as required. The complete cycle with all the components is shown below.

[redacted]

Figure 15: Complete Organic Rankine Cycle

5 Complete ORC Geothermal Power System modelled in DWSIM

Shown below is the complete ORC system modelled on DWSIM, generating about 758KW of power whilst also inculcating a waste heat recovery mechanism.



- Overall system power generated = 757.95KW (Main Turbine) + 330KW (Sub-Turbine)
- Overall system power consumption = 330KW (Compressor) + 2.45KW (DHE Pump)
- System net power generation = 755.5KW

5.1 Stage-I a): Evaporator/Boiler-1

The cycle begins at the evaporator stage, where Isopentane at a supply temperature and pressure undergoes heat exchange with a set of hot geothermal water at 80°C using a Shell & Tube heat exchanger. The end goal of this stage of the cycle is to get the organic working fluid - Isopentane to a vapour state with a substantial amount of pressure increase due to the heat gain and vapour phase change from a liquid. The properties of both fluids at the inlet are shown below.

Figure 16: Fluid properties at the Boiler's inlet

Figure 17: Boiler-1

The geothermal water loses heat and temperature and leaves the first boiler as warm water, while the Isopentane is a 98% vapour mixture. As can be seen, the Isopentane has not fully converted to the vapour state, while the warm water leaving can still be reused for heating purposes.

As can also be viewed on DWSIM's material stream taskbar, the Isopentane leaving the first boiler has a temperature of 44.1471°C and a pressure of 172.253KPa and is a 98% vapour-liquid mixture. Hence, a second Boiler will need to be used to raise the temperature and pressure further while also converting the Isopentane to a pure vapour state. The properties of the first boiler, which is a Shell & Tube heat exchanger, are shown below. This boiler has an 84.87% thermal efficiency, with a global heat transfer coefficient U of 2800 $W/m^2 \cdot K$ and a total heat exchange area A of $20.5m^2$.

Figure 18: Boiler-1 Heat Exchanger properties

DWSIM predicts the heat exchange profile beyond the operating point to what it would be under ideal cases (100% heat transfer efficiency). The ideal pinch point at the highest predicted heat exchange point is 1.2439°C. The realistic operating point is where the current heat exchange process ends (denoted by the green line), with 2485.85 KW of heat exchanged, the hot geothermal water's temperature dropping from 80°C to 56.7684°C, the cold Isopentane's temperature rising from 5.02°C up to 44.1471°C. The actual and realistic heat exchange profile is shown below, with a pinch point of 12.6213°C.

[redacted]

Figure 19: Boiler-1 Heat Exchange profile and operating point

5.2 Heat recovery mechanism to power the Compressor

In the first boiler(HEX Boiler-1), the geothermal water from the reserve, which heats and converts the cold Isopentane to a 98% vapour mixture, leaves the boiler at a temperature of 56.7684°C and a pressure of 0.5atm or 50.6625 KPa. This temperature is still sufficiently hot enough to reheat a second stream of Isopentane, converting it to a vapour with a pressure increase and subsequently using an expander(turbine) to generate some power out of it.

[redacted]

Figure 20: Heat recovery mechanism from Boiler-1

The warm water entering the recovery boiler undergoes a heat exchange process, after which it leaves at a temperature of 33.5317°C. Hence, after a dual-stage heating system, the geothermal water from the reserve at a surface temperature of 80°C has been successfully brought down to 33.5317°C. This temperature can, of course, be brought down further, however, it will incur excess machinery costs to install and operate more heat exchangers to continue the heat recovery process. This water stream can be purified and distributed to homes for domestic use.

5.2.1 Recovery Boiler

The recovery boiler, which is also a Shell & Tube heat exchanger, takes the geothermal water at the end of the first evaporative heat exchanger at the end of boiler-1 and heats a second stream of Isopentane at storage conditions. Both the fluid streams' inlet and outlet properties of the recovery boiler, as seen in fig-20, are shown below.

[redacted]

Figure 21: Recovery Boiler's fluid stream properties

As can be seen, the warm water entering this boiler leaves as a very low pressure, 33.5317°C water stream and can be reused for household supply. The Isopentane stream has now become 99.53% vapour at a pressure of 1.5atm or 151.988 KPa. The recovery boiler must have the following properties in order to ensure efficient heat recovery and reuse.

[redacted]

Figure 22: Recovery Boiler's heat exchanger properties

The recovery boiler requires a total heat exchange area of 37.5m^2 and a global heat transfer coefficient of 3000 W/m^2·K with 2478.41 KW of heat exchanged between the two fluid streams, giving a thermal efficiency of 92.859%. The maximum theoretical heat exchange that can occur under ideal conditions is 2669KW. The recovery boiler increases the pressure of the cold Isopentane by 0.5 atm or 50.6625KPa to a vapour pressure of 1.5atm or 151.988KPa and further reduces the warm water's pressure by 40.530KPa making it a very low-pressure water stream, which can be re-pressurized via a pump before household supply as usual. The heat exchange profile of this recovery boiler is shown below.

Figure 23: Recovery Boiler's heat exchange profile

The pinch point of this recovery boiler is 1.1908°C, which occurs when 2135.2 KW of heat has been exchanged between the fluid streams, with the warm water attaining a temperature of 36.7605°C and the cold Isopentane attaining a temperature of 37.9513°C. Th best operating point, as can be seen in the figure above is at the end of the heat exchange process with 2478.41 KW of heat exchanged between the two fluid streams. The water leaves at 33.5317°C, and the Isopentane leaves at 40.1215°C as a 99.53% vapour. It can once again be noted that the pinch point is not at the best operating point. With the isopentane now in a vapour state, an expander(Turbine) is used to create a pressure drop, generating some power.

5.3 Downhole Heat Exchanger - Heat Pump Technology

As mentioned in the brief, it was desired to utilize the geothermal reserve water and somehow convert it to a temperature greater than or equal to 100°C.

Figure 24: Geothermal Hot water reused in DHE

The geothermal water leaves the second boiler at 76.1115°C and a pressure of 0.5atm or 50662.5 KPa. This stream of water is then passed through a borehole/downhole heat exchanger to raise its temperature above 100°C.

5.3.1 DHE - Working Principle

It is quite important to understand the downhole heat exchanger's heat transfer mechanism for the following reasons **[10]**:

- Systems can be designed in a more cost-effective manner, making better use of the available geothermal reserves/wells, which are expensive to build.
- Reservoir fluid is directly used, resulting in less waste and environmental harm.

A basic DHE is a simple device that mimics a shell & tube heat exchanger, with the bored hole and the well's casing, which contains the geothermal reserve water - acting as a heat exchanger shell ***[10]***. A U-shaped pipe bundle is then installed with fluid from the surface flowing down, undergoing a heat exchange process with the geothermal reserve water and pumped back up at a much higher temperature.

[redacted]

Figure 25: DHE Schematic

Factors such as the depth of the u-tube piping, diameter of the pipe, heat exchange area and material used can be adjusted to adjust the outlet temperature of the water. As can be seen, the geothermal reserve is typically at temperatures of 160°C, and the feed zone at the u-bend is at 112°C. As the water is pumped up, it loses heat to the surrounding piping walls and soil. Due to the high temperature, a flash pump will be required after the U-bend to pump up the water. or if a pump is installed before the bend, a normal high-temperature pump will be required.

[redacted]

Figure 26: DHE system modelled in DWSIM

Thus, by using such a DHE system as a natural heat pump, the water's temperature was raised to 103.876°C. The advantage of such a setup is that the geothermal fluid remains within the reservoir and doesn't have to be disposed off.

6 Reflective Appraisal

During my summer research internship at Victoria University Wellington, I encountered a continuous learning curve, prompting rapid self-improvement. Applying my engineering and design expertise to a real-world simulation of a geothermal power system allowed me to amass a wealth of practical knowledge, spanning from research and development stages to industry applications. Working within a leading New Zealand research institution provided invaluable insights into the intricacies of engineering research, development, collaboration, and application processes.

Navigating through the initial literature review phase presented a multitude of variables and starting points, necessitating careful consideration to discern the most feasible options for system design. Despite encountering challenges such as design constraints, operational limitations, and rigorous scheduling, I persisted in iteratively refining and optimizing the system. The iterative nature of the process underscored the importance of continuous design optimization and error prevention, compelling me to generate multiple prototypes to ascertain the most efficient operating system.

Adhering to a systematic design approach, I meticulously analyzed and iterated upon each component of the system, from the boiler to the compressor, turbine, and condenser, ensuring seamless functionality and efficiency. This process instilled in me a deep appreciation for the immense potential of engineering to deliver sustainable, innovative solutions amidst the pressing climate change crisis.

Collaborating with GNS New Zealand's head geothermal modeller, [redacted], and my supervisor throughout the project honed my technical, communication, and collaborative skills, particularly under tight deadlines. My experience in developing, modelling, and optimizing a geothermal power system with a low-temperature heat source, including waste heat recovery systems, provided me with a profound understanding of the scope and potential within the field of sustainable and clean power generation.

This internship has fueled my passion for pursuing a career in geothermal mechanical process engineering, driven by the desire to contribute to the ongoing efforts in decarbonization and sustainable energy solutions. I am immensely grateful for the opportunity afforded to me by Victoria University Wellington, which has equipped me with the skills and insights necessary for future endeavours in this field.

7 Conclusions

Geothermal power systems design with an Organic Rankine cycle is a very broad, complicated and open-ended field. As a summer research intern, I was tasked with the responsibility of modelling a system and modifying required parameters to ensure a fully functional simulated system design that can be provided to the industry as a viable solution for an optimised design. I am grateful for the help provided by my supervisor and his PhD student, who enabled me to test out various possibilities in design, as they could see that creative thinking and critical analysis were some of my key strengths. My work on this project has been a truly memorable experience, one that I shall fondly cherish and apply the learning outcomes in my career going forward as a mechanical engineer.

References

[1] Victoria University of Wellington : Te Herenga Waka.

[2] Industrial Heat Pumps, High temperature heat pumps, SINTEF, https://www.sintef.no/en/expertise/sintef-energy-research/high$_temperature_heat_pump_industrial_heat_pum$
$text = Current$

[3] P. L. Carlo Carcasci *, Lapo Cheli, L. Winchler, Off-design performances of an organic rankine cycle for waste heat recovery from gas turbines, Organic Rankine Cycle for Energy Recovery System, Energies, DIEF—Department of Industrial Engineering, University of Florence Via Santa Marta, 3, 50139 Florence, Italy (2020).

[4] T. W. S. Hung, T.C.; Shai, A review of organic rankine cycles (orcs) for the recovery of low-grade waste heat., Energy 1997 (1997).

[5] The voice of geothermal in Europe, European Geothermal Energy Council, https://www.egec.org/about/aboutgeot.

[6] Geothermal Rising, Powering our Renewable Future, https://geothermal.org/resources/geothermal-basics.

[7] M. H. H. L. V. Quoilin, S.; Orosz, Performance and design optimization of a low-cost solar organic rankine cycle for remote power generation., Sol. Energy 2011, 85, 955–966 (2011).

[8] S. K. E. S. H. Schuster, A.; Karellas, Energetic and economic investigation of organic rankine cycle applications, Appl. Therm. Eng. 2009, 29, 1809–1817 (2009).

[9] A. L. A. P. M. Manente, G.; Toffolo, An organic rankine cycle off-design model for the search of the optimal control strategy., Energy 2013, 58, 97–106, doi:10.1016/j.energy.2012.12.035 (2013).

[10] M.G.Dunstall, Downhole heat exchangers performance analysis (rotorua geothermal field), Ph.D. thesis, Department of Mechanical Engineering, University of Auckland (1992).