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Development Proposal:

Moreamps Heat Engine

Revision 2

EXECUTIVE SUMMARY

This document provides an overview of the Amps family of heat engine technologies (Amps, Euroamps, Moreamps) owned by International Innovations Limited. The document includes a preliminary assessment of potential applications of the technology and presents a three-stage development proposal. It is shown that there are many potential applications of the Amps family of heat engine technologies over a wide power output range. At the small (5 – 10 kW) scale, these include combined heating and power, remote power and mobile/automotive applications. At larger sizes (30 – 60 kW), stationary diesel generators, industrial applications and heavy marine systems all represent potential markets for the technology. Some high power output applications are also discussed. The competitive advantage of the Amps family of heat engine technology lies in its exclusive use of readily available parts, which makes the system robust and enables the rapid development and global supply of these products.

A preliminary technical review of the three individual heat engines: Amps, Euroamps and Moreamps, indicates that the Moreamps system is the most favourable for continued development. However, an innovation described in the Amps patent has been incorporated into the proposed design to simplify the system.

The proposed three stage development program begins (Stage 1) with the construction of a small scale, 5 – 10 kW power output technology demonstrator prototype. As is detailed in the proposal, this prototype can be assembled from existing components in a small workshop on a 4 – 6 month time scale. In addition to providing an opportunity to more accurately assess the technology and performance, the prototype may lead directly to the development of products at a similar power output level (combined heat and power, automotive, etc.), and also to scaled-up versions for stationary diesel generators, industrial applications and other systems. Increasing the power output to the 60 kW level will occur during Stage 2, following the successful completion of Stage 1. Stage 3 calls for the potential further expansion of the systems to the 100 kW power output level and the ongoing adaptation of the other (smaller) systems for new applications.

There is global interest in converting the energy recovered from waste heat sources into valuable electricity, driven by a combination of social, political, environmental and economic factors. It is the intention of International Innovations Limited to develop the Amps family of waste heat recovery products to supply to these global and increasingly important markets.

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1. INTRODUCTION

This document presents a proposal for the development of the heat engine technology described by the Amps family of patents (Amps, Euroamps, Moreamps). The Amps technology is owned by International Innovations Limited, IIL, (online: www.internationalinnovations.com.au). This document provides a general overview of waste heat recovery technology, followed by an initial summary of potential applications of the Amps family of heat engine patents, at various power output levels. Based on the identified applications, three stages of development are proposed. More detailed thermodynamic analysis of the three individual heat engines (Amps, Euroamps and Moreamps) is provided as an appendix.

IIL has sold a non-exclusive license for use of the Euroamps patent to Euroenergie of Germany, where the product is currently under development. Additionally, there is a need to expand and improve the product range, which motivates the development and testing of Amps-derived products in Australia. Awareness of the IIL waste heat recovery technology is increasing, and IIL has been approached by Big Biogas of Germany with an expression of interest in marketing Amps-derived waste heat recovery technology to European customers in the stationary diesel generator market. IIL is also working closely with global company Olaer as a development partner for the Amps technology.

2. TECHNOLOGY OVERVIEW

The Amps family of patents describes and protects a group of external combustion engines (including Amps, Moreamps and Euroamps) that recover energy from a heat source to produce useful work or electricity. There are many existing technologies that allow useful work to be obtained from a heat source, such as the steam cycles used in large power stations or the internal combustion engines in automobiles. However, these existing technologies typically draw energy from very high temperature heat sources (such as the high combustion temperatures near 1000 °C inside an internal combustion engine), which are generally referred to as "high grade" heat sources. The dependence on high grade heat sources typically limits the use of most existing power generation technology to specific fuels and/or operating conditions, and places extreme demands on material performance.

The feature of the Amps heat engines is that they are configured to draw energy from "medium grade" and "low grade" heat sources at temperatures less than approximately 200 °C. This greatly widens the potential operating range of the Amps family of patents, compared to most conventional power generation technology. Moreover, the technology is assembled from existing and readily available fluid components, which improves robustness and makes possible the rapid development and global supply of these products. With medium and low temperature heat sources, the proportion of energy that is available to be recovered and converted into electricity is typically low, meaning that it has, in the past, been difficult to justify the use of medium and low grade heat sources from an economic point of view. However, recent social, political and economic factors indicate that this situation is beginning to change, with the use of medium and low grade heat sources likely to become highly favourable in some applications.

All heat engines waste energy. In a modern power station, maximum efficiencies of approximately 50 - 60 % are typically obtained, meaning that only 50 - 60 % of the energy released by the heat source (burning coal, for example) is converted into electricity. Similarly, in

an internal combustion engine, efficiencies are generally near 30 %, meaning that only one third of the energy released by burning the petrol or diesel is converted into kinetic energy (vehicular motion). For example, if petrol costs \$1.20 per litre, this means only approximately 40 c of every \$1.20 of fuel cost is directly converted into motion. Most of the remaining energy (and fuel cost) is "dumped" into the atmosphere by the radiator and in the hot exhaust gasses. Historically, fuel costs have been sufficiently low, meaning that the inherently wasteful use of conventional power generation technology has been acceptable to industry and the average consumer. However, fuel costs are rising due to increasing demand, the depletion of oil reserves (and other fossil fuels) and the costs associated with reducing the environmental impact of conventional fuel sources (such as converting to "clean coal" or nuclear technology). This is evidenced in the recent rise in the price of oil near USD 100 per barrel. As fuel and energy prices continue to rise, there will be increasing economic pressure to improve the efficiency of power generation (and other processes) and reduce fuel consumption. There is also increasing general awareness and concern about the impending effects of global warming and climate change, which is leading to increased social and political motivation to reduce greenhouse gas emissions. One example of this new urgency is in the UN Climate Conference held in Bali, Dec 3 – 14, including representatives from over 180 countries, which indicates that people and governments around the world are beginning to recognise the need to cut emissions and address climate change. This is relevant to the Amps family of technology because recovering the energy in the heat wasted by conventional engines and/or industrial processes will clearly reduce fuel consumption and therefore also reduce greenhouse gas emissions. In this way, there is increasing economic, social and political pressure to improve power generation efficiency and reduce fuel consumption - and these factors increasingly justify the development of technology such as the Amps family of patents.

The Amps family of patents owned by International Innovations Limited (IIL) represents a significant opportunity to enter the heat recovery and electricity generation market. It represents an opportunity to develop products that will not only contribute to reducing fuel consumption and greenhouse gas emissions, but also the opportunity to benefit from the economic, social and political factors that are beginning to drive this market.

3. POTENTIAL APPLICATIONS

The Amps family of heat engines has many potential applications at various scales of power output. This section describes potential applications of Amps-derived heat engines sized at: small scale (5 – 10 kW), medium scale (30 – 60 kW), and large scale (100 kW and above).

3.1 Small Scale (5 – 10 kW)

A small scale power generation unit based on Amps family technology, producing up to 10 kW of shaft power, may have the following applications:

(a) Combined Heat and Power

Combined Heat and Power is an energy supply application in which a single power unit produces both electricity and heating. Such units could be used, for example, to supply a single home with electricity and hot water for either direct use or a household heating system. An Amps-derived device could burn natural or LPG gas, heating oil, or any other appropriate fuel to achieve this. Whilst it may seem environmentally "unfriendly" to burn these fuels, the important point is that the fuel is already being burned to supply heat, and, by using the Amps

system, this process can also be used to produce electricity *in addition* to heating. This takes load off the electricity grid, which means there is less demand on the power station (potentially representing a fuel and emissions saving there). Thus, the user can offset the cost of the power unit by reduced electricity expenses (with similar heating fuel expenses).

The benefits of generating electricity at the point of use include the removal of transmission losses (which are typically up to 20 %), and the potential for improved overall thermal efficiency, since the heat rejected by a power station is vented to the atmosphere and lost (instead of being used to supply household heating). Finally, if implemented on a wide scale, localised power generation improves energy security, since the system may be less susceptible to an attack at a single, critical point.

These systems would be most appropriate where there is an existing requirement for household heating, for example in the UK, Europe and parts of North America. It would also be most suited to places with existing fuel supply infrastructure such as mains gas or an established household oil supply system.

(b) Remote Power

Amps-derived power generation units could be configured with a generic “firebox”, suited to a very wide variety of fuels and external combustion (or other heating) processes. Such systems would be suited to applications including:

- *Off-Grid Power Generation*

In some circumstances, in remote locations where a local fuel supply is readily available and a connection to the electricity grid is not, the Amps-derived system may be the most economically viable energy supply solution. Any locally available fuel (or heat source) may be used to generate electricity, removing the dependence on a regular supply of, for example, diesel for a generator.

- *Developing World Power Generation*

Similar to the previous application, Amps-derived systems could be sold to governmental and non-governmental aid agencies for distribution to numerous developing countries (systems may also be sold directly in these regions). The significant advantage of the Amps-derived external combustion engine over conventional power generation methods (such as diesel generators) is *flexibility* in the fuel supply. Communities would not be dependent on a continuous supply of a specific fuel, but would instead be able to burn any locally available materials to provide a heat source for the Amps system. Again, whilst this may seem environmentally “unfriendly”, it is important to note that these communities will generally already be using combustion processes for cooking and/or heating, so the Amps system can provide electricity without the requirement to burn significantly more fuel. These systems would clearly be extremely useful in “disaster relief” applications, in which a power generation system could be provided to a community in distress as a once-off delivery and then local materials and debris could be burned to provide a vital electricity supply.

- *Military/Battlefield Power Generation*

Amps-derived power generation units provide a very flexible and robust energy supply solution, which may be of great interest to the military. During remote operations or during a time of

hostility, a reliable supply of diesel may not be available to run conventional generators. However, an Amps-derived power generation system would enable soldiers to generate electricity by burning *any* locally available fuels. This makes the electricity supply *extremely robust*, since it is less susceptible to interruption of the fuel supply chain - which is clearly of immense value in modern warfare scenarios where high-tech electronic equipment is common.

- *Camping*

Small Amps-derived power generation units may be used in camping applications, in which the heat of a campfire (or gas burner) could be used to generate electricity. Increasingly sophisticated and energy intensive camping equipment (such as hot water systems and refrigerators) is popular amongst some frequent campers.

- *Solar*

Concentrated sunlight has been shown to produce very high temperatures, which may be directed onto the boiler of a small Amps-derived system to produce electricity. However, the power density of sunlight is very low (100 W/m^2), which means a large solar collector would be required to produce a useful electrical output.

(c) Mobile/Automotive Applications

An Amps-derived power generation system could be adapted for mobile/automotive applications, although this adds an additional engineering constraint requiring a sufficiently high power to weight ratio. If this can be achieved, then the heat wasted by a car's engine could be used as input to an Amps-derived system and used to turn an alternator. With this system, it would no longer be necessary to drive the alternator from the fan belt, which would increase the net shaft power output of the engine (for the same fuel consumption). In this way, the entire electrical system of the car could source its energy from the wasted heat rather than the valuable shaft work (in the flywheel). An electrically driven (or Amps output shaft driven) supercharger could then boost the performance of the engine by compressing the incoming air. This system would work as long as the engine was warm, which means it could deliver compression immediately upon acceleration and reduce or eliminate the "lag" typically associated with turbochargers (which are an alternative waste energy recovery system). Depending on the heat exchanger design, this system may also provide less flow interruption and backpressure than a conventional turbocharger.

An extension of this concept applies in the hybrid car sector. A hybrid car uses an internal combustion engine to turn a generator which provides electricity for an electrical drive system. A miniaturised Amps-derived automotive power generation system could recover wasted heat from the internal combustion engine's exhaust and coolant to provide additional charge for the electrical system. This may boost the overall efficiency of the hybrid vehicle (depending on the power to weight ratio of the Amps system).

3.2 Medium Scale (30 – 60 kW)

Medium scale Amps-derived power generation units, producing up to 50 kW power output, could see potential use in applications such as:

(a) Stationary Diesel Generators

In this application (as identified by Euroenergie and Big Biogas in Europe), the Amps-derived system could be used to increase the electrical output of a stationary diesel generator - for the

same fuel consumption. In one application being considered by ILL, it is proposed that the Amps-derived system be used to recover waste heat from the coolant and/or exhaust of a 300 kW (electrical power output) diesel generator to increase the total electrical power output. A 300 kW power output generator would produce at least 600 kW of waste heat (based on the assumptions described in Section 2), split approximately evenly between the low temperature coolant and medium temperature exhaust. If it is assumed that up to 10 % of the energy in the waste heat can be recovered and converted to electricity, then an Amps-derived system could use the 600 kW waste heat source to generate up to an additional 60 kW of electricity. In this way, the Amps-derived system could be used to take a heat source that is essentially free (because it would otherwise be vented to the atmosphere) and use this to increase the power output of the overall (combined) system by up to 20 % (from 300 kW to up to 360 kW).

The addition of an Amps-derived system to a stationary diesel generator may provide a significant improvement in performance, giving the device the ability to “pay for itself” through:

- (a) Either higher power output for the same fuel consumption or a reduction in fuel consumption for the same power output
- (b) The generation of carbon credits or savings related to carbon taxes (depending on the applicable legislative environment)
- (c) Bonuses paid through government incentives for environmentally friendly technologies.

The addition of an Amps-derived system to diesel generators is also highly beneficial for the environment, because more electricity is produced for the same fuel usage and greenhouse emissions, which results in a reduction of tonnes of carbon dioxide emitted per kWh of electricity generated.

(b) Industrial Applications

Heat is a by-product of many large industrial processes such as cement production, fertiliser production and food processing (such as abattoirs). Whilst many of these processes reuse their waste heat directly, such as by pre-heating other parts of the cycle, there is an opportunity to use an Amps-derived system to generate electricity from these heat sources, which may be a more convenient or valuable use of the energy. Electricity generated in this way could be either sold to the grid or used on site to reduce the need for the user to buy from the grid. Both of these applications may result in a net benefit to the user.

For example, the fertiliser production plant at Garden Island in Brisbane is a net producer of heat and vents a significant amount of steam directly to the atmosphere every day. No waste heat recovery for electricity generation is currently implemented. The plant is a large energy user and will be economically hurt by any form of carbon trading or carbon tax. Implementing an Amps-derived power generation system may enable this plant to reduce its total energy use (and, hence, reduced its carbon footprint).

The reduction in energy costs (or increased revenue from sale of electricity to the grid) may make the implementation of Amps-derived power systems favourable in many industrial applications. However, the possible future introduction of a carbon tax or an emissions trading scheme may make the implementation of Amps-derived systems even more favourable, since they contribute to reduced emissions by cutting fuel and/or grid electricity consumption. Any future carbon management system that puts economic value on greenhouse emissions is very

likely to improve the economic viability of Amps-derived power generation systems.

(c) Heavy Marine

Similar to 3.2 (a), large marine power plants are also potential sources of waste heat for Amps-derived systems. Amps-derived technology offers the opportunity to run the vessel's entire electrical system on waste heat (instead of engine output shaft power), which may reduce overall fuel consumption. The power to weight ratio would be less important, due to the large size of the vessel and existing fittings. Large ferries (such as the Manly Ferry), which have diesel engines running - and venting two thirds of the input energy - for most of the day, would be most suitable applications of a medium sized Amps-derived system. These ferries could run all the secondary systems such as air-conditioning, lighting, auxiliary power, etc. on primary power plant waste heat, which means a higher proportion of the shaft power output of the primary engine could be directed to the propulsion system. This may reduce the overall fuel cost and potentially result in significant savings over the life time of the installed components.

3.3 Large Scale (100 kW and Above)

Large scale Amps-derived power generation units, producing 100 kW or more power output, could be used in applications such as:

(a) Bottoming Cycle

A bottoming cycle is a waste heat recovery power generation cycle applied to the waste heat rejected by a power station. Large scale Amps-derived systems could be used in this way to increase the overall output of power stations in the 1 MW power output range, such as those used on remote mining sites. Industry advice indicates that an output increase of 15 - 25 % (on a 1 MW power station) is necessary for economic viability. However, with rising fuel prices and any new carbon management regulations, this figure may drop to approximately 10 %, meaning that Amps-derived units in the 100 kW power output range may be viable. Systems above the 100 kW size may require transmissions to ensure adequate shaft speed for the alternator. Whilst this is feasible, it increases control requirements, size, weight, cost, maintenance and general complication.

(b) Refuse / Geothermal Power Generation

A 100 kW size Amps-derived system may be appropriate for use in geothermal power generation systems and also for power generation based on the combustion of gases recovered from refuse tips. However, there are currently many existing systems available in this market. These are generally based on the Organic Rankine Cycle and are likely more efficient than an Amps-derived system, due to the use of highly optimised turbines.

4. DEVELOPMENT PROPOSAL

As shown in Appendix A, the recommended system for development is based on the Moreamps patent, incorporating the concept of a reversible drive system similar to that described in the Amps patent. As shown in Appendix B, the recommended working fluid is an organic refrigerant produced by Honeywell called *Genetron 245 fa*. Three broad stages of development are proposed, including:

4.1 Stage 1 - Technology Demonstrator

The objective of this stage will be to construct a prototype technology demonstrator in the 5 -

10 kW power output range. The proposed prototype system will be approximately the size of a household barbeque and will use a gas burner as a heat source. The system will turn an output shaft connected to a flywheel and small alternator. An overview of the proposed prototype system is presented in Figure 1.



Figure 1 – Stage 1 (prototype system) overview.

(a) System Schematic and Operation

A schematic of the proposed system is shown in Figure 2.

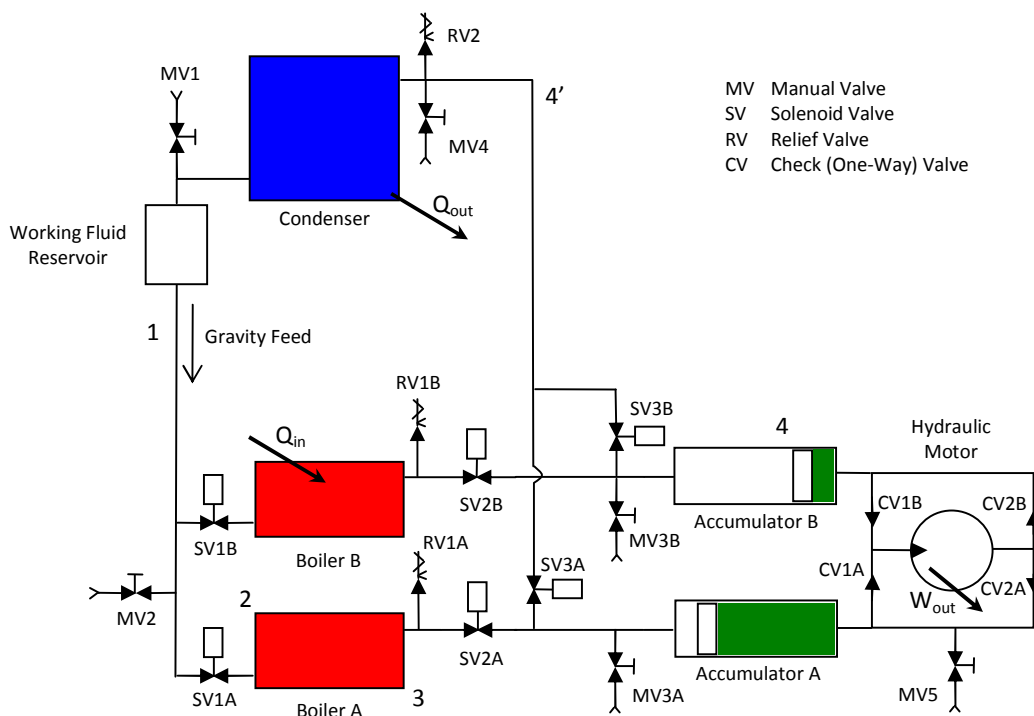


Figure 2 - Schematic of the proposed system.

Beginning in the Working Fluid Reservoir, with Valves SV1A, SV2A and SV3A open, liquid working fluid is gravity fed into Boiler A, with the entire “A” side of the working fluid circuit at pressure of approximately 4 bar (400 kPa) and temperature 50 °C. Valves SV1A, SV2A and SV3A are closed. The working fluid is now heated at constant volume in Boiler A, causing the temperature to rise

to 140 °C and the pressure to rise to 28 bar (2.8 MPa). During this time, Accumulator A is filled with hydraulic oil, so the piston is at the position shown in Figure 2. Valve SV2A is opened and the working fluid expands, driving the piston to the other end of the accumulator. During the expansion process, the pressure drops from 28 bar (2.8 MPa) to 10 bar (1.0 MPa). Movement of the piston forces hydraulic oil out of Accumulator A and under pressure through Check Valve CV1A, through the Hydraulic Motor, through Check Valve CV2B and into Accumulator B, where the pressure is 4 Bar (400 kPa). This process transfers hydraulic oil from Accumulator A to Accumulator B through the hydraulic motor (which turns the output shaft and alternator). In the gas side of Accumulator A, after the expansion process is complete, Valve SV3A is opened and the remaining 10 bar (1.0 MPa) pressure in Boiler A and Accumulator A blows into the Condenser, equalising the pressure throughout the "A" side of the working fluid circuit. Valve SV1A opens to refill Boiler A with liquid working fluid for the next cycle. With Valve SV2A closed and Valve SV3A open, during the constant volume heating process in Boiler A, Accumulator A is refilled with hydraulic fluid, which flows from Accumulator B through Check Valve CV2A, hydraulic motor, and Check Valve CV1B.

Relief valves have also been incorporated for the protection of various components. Manual valves and vents are included for purging, filling and draining the system. Pressure and temperature transducers may also be added at various important points in the system.

(b) Major Components and Suppliers

Table 1 lists the most important components of a single, small scale technology demonstrator prototype system.

Table 1 – Major Components and Recommended Suppliers

Component	Quantity	Recommended Supplier	Supplier Status	Comment
Accumulator	2	Olaer	Confirmed	Limit switches, possible seal change so compatible with working fluid vapour, aluminium construction, max allowable working pressure 40 bar.
Radiator	1	Olaer	Confirmed	DC powered fan, design condition: T = 50 °C, p = 4 bar, max allowable pressure 14 bar, aluminium construction.
Hydraulic Motor	1	Berendsen Fluid Power/ Vickers	Pending	Vane type hydraulic motor, ~ 5 kW output power, speed: 3000 rpm, max allowable pressure 34 bar.
Solenoid Valves	6	Olaer/Other	Pending	12VDC Actuation.
Relief Valve	5	Swagelok	Pending	
Check Valve	4	Swagelok	Pending	
Manual Valve	6	Swagelok	Pending	
Piping / Fittings	-	Swagelok	Pending	Pipe bending, cutting, deburring tools also required

Hydraulic Hoses / Fittings	-	-	-	
Boiler	2 – 4	-	-	Max allowable working pressure 40 bar.
LPG Burner	2 – 4	BOC	-	
LPG Supply	-	BOC	-	
Gas Hoses / Fittings	-	BOC	-	
Nitrogen	-	BOC	-	
Regulator	1	BOC	-	
Working Fluid	-	A-Gas (Aus supplier for Honeywell)	Confirmed	
Alternator	1	-	-	Possibly use automotive alternator.
Steel Framework	-	Built as required	Confirmed	
Relays	6	Built as required/NTC	Confirmed	Control System will be built as required and/or with support of NTC
Control Board	1			
Computer	1			
Control System - Other	-			
Workshop Space	6 months	Queensland University of Technology	Pending	Private workshops also available if required.

(c) Stage 1 Timing and Milestones

Table 2 outlines the major milestones in the Stage 1 development plan. The overall estimated time for development of the small scale technology demonstrator is 4-6 months.

Table 2 – Major Milestones, Stage 1

Milestone	Description	Estimated Time Required (months)
1	Construction and testing of hydraulic circuit. Test operation and control with compressed nitrogen.	1 – 2
2	Construction of complete system, initial testing of constant volume heating and overall operation.	1 – 2
3	Further testing and tuning leading to improvement of the control system and steady operation.	2

(d) Roles

Physical construction of the technology demonstrator will involve plumbing together the components listed in (b) and assembly into a convenient package. System design, assembly and testing will be performed by Nicholas Ward. It is anticipated that NTC will provide engineering guidance/mentoring and assistance in the development of a control system.

(e) Expected Outcomes

At the end of Stage 1, the following outcomes are expected:

- Demonstration of the use of Amps-derived technology to generate electricity from a heat source.
- An ability to make an assessment of the technology and its suitability for further development.
- The small scale technology demonstrator may provide the basis for future products in the same output power range (5 - 10 kW), as described in Section 3.1.
- Development of small scale technology demonstrator will provide valuable insight and experience that will be necessary in the later development stages when the system is "scaled up".

4.2 Stage 2 - System Scale Up

The objective of this development stage will be to produce a waste heat recovery product specifically for use with 300 kW diesel engines. During Stage 2, the system will be "scaled up" to the 60 kW level and mated to a 300 kW diesel generator, as shown in Figure 3.

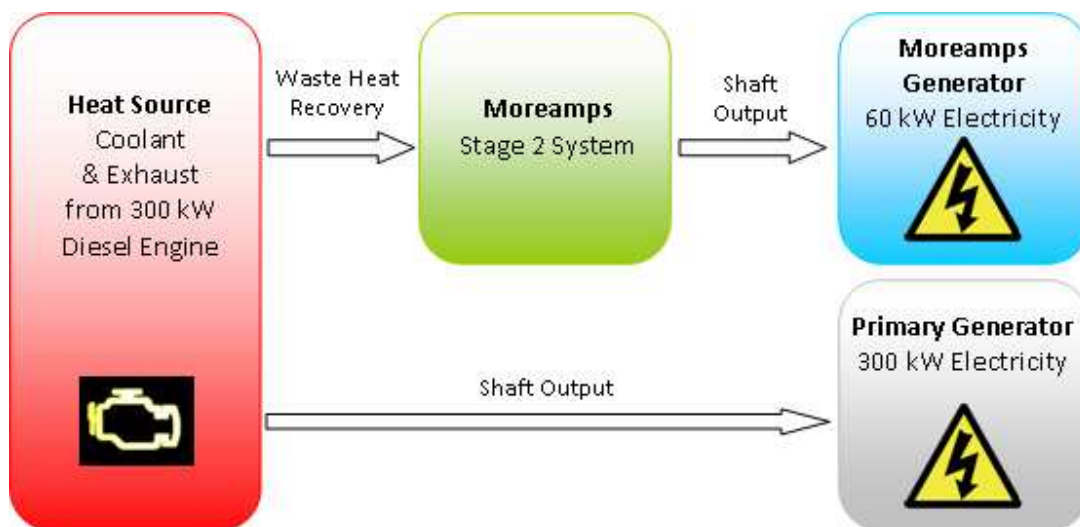


Figure 3 – Stage 2 overview.

Two stages of heating will be included: one connected to the diesel engine cooling system and the other connected to the exhaust system. During this stage, it will likely be necessary to include in the system multiple parallel circuits to boost the power output, although the operation will be conceptually similar to the successful prototype built in Stage 1. This added circuitry and complication will place increasing demand on the control system, and the experience and support of NTC (in designing and prototyping control systems) will be essential.

Further, due to the use of a diesel engine and the generally larger size of the system, a larger workshop space will be required, such as the space offered by NTC at the Castle Hill site in Sydney.

Further development during this stage may include adaptation of the system for the industrial and heavy marine applications described in Section 3.2.

4.3 Stage 3 - Large Scale Applications

Following the satisfactory completion of Stage 2, ongoing development of the technology may include further scaling up the system to the 100 kW and above power output level. The small and medium scale systems may also be further developed and adapted for new applications.

5. Summary

This document has provided an overview of the Amps family of heat engines owned by IIL, identified possible applications of the technology, and presented a development proposal. The recommended system for further development is based on the Moreamps patent, with an innovation described in the Amps patent also included. A three-stage development process was proposed, beginning with the development of a 5 – 10 kW power output prototype technology demonstrator. Further refinement of the system at the small scale (10 kW) power output level and scaling up to larger scale applications (50 kW or higher) may follow.

As energy costs continue to rise and as social and political motivation to reduce greenhouse gas emissions increases, there will be an ongoing need to use heat sources more effectively and efficiently. As has been shown, this provides many potential opportunities for Amps-derived technology. The strength of the Amps family of heat engines is that they can be assembled from readily available existing products, and be rapidly brought into these new markets.