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INTERNATIONAL
INNOVATIONS
LIMITED

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Development Proposal:

Moreamps Heat Engine

Technical Overview

EXECUTIVE SUMMARY

This document provides an overview of the MOREAMPS from the AMPS family of "waste heat engines" (MOREAMPS & OTELLO) technologies owned by International Innovations Limited (IIL) www.internationalinnovations.com.au , including a preliminary assessment of potential applications, 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 (up to 10 kW) scale, these include combined heating and power, remote power and mobile/automotive applications. At larger sizes for stationary diesel generators, industrial applications and heavy marine systems all represent potential markets for the technology. The competitive advantage of the Amps family of heat engine technology is in its exclusive use of readily available parts, which makes it a robust system and potentially lowers the cost with the use of readily available parts may make this technology favourable in applications where a minimal pay-back period is important.

A preliminary technical review of the main individual heat engines: Moreamps, and OTELLO indicates that the Moreamps & OTELLO system is the most favourable for continued development. In this document we focus on MOREAMPS using "bladder accumulators but preferred is using **piston** accumulators".

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 30 – 50 kW level will occur during Stage 2, which will take at least 12 months 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, although this stage is highly contingent on the outcomes of the preceding work.

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1. INTRODUCTION

This document presents a proposal for the development of heat engine technology described by the Amps family of patents. This document provides a general overview of waste energy technology, followed by an initial list of potential applications of the Amps family of heat engine patents, from small to large power output ranges. The competitive advantages of the technology are highlighted and a three-stage development proposal is described.

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 ^{o}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 operating conditions.

The feature of the Amps heat engines is that they are configured to draw energy from "low grade" heat sources at temperatures less than approximately 150 ^{o}C. This greatly widens the potential operating range of the Amps family of patents, compared to most existing technology. At these low temperatures, efficiency (the proportion of energy recovered from the heat source and converted into electricity) is typically very low, meaning that it has, in the past, been difficult to justify the use of low grade heat sources from an economic point of view. Thus, there are very few commercially successful technologies that use low grade heat sources. However, current social, political and economic factors indicate that this situation is beginning to change, with the use of low grade heat sources likely to become highly favourable in some applications.

All Power Stations & 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. Recovering energy from low grade heat sources such as the heat wasted by conventional engines or industrial processes will clearly reduce fuel consumption and therefore also reduce greenhouse gas emissions. Thus, 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 heat engines suited to low grade heat sources, 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 low grade heat recovery market. It represents an opportunity to develop products that will not only contribute to reduced 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 (up to 10 kW), medium scale (up to 50 kW), and large scale (100 kW and above).

3.1 Small Scale (Up to 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 low grade 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.

- *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 certain, 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 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). The Hon. Kevin Rudd recently announced that a Labor government may encourage Australian car manufacturers to develop hybrid cars. In this case, car manufacturers may be interested in using Australian owned and developed technology to improve the performance of their hybrid vehicles.

3.2 Medium Scale (Up to 50 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 for example customer www.big-biogas.de (BIG) in Germany, the MOREAMPS (or OTELLO) 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 IIL, 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. BIG has calculated that approximently 25% percent 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 (at least) an additional 150kW of electricity. (1) the heat source is essentially free, because it would otherwise be vented to the atmosphere, and (2) increasing the power output of the generator from 300 kW to 450 kW represents a 50% increase in overall performance, which is a very significant improvement.

This modification would be most appropriate in regions where the cost of electricity is highest. In Europe, for example, governmental incentives mean that electricity generated in this way can be sold for EUR 0. 18(AU $ 0.30) per kWh. Thus, for an extra 150kW from MOREAMPS generator running all day, the Amps-derived modification may generate an additional EUR 648 (AU $1,080) per day - for the same fuel usage (and cost). This 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). Whist 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 the low grade heat and an Amps-derived system to generate electricity. 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 Incitec Pivot (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 electrical 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, 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.

Further, and more importantly, Organic Rankine Cycle systems may be a more appropriate technology for bottoming cycles of this size, due to their higher efficiency and high shaft speed at high power.

(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. COMPETITIVE ADVANTAGE

Many systems already exist for converting heat (including waste heat) into electrical energy (or other forms of work). These include Rankine Cycle systems (using water as the working fluid), Organic Rankine Cycle systems (using an organic refrigerant as the working fluid), Stirling Cycle systems, and more novel reciprocating systems. Rankine Cycle systems (using water or organic working fluids) have the advantage of containing as little as one single moving part, which leads to much longer engine life than reciprocating systems. Their simplicity also leads to generally high efficiency. The Stirling Cycle is the most efficient cycle known, although it does not scale up well to high power outputs.

There are existing products at the small scale power output range (such as Cogen Microsystems of South Australia), and there are many large companies offering products at the large scale (100 kW +) range, typically based on Rankine Cycle systems. There may be an opportunity at the 50 kW power output range, and also space in the other markets for an additional supplier.

The main competitive advantage of the Amps-derived technology is that it is simple and robust, or, as one expert has described it, “agricultural”. The systems can be assembled from readily available parts (in many regions of the world), which may tend to reduce the cost. Efficiencies will likely not be as high as in the other, highly specialised systems, although this is not necessarily a problem since, in many cases (such as in waste heat recovery) the energy source is essentially free.

This advantage should drive the product development and marketing. For example, it would be difficult for Amps-derived technology to compete with an Organic Rankine Cycle for a single point, high power output geothermal power station, in which efficiency would be an important parameter compared to the one-off cost to purchase the system. However, in other applications, where a minimal pay-back period is critical, the Amps-derived technology may be highly favourable.

5. 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:

5.1 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.

(a) System Description

The proposed prototype system will be approximately the size of a household barbeque and will use an LPG gas burner as a heat source. The system will turn an output shaft connected to a flywheel and small alternator. A schematic of the proposed system is shown in Figure 1.

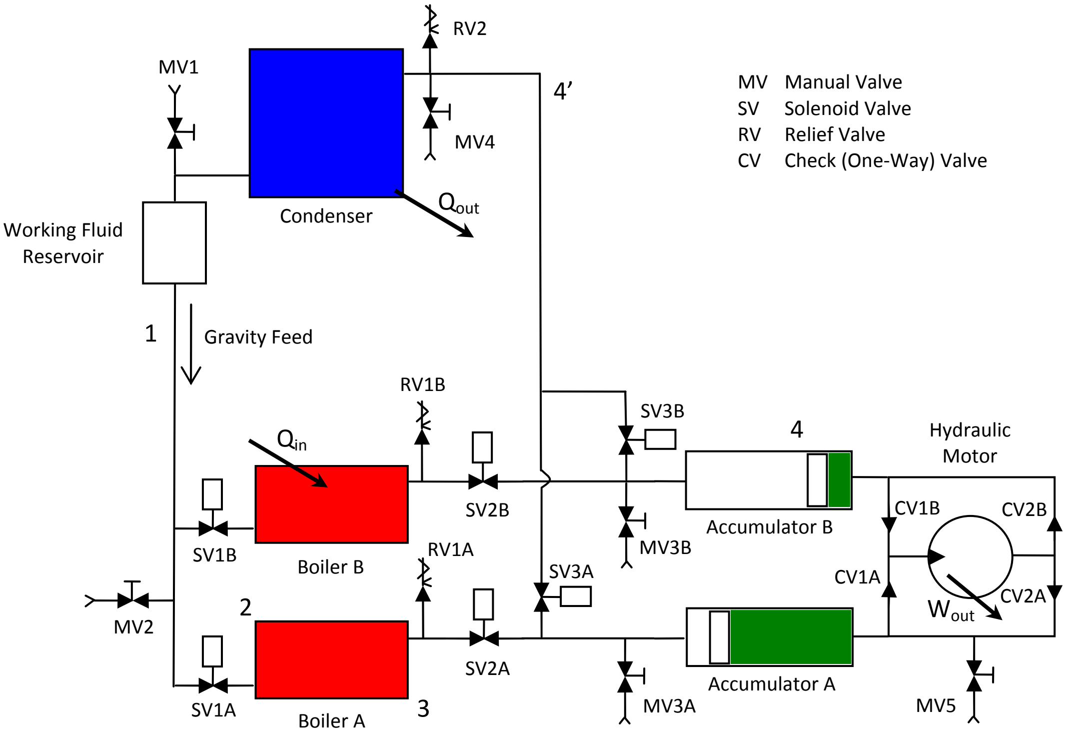

Figure 1 - Schematic of the proposed system.

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 1. 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			Limit switches, possible seal change so compatible with working fluid vapour, aluminium construction, max allowable working pressure 40 bar.
Radiator	1			DC powered fan, design condition: T = 50 ^oC, p = 4 bar, max allowable pressure 14 bar, aluminium construction.
Hydraulic Motor	1		Pending	Vane type hydraulic motor, ~ 5 kW output power, speed: 3000 rpm, max allowable pressure 34 bar.
Solenoid Valves	6		Pending	12VDC Actuation.
Relief Valve	5		Pending	
Check Valve	4		Pending	
Manual Valve	6		Pending	
Piping / Fittings	-			Pipe bending, cutting, deburring tools also required
Hydraulic Hoses / Fittings	-	-	-	

Boiler	2 – 4	-	-	Max allowable working pressure 40 bar.
LPG Burner	2 – 4		-	
LPG Supply	-		-	
Gas Hoses / Fittings	-		-	
Nitrogen	-		-	
Regulator	1		-	
Working Fluid	-	A-Gas (Aus supplier for Honeywell)	Confirmed	
Alternator	1	-	-	Possibly use automotive alternator.
Steel Framework	-	Built as required	Confirmed	

(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. It is proposed that this work be completed in a small workshop at Caloundra, Queensland, 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".

5.2 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 150 kW level and mated to a 300 kW diesel generator. 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.

Other developments that may be appropriate during this stage include further increases in power output up to approximately 50 kW, and adaptation for the industrial and heavy marine applications described in Section 3.2.

5.3 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 500 kW and above power output level. This may produce a product suitable for bottoming cycle or other power generation applications detailed in Section 3.3, subject to an assessment of technology viability and competitiveness. Estimated development time for a 500 kW

6. 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 (500 kW or higher) is the intention to 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. An 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.