Zero Emmission Vehicle for Mines Rescue and General Underground Use Utilising the Allison Gas Turbine Engine in a Mines Escape Rescue Vehicle

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Abstract

The search has been going on for the last 7 years (since the Moura disaster) for an air independent power plant to power a mines escape rescue vehicle (MERV). Using the vehicle automation technology developed for the CSIRO Numbat we are now constructing a tracked remote controlled vehicle which, can carry 10 people, a description of the power plant follows:

A gas turbine engine (Brayton Cycle) can be closed cycle and externally fired. This requires a relatively constant heat source with at least 900° C temperature. This can be provided from an electrically heated liquid salt heat cell utilising the latent heat capacity of salt with a storage capacity of at least 1000 kWh of useable heat (about 4-8 hours duration for the MERV on a fully charged heat cell, approx. equivalent to 100ltrs diesel fuel). The gas turbine will be operated in a closed cycle configuration that is the exhaust gas of the gas turbine is fed into the input (compressor stage) after cooling through a recuperator and a gas to liquid heat exchanger. To move the heat from the heat cell to the turbine requires the compressed gas (air) from the compressor stage of the gas turbine to pass through the recuperator where the temperature is raised to 450°C then through the heat exchanger in the liquid salt. This will raise the temperature of the compressed gas to >900 °C. The gas will expand due to the increase in temperature and in exhausting at constant pressure will spin the turbine stage of the gas turbine. The turbine stage is connected to a gearbox with a step down ratio of approx. 6:1 (54,000 RPM to 6,000 RPM. This will drive a wobble plate type hydraulic pump that will drive the MERV through hydraulic motors.

The expected output of the Allison T63-A-700(250-C18) gas turbine is 236 kW at an efficiency approaching 35%.

Executive Summary

Since the withdrawal of ANI Ltd. from the Mine Rescue Vehicle (MERV) project a search commenced for a vehicle manufacturer to replace ANI. A Queensland company called Kirktrac Aust. was located that designed and built hydraulic tracked vehicle similar to that proposed by ANI. Kirktrac have many years' experience in the manufacture of specialised tracked vehicles. A presentation was made to CSIRO on their design (see fig. 1) for the MERV and their vehicle conforms to the requirements for the Rescue Emergency Vehicle outlined in the report of the Moura mine disaster. The MERV will utilise a novel type of propulsion unit comprising an ex-aviation Allison gas turbine engine modified to run in closed cycle configuration from the latent heat of salt.

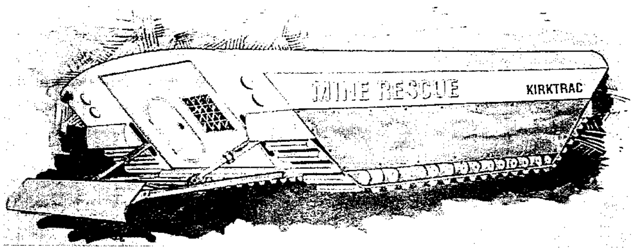

Fig. 1 Mines Rescue Vehicle

Vehicle Operation

Most people associate "mine rescue" with "saving lives". Although saving lives is the most important part of mine rescue work; there are other tasks involved. A more complete definition of mine rescue is:

> ***"the practiced response to a mine emergency situation that endangers life, property, and the continued operation of the mine"***

Mine rescue and recovery work involves a wide variety of tasks. Four fundamental principals exist for an effective mine rescue operation. These principals in order of importance are:

1. Ensure the safety of the mine rescue team
2. Make every effort to rescue or secure the safety of mine workers
3. Protect mine property from further damage caused by fire, cave-in, etc.
4. Return the mine to a safe condition so operations can continue.

Operating within the parameters of these four principals, some of the duties a team may have during an actual emergency are:

- Explore the affected area of the mine
- Searching for and rescuing survivors
- Performing first aid
- Resuscitating victims
- Administering oxygen
- Determining the extent of the damage
- Determining gas conditions and ventilation flows
- Mapping the teams findings

- Locating and fighting fires
- Building temporary and/or permanent stoppings
- Erecting seals in a fire area
- Clearing debris, pumping water and installing temporary roof supports
- Moving equipment
- Extracting causalities

Careful consideration must be given to:
- The method and extent of work a team is expected to perform
- How the team wearing breathing apparatus can best be utilised
- Weighing the benefits of the operation against the hazards the team will encounter
- The best way to perform the work safely
- What offers the best chance of saving trapped workers

MERV fitted with the EAGLE (Environmental Alternate Gas "Latent heat" Engine) has been designed to give rescue teams and mine management the best possible opportunity to carry out their duties during an actual emergency and to minimise the risks associated with these tasks.

During a mine disaster, time is of the essence.

MERV can be dispatched unmanned and guided by remote control, operated from an above ground location within an operations room.

The information feedback from the vehicle such as video pictures of the affected area, determining the extent of the damage, determining gas conditions and ventilation flows, searching for survivors can be viewed and decisions made for the ongoing rescue.

This data is received and disseminated by management and the rescue co-ordination staff without placing any rescue team member in jeopardy in this information-gathering phase of the rescue operation.

If survivors are encountered they can board the vehicle and utilise the wide range of tools and attachments in the vehicle to rescue other miners.

after carrying out a reconnaissance MERV can be returned to the surface and used to transport a rescue crew to the affected area.

During a mine disaster, time is of the essence. Often a mine rescue team can be better used if it travels to the affected areas by vehicle.

MERV Description

MERV is a purpose built vehicle with the following capabilities:
- Seating capacity for 10 members of a mine rescue team with sufficient space to wear SCBA's
- Sufficient room for five members and two stretchers
- Fire fighting equipment(portable dry chemical – AFFF equipment)
- First aid boxes, splints and resuscitators
- High intensity lighting and thermal imaging equipment, infrared.

- Equipment and materials for erecting stopping's
- Auxiliary breathing equipment
- Hydraulic saw
- Hydraulic drill
- Hydraulic jack
- Hydraulic jack hammer
- Hydraulic winch
- Jaws of life
- Scaling bars, axes, shovels
- Communications equipment
- Gas monitoring equipment
- Long duration respiratory equipment

The advantages of using MERV
- Teams can accomplish more work in less time
- More equipment can be carried
- Less tiring for team members
- Heavier more sophisticated equipment can be carried
- Easier to transport casualties
- More light and efficient heat sensing equipment
- Seating suitable for personnel in apparatus

The use of MERV together with the EAGLE turbine engine allows the vehicle to progress directly to the affected area in atmospheres containing heavy smoke and explosive gases and to provide full support required by a rescue team in searching for and rescuing survivors.

MERV will be fitted with a communications module able to record full video, voice and data collected by the vehicle and fed to the operations room on the surface. This data and information can be continually monitored by rescue co-ordination staff for timely decisions to be made. All information from MERV will be recorded in the operations room to be used at a later time for de-briefing and or a coronal inquest.

MERV Power Plant

Originally the MERV was to be powered by a diesel engine supplied with liquid Oxygen and liquid Nitrogen carried on board the MERV, this was abandoned mainly due to safety concerns. It was then decided to investigate Stirling Engine technology as used by the Swedish Navy to drive their submarines. As the time required for development of the Stirling Engine increased it was decided to renew the search for an new engine or existing engine modified to power the MERV that had similar operating parameters to the Stirling, eg. It could operate in an oxygen free atmosphere.
An existing engine using gas turbine technology was located, which can be modified to operate from a liquid salt latent heat storage cell. The engine is an Allison gas turbine (see fig. 2) used in Jet Ranger helicopters, the output is 236 kW at 6000 RPM. The Allison jet engine will have to be modified to operate in a closed cycle configuration, technically this modification is relatively simple.

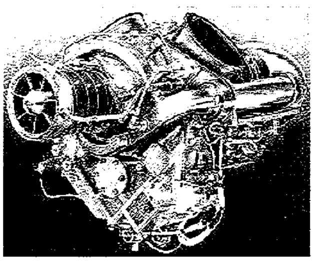

Figure 2 Allison T63-A-700(250-C18) gas turbine

The development of the liquid salt latent heat storage heat cell has continued with the final size and heat storage parameters agreed on. The salt that most closely matches the design requirements of the MERV is Sodium Fluoride, the amount of salt required to store 1000kWh's is 4.58 Tonnes with a volume of 1.81 m^3, which allows operation for a minium of 4 hours.

Organisation:

It is proposed to have Kirktrac Aust. as principal vehicle developer with CSIRO modifying the Allison Gas Turbine for use with the salt energy storage unit. Mr Edgar Edgerton, Kirktrac Aust. will be project Leader for vehicle construction and Mr Patrick Glynn, CSIRO will be project leader for engine and heat cell development. Both New South Wales Mines Rescue (Murray Bird) and Queensland Mines Rescue Service (Malcolm Smith) will be involved in the MERV project.

Objective:

To produce a Mines Rescue Vehicle and general-purpose vehicle, capable of operation in oxygen free

atmospheres and that conform to all mine safety regulations.

Outcomes and Benefits:

- Build a tracked vehicle capable of operating in oxygen free atmosphere
- MERV will conform to all coal mine safety regulations
- MERV will carry up to 10 Mine Rescue Personnel, stretchers and necessary rescue equipment
- MERV will have a minimum operation time of 4 hours underground
- Gas Turbine Engine will be capable of stopping and starting underground

- Technology developed for MERV can be applied to all underground vehicles

In the event of a mine explosion similar to Moura 1994 there is now a possibility at some mines of survivors of the initial explosion making their way to a refuge positioned close to the coal face. The GAG-3 inertisation tool could be used to inertise the mine to minimise the risk of a second explosion that normally occurs due to the release of methane from goafs which have had their seals blown open. Once the situation has stabilised the MERV would be used to retrieve the survivors from the refuge.

Discussion

Utilising the Allison Gas Turbine Engine in a Mines Rescue Vehicle

A gas turbine can be closed cycle and externally fired. This requires a relatively constant heat source with at least 900° C temperature. This can be provided from an electrically heated liquid salt heat cell utilising the latent heat capacity of salt with a storage capacity of at least 1000 kWh's of useable heat (about 4-8 hours duration for the MERV on a fully charged heat cell, approx. equivalent to 100ltrs diesel fuel). The gas turbine will be operated in a closed cycle configuration that is the exhaust gas of the gas turbine is fed into the input (compressor stage) after cooling through a recuperator and a gas to liquid heat exchanger (see Fig. 3). To move the heat from the heat cell to the turbine requires the compressed gas (air) from the compressor stage of the gas turbine to pass through the recuperator where the temperature is raised to 450°C then through the heat exchanger in the liquid salt. This will raise the temperature of the compressed gas to >900 ° C. The gas will expand due to the increase in temperature and in exhausting at constant pressure will spin the turbine stage of the gas turbine. The turbine stage is connected to a gearbox with a step down ratio of approx. 6:1 (35,000 RPM to 6,000RPM. This will drive a wobble plate type hydraulic pump that will drive the MERV through hydraulic motors.

The expected output of the Allison T63-A-700(250-C18) gas turbine is 236 kW at an efficiency approaching 35% which is similar to the efficiency of a diesel engine (see Fig. 3).

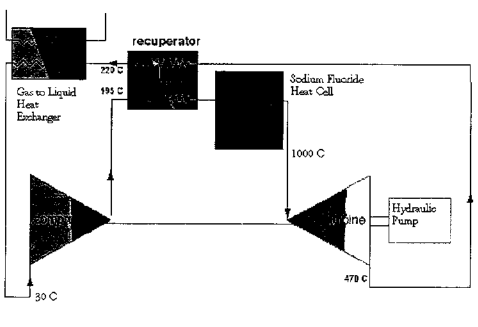

Fig. 3 Operational Diagram for Closed Cycle Gas Turbine

Energy Storage Using the Latent Heat Characteristics of Molten Salt

One of the attractions of using heat engines such as Stirling and Gas Turbines is their ability to accept heat for propulsion from any heat source. To this end if we take a substance (see table. 1) with a high latent heat capacity such as Sodium Fluoride we can store heat at a constant temperature over the major part of its heating and cooling cycle. This gives us a substitute for electrical storage batteries with an energy storage capacity of up to 8 times that of lead acid batteries. The heat cell is heated electrically using 3 x 50kW elements giving a charge time of 7 hours. A table is presented (Table 2) to show the capacities of different storage mediums suitable for powering the MERV.

Table 1: Heat Characteristics of Suitable Salt

Mines Rescue Vehicle Propulsion Using Allison Turbojet.
Heat Storage Capacity 1000 kW @ Salt Melt Temperature
Latent Heat Only

Ref. SI Chemical Data Second Edition

Material	Formula	Melting Point	Latent Heat Joules/ Mole	Mole Grams/ Mole	Weight Tonnes	Size Cu. Metres	Cost
Sodium Chloride	NaCl	801	28000	58.5	7.52	3.48	$2,659
Lithium Fluoride	LiF	870	27000	25.9	3.45	1.3	$110,116
Sodium Fluoride	NaF	992	33000	42	4.58	1.81	$6,412

TABLE 2: Energy Densities of Suitable Storage Mediums

Energy Source	Capacity kWh/kg	Energy Density vs. Lead Acid Battery
Diesel	11.6	309
Lithium Flouride	0.29	8
Sodium Flouride	0.218	6
Sodium Chloride	0.133	4
Lithium Ion Battery	0.126	3
NiMH	0.0608	2
Lead Acid	0.0375	1