Dearman.

A Technical Introduction

Dearman is a global technology company delivering clean ‘cold and power’.

Dearman’s cutting-edge technology uniquely harnesses liquid air to deliver zero-emission power and cooling. It is developing and demonstrating a portfolio of proprietary technologies, products and services, which deliver significant reductions in operating cost, fuel usage and emissions, at low capital cost.

With the global demand for cooling growing rapidly, Dearman is well placed to take advantage of the significant market opportunity it presents. The company is already building an international reputation for innovation, rigor, commercial acumen and engineering excellence, all to fulfil its primary objective – to make the world a cleaner, cooler place.

The Dearman engine

Dearman is developing liquid air technologies in partnership with academics, industry leaders and experts in cryogenics. At the heart of this technology portfolio is the Dearman engine – a novel piston engine driven by the expansion of liquid nitrogen (LiN) or liquid air, to produce clean cold and power.

LiN expands 710 times between liquid and gas phases and this expansion is used to drive the pistons of an engine. Dearman engines operate like high-pressure steam engines, but the low boiling temperature of LiN means that low-grade or ambient heat can be used as a heat source, eliminating the need for a traditional fuel.

Dearman engine
Generation 2 design

A unique feature of Dearman engines is the use of heat exchange fluid, which when mixed with LiN, enables a quasi-isothermal (near constant) expansion and significantly increases the engine’s efficiency.

Crucially, the only emission from a Dearman engine is air or nitrogen, with no emissions of NOx, CO_2 or particulates.

Dearman technology has a number of benefits compared to other low carbon technologies:

- Low capital cost & embedded carbon – Dearman engines are made from conventional materials, using methods known to the engine manufacturing industry.
- Fast refuelling – liquid air can be transferred between vessels at high rates, the industrial gas industry has developed filling systems capable of >100 litre/min transfer rates.
- Significant existing infrastructure – the industrial gas industry is established and global. There is sufficient spare LiN production capacity to supply thousands of Dearman engines.
- Mature fuel manufacturing process – liquefaction of air is a 100-year-old process and the only requirements are air and electricity. Production facilities can be operated flexibly, during off-peak times or used to harness wrong-time renewable energy to minimise costs.

How a Dearman engine works

The Dearman engine builds upon understood and industry tested piston engine technology, but includes proprietary heat exchange techniques, which significantly increase the efficiency, applicability and cost benefits of the engine.

The engine works as follows:

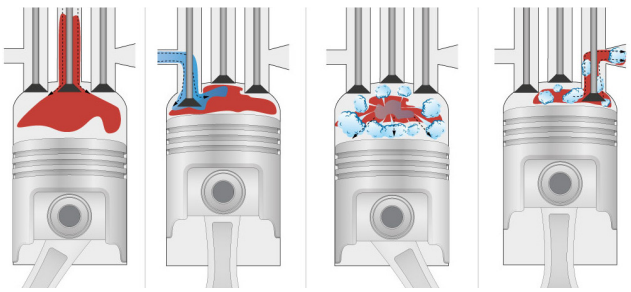
i) heat exchange fluid is pumped into the engine filling nearly all of the cylinder’s volume;

ii) cryogenic nitrogen is then introduced to the cylinder, coming into to contact with the heat exchange fluid where it begins to expand;

iii) heat from the exchange fluid is absorbed by the expanding gas, causing near-isothermal expansion;

iv) the piston is forced down, the exhaust valve opens and a mixture of gas and heat exchange fluid is exhausted from the engine;

v) the heat exchange fluid is reclaimed, reheated and reused, while the nitrogen or air is released back to the atmosphere.



LiN expansion in a Dearman engine

Applications of Dearman technology

The Dearman transport refrigeration system

The first application of Dearman engine technology is to provide high efficiency, zero-emission transport refrigeration units (TRUs). The global market for refrigerated transport is projected to at least double by 2025, with more than 9.6 million vehicles on the road.

There is a major opportunity for Dearman to be an efficient, cost effective and environmentally sustainable improvement to existing TRUs, which are generally inefficient – consuming up to 20% of the vehicle's overall fuel – and polluting as they release disproportionate amounts of NOx and particulates.

Dearman's transport refrigeration system is able to address these issues, using LiN as both a source of zero-emission cooling and power.

How the Dearman transport refrigeration system works:

i) LiN is stored at ~3bar in a cryogenic vessel.

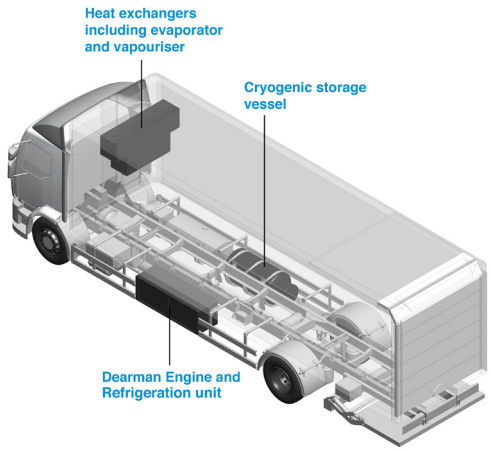
ii) LiN is then pumped to ~40bar and transferred to a vaporising heat exchanger where it provides cooling for the chilled compartment. Approximately two thirds of the total cooling supplied comes from this source.

iii) The LiN is fed to the Dearman Engine, where after being combined with heat exchange fluid it expands, producing shaft power, which is used to:

a. Support ancillary systems such as feed pumps, an alternator and fans for air circulation.
b. Drive the compressor of a vapour compression refrigeration cycle that provides additional cooling, a third of the total cooling supplied comes from this source.

iv) The heat exchange fluid is then reclaimed and used to harvest heat from the condenser of the refrigeration cycle, which has the advantage of approximately doubling its efficiency.

v) The heat exchange fluid is re-used in the engine. The only emission back to the atmosphere is air or nitrogen.



Dearman transport refrigeration unit model

In addition to significant reductions in NOx and particulate emissions, the Dearman transport refrigeration system results in substantial well-to-wheel CO_2 savings. The operating costs are also lower than conventional TRUs with no material increase in capital cost and pay-back is likely to be less than one year.

The Dearman transport refrigeration system is currently in closed-road trials, entering commercial field trials later this year and low volume manufacturing in 2017.

The Dearman auxiliary power system

There is a need for cost-effective technology to improve the efficiency of urban heavy duty vehicles like buses and delivery trucks. Air-conditioning can double the fuel consumption of a bus in the worst conditions, so addressing this secondary use of power can bring significant environmental and cost benefits.

In a future where more urban vehicles adopt electric drive, providing power for cooling and other services can also have a serious impact on the vehicle's range. In hot climates the combination of cooling and battery temperature control can make electrification unfeasible.

Dearman is developing a zero-emission solution, using a Dearman engine in a combined auxiliary power and cooling unit that will offer lower life-cost, reduced fuel usage and reduced emissions, for a minimal increase in capital cost.

Economic modelling indicates that bus operators could achieve a payback on a Dearman system in as low as two years. Operators of refrigerated vehicles could achieve payback within a year.

The Dearman auxiliary power system would be a cost effective enhancement to a vehicle's systems, utilising the unique properties of an engine powered by LiN to provide efficient cooling and also sufficient power for the vehicle's electrified braking / steering assistance, electric doors, lighting etc.

This approach would reduce the requirement for a vehicle to run its engine while stationary, it would reduce fuel usage or increase battery range and it could have a positive impact upon long term vehicle design, by reducing the maximum load on the engine or the battery, enabling both to potentially be downsized and made lighter.

The Dearman built environment system

Electricity grids around the world are being stretched by increasing demand, the retirement of older power stations and the growing use of intermittent renewable generation.

The capacity to meet the very highest demand peaks, has typically been provided by a fleet of distributed diesel generators. These are used to generate backup power in the event of a power cut; reduce consumption of grid electricity when power is most expensive; and earn revenue by providing reserve capacity to network operators. But diesel gensets are highly polluting and now being used increasingly often.

Dearman technology can provide an efficient, zero-emission alternative.

Dearman is developing a genset based on the Dearman engine, which will perform the same functions as a diesel system, including providing emergency backup power, reducing the owner's energy costs and providing reserve services to the grid. What's more, the Dearman genset would provide 'free' cooling, making it particularly advantageous for applications such as supermarkets and data centres, which require extensive cooling.

The Dearman genset is based upon the Dearman engine, utilising the expansion of LiN to provide power, while the gas can be used directly in a heat exchanger to provide cooling to the building or its essential services.

The Dearman heat hybrid

A future application of Dearman technology will deliver waste heat recovery for urban vehicles, such as buses and refuse trucks.

Hybrid systems can increase fuel efficiency in urban areas by up to 20-30%. The most common hybrid systems seek to harness braking energy in kinetic or electrical recovery systems, and then use it when the primary engine would be operating inefficiently. Hybrid systems for large vehicles are expensive, hard to retrofit, and without subsidy the economics are insufficiently attractive for them to be deployed.

However, typically vehicles lose about two thirds of the available energy in their fuel as waste heat. Heat recovery technologies to capture high-grade waste heat have been developed, but in urban settings insufficient heat is generated to make these technologies economically viable.

There is an alternative. A Dearman engine working alongside a diesel engine – a heat hybrid. Dearman technology is capable of offering a unique combination of heat recovery and hybrid power, delivering similar levels of fuel saving to other hybrid systems, but at a much lower cost, resulting in a comparatively rapid payback.

The advantages of a Dearman heat hybrid include:

- Unlike other state-of-the-art technologies, the Dearman heat hybrid can convert low-grade waste heat from a diesel-powered internal combustion engine into shaft power at high efficiencies.
- The Dearman heat hybrid and internal combustion engine can be used individually or together to meet the power requirements of the vehicle.
- A Dearman heat hybrid would allow the internal combustion engine to be downsized and operated more efficiently to achieve a fuel saving of up to 25%.
- Because of the Dearman system's low cost, it would be possible to achieve significant reductions in operating costs while providing payback in less than three years.

The Dearman heat hybrid system is expected to enter on vehicle trials in 2016, with low volume manufacturing and extended field trials to begin subsequently.

The Future

Dearman is investing heavily in the development of future technologies and applications that can deliver both environmental and economic benefits.

In addition to transport refrigeration, heat hybrid systems, auxiliary power for large vehicles, and back up power and cooling systems for buildings, Dearman is researching a system to provide propulsion for zero-emission urban vehicles, in particular last mile delivery vehicles.

As the world faces global challenges of food scarcity, climate change, increasing middle classes and growing energy demand, how we deliver clean and sustainable cold is a major issue. Dearman, with its unique clean cold and power technology, and world class engineering know-how, is well placed to make the world a cleaner and cooler place.