

NATURAL GAS POWER GENERATOR FOR CNG VESSEL

The present invention relates to a natural gas power generator and ships and boats carrying such generators.

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Emissions from boats and ships – from their engines – have long been a target of regulation, yet despite this there are still few regulations in place to control/eliminate those emissions.

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Regulations were proposed back in 2001 and have long been fought by the marine industry. It is nevertheless believed that regulations will come into effect in the near future that will require a significant reduction in hydrocarbon or nitro oxide emissions from ships and vessels, and in particular from stern driven and inboard ships and vessels.

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There will also most likely be a call for a reduction in carbon monoxide emissions.

Reductions of between 50 and 70% are likely to be required.

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Due to the marine industry resisting these changes, at present such regulations are not in place or are not enforced. Nevertheless, it is likely that such regulations will soon be implemented and at present there are no reliable approaches available for achieving these reductions for ships. For this reason there has been a tendency with ships at the dockside to “cold iron” themselves to the dockside – the connecting of the ship to onshore electrical supplies. Such cold ironing, however, is not an ideal solution. It would be desirable, therefore, to provide an alternative means for a ship or boat to meet its electrical demands at the dockside, and possibly also in its approach to the dockside.

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According to the present invention there is provided a ship comprising a plurality of pressure vessels for the transportation and distribution of CNG, the CNG being transported at storage pressures in excess of 200 bar, the ship comprising a CNG powered electrical generator, the generator being connected to extract its fuel requirements from one or more of the plurality of pressure vessels.

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Preferably the CNG used to power the generator is residual CNG, the residual CNG being extracted from a pressure vessel that has had its transportation quantity substantially offloaded therefrom, the residual CNG therefore being the CNG that remains therein after the offload, it being at a pressure below 100 bar.

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Preferably the CNG is extracted via pipework connected to the lower end of the pressure vessel.

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The offload procedure may have been carried out just prior to switching on the generator, i.e. subsequent to the most recent docking procedure. In this arrangement, the generator is then for use only at the dockside, or during the return voyage. Alternatively, the low pressure CNG may have been held in a designated one of the pressure vessels from a previous voyage, whereby that residual CNG supply is designated for the purpose of running the generator during the latest voyage, or during the docking procedure.

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By using CNG as the fuel for the generator, rather than using a conventional power take-off from the primary engines of the ship, or from a conventional diesel generator that runs off the ships fuel supply, a more efficient and clean fuel-burn can be provided – CNG powered generators have less toxic or undesirable emissions than a diesel generator or a diesel engine.

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Due to the residual pressure of the CNG still being significant, no fuel pump is needed to supply the CNG to the generator – it will be self-feeding.

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Since CNG is stored onboard the ship substantially at room temperature, rather than at the cryogenic temperatures required for LNG, no (or only minimal) cooling or heating mechanisms are needed to condition the fuel prior to use within the generator.

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Ambient air may be provided as the oxygen source for the combustion process within the generator. That air may be pressurised upon entry into the generator using a compressor or turbo/supercharger.

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The compressor may additionally have an air-heating mechanism for increasing the temperature of the air prior to its entry into the combustion chamber. This may simply

be the result of the compression by the compressor/turbo/supercharger. Alternatively it may be via a separate heater, for example a heat exchanger.

5 The CNG and compressed air may be fed to a combustion chamber within the generator, with the exhaust of that combustion chamber being driven through a turbine/alternator to provide an output of electricity.

A filter may be provided for filtering the air prior to compression by the compressor/turo/supercharger.

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The pre-heater for the air for heating the air before it enters the combustion chamber may be provided after the compressor.

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The pre-heater may be fed by a heat exchanger that utilises the heat of the gas exiting the turbine – the primary exhaust gas. The secondary exhaust gas – which exits the heat exchanger – will then be exiting the generator at a lower temperature.

By using the generator rather than generating electricity from the engines of the ship, lower emissions are produced by the ship at the dockside.

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Preferably the ship comprises both a conventional diesel powered engine, for driving the propellers, and potentially for providing electical requirements at sea, and then the separate natural gas powered generator for providing electrical requirements at or near the dockside.

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Preferably the ship's pressure vessels are arranged on the ship in arrays.

Preferably the pressure vessels are formed of composite materials, and comprise type 3 or type 4 pressure vessels.

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Preferably CNG is the primary cargo of the ship, with no other cargo having a greater storage volume demand compared to the CNG.

Preferably the pressure vessels are at least 15m long and at least 2m diameter.

The present invention also provides a method of providing electrical power on a ship as defined above, comprising powering the generator of the ship by burning CNG stored on the ship within the combustion chamber of the generator.

- 5 The combusted gas exiting the combustion chamber preferably drives a turbine/alternator for producing an electrical output therefrom.

Preferably the turbine/alternator is connected to a compressor for compressing air as it enters the generator.

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These and other features of the present invention will now be described in further detail with reference to the accompanying drawings, in which:

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Figures 1 and 2 are flow diagrams showing the operation of the present invention in accordance with a first embodiment;

Figures 3 and 4 are flow diagrams of a second embodiment of the present invention; and

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Figures 5 to 7 are schematic drawings of an arrangement of pressure vessels on board a ship that has the present invention arranged thereon, e.g. in the pump room or in the electrical deck.

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Referring first of all to Figure 1, there is shown an arrangement for the operation of the CNG generator of the present invention. There is an air inlet 1 which feeds air towards a combustion chamber 3. Further, a containment system 5 for containing CNG is also shown to be feeding CNG – typically residual gas therefrom at a lower pressure than standard transportation pressures, i.e. sub 100 bar pressures rather than over 200 bar pressures – to the combustion chamber 3.

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The burned gases – combusted gas 7 – then exits the combustion chamber to drive a gas turbine 9. The expanded gas then exits the system at the exhaust 11.

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Referring next to Figure 2, the air inlet comprises an air filter 13 which brings clean air to a compressor 15. The ambient air entering the air inlet will typically be at

atmospheric temperature and pressure, such as 15°C and 1 bar. That ambient air enters into the compressor which compresses the gas and heats it to a higher temperature. That air then passes to a combustion chamber 3. Meanwhile, CNG from the containment system is fed from the bottom of pressure vessels 17 through a valve arrangement and also into the combustion chamber 3. The air and CNG are then combusted which then allows the combustion chamber to exhaust output gas at a high temperature and pressure, which gas expands into a turbine, produces work and drives the compressor 15 and an alternator 19 for producing electrical outputs. The exhaust 11 from the turbine is then the output from the ship and since the fuel was CNG, that output will be relatively clean – certainly it would have fewer undesirable emission gases than the equivalent exhaust from a diesel engine/diesel generator.

Referring next to Figures 3 and 4, a similar arrangement is provided with an air inlet 1, a combustion chamber 3, an air filter 13, a compressor 15, a turbine 9, an alternator 19 and a containment system 5 having a plurality of pressure vessels 17. However, instead of the exhaust 11 exiting directly into the atmosphere from the turbine, that exhaust is used by feeding it into a heat exchanger 21 for heating the compressed air exiting the compressor 15. Therefore, the air mixing with the CNG is at a higher temperature than that of the first embodiment, whereby a cleaner (less carbon monoxide) and more efficient combustion can occur in the combustion chamber 3.

Although the above described arrangements for the generators are generally fairly simple in nature, it is the provision of that generator onboard the ship – a CNG transport ship – for providing the electrical needs of the ship at the dockside that provides the present invention with both novelty and an inventive step. Since ships already have electricity producing capabilities from their engines, and since cold ironing can provide the electricity where needed more cleanly, the idea to use the cargo, or even the residual cargo after the off-load, is not an obvious solution for meeting the requirements of emission regulatory controls.

This is further exemplified by the fact that it is counter-intuitive to use the goods to be transported by the ship as the fuel source for such power generation. That is because the CNG is stored at a pressure that is higher than that which would conventionally be manageable by the generator, whereby the use of residual CNG – at the lower pressure – offers a novel and inventive solution.

Bear in mind too that the ship may comprise a plurality of CNG pressure vessels for transporting CNG from its source to its distribution or processing centre, i.e. certainly in excess of three such vessels, and as shown in Figures 5 to 7, potentially many more than that (here shown 258 of them), all of which vessels are of a significant volume – for example the pressure vessels will typically be at least 15m long and have a diameter of at least 2m, and potentially they could be up to 30m or even up to 60m long (e.g. arranged horizontally, rather than vertically as shown), and potentially of 6m or more in diameter. Therefore, it would not be obvious to consider these pressure vessels as being a suitable fuel tank for a generator.

The ship shown has a CNG containment volume in excess of 150,000 square meters, thereby being able to contain in excess of 150,000 square meters of CNG at a pressure in excess of 200 bar.

Since the generator will preferably be powered by CNG extracted from an “emptied” pressure vessel, i.e. one where the majority of the rapidly extractable CNG has been removed, thus leaving just residual CNG, e.g. at a pressure of 20 bar, and since there are so many of the pressure vessels, it is an option to allocate one or more of the pressure vessels after a voyage (and off-load) as being the ongoing fuel tank for the generator. As such one of the illustrated 256 pressure vessels, in this example, may be set aside or used just for the purpose of supplying the CNG – the residual gas following an offload of the CNG previously stored therein.

There remains the residual CNG in a pressure vessel after an offload due to the economics of off-load timings and off-loading effort. CNG transported onboard pressure vessels, e.g. on ships or trains or lorries, will not necessarily be offloaded completely, i.e. down to ambient pressures. That is because the time required to do that, or the cost of running the pumps to do that (and thereafter recompress the CNG to network distribution pressures), render the approach non commercial, be that in time or financial cost. As such, after an offload, CNG may still remain in the pressure vessels in significant useable volumes, and at pressures in excess of the ambient pressure whereby it can be self propelling towards a combustion chamber. The pressure will be well below 100 bar, such as at a pressure of between 10 and 30 bar. That pressure

will still be adequate, however, to supply the CNG as a fuel to the combustion chamber.

5 Pressure vessels for the transport of compressed fluids presently constitute four regulatory agency approved classes or types, all of which are cylindrical with one or two domed ends:

10 Type I. Consists of an all metal, usually aluminum or steel, construct. This type of vessel is inexpensive but is very heavy in relation to the other classes of vessels. The entire vessel is of sufficient strength to withstand the intended pressure exerted on the vessel by a contained compressed fluid and therefore does not require any manner of strength-enhancing over-wrap, including the dry filamentous over-wrap of this invention. Type I pressure vessels currently comprise a large portion of the containers used to ship compressed fluids by sea, their use in marine transport incurs very tight economic constraints.

20 Type II. Consists of a thinner metal cylindrical center section with standard thickness metal end domes such that only the cylindrical portion need be reinforced, currently with a composite over-wrap. The composite wrap generally constitutes glass or carbon filament impregnated with a polymer matrix. The composite is usually "hoop wrapped" around the middle of the vessel. The domes at one or both ends of the vessel are of sufficient strength to withstand the pressures developed in the vessel under normal use and are not composite wrapped. In type II pressure vessels, the metal liner carries about 50% of the stress and the composite carries about 50% of the stress resulting from the internal pressure of the contained compressed fluid. Type II vessels are lighter than type I vessels but are more expensive.

30 Type III. Consists of a thin metal liner that comprises the entire structure, that is, the cylindrical center section and the end dome(s). Thus, the liner is currently reinforced with a filamentous composite wrap around entire vessel. The stress in Type III vessels is shifted virtually entirely to the filamentous material of the composite wrap; the liner need only withstand a small portion of the stress. Type III vessels are much lighter than type I or II vessels but are substantially more expensive.

Type IV. Consists of a polymeric, essentially gas-tight liner that comprises both the cylindrical center section and the dome(s), all of which is currently fully wrapped with a filamentous composite. The composite wrap provides the entire strength of the vessel. Type IV vessels are by far the lightest of the four approved classes of pressure vessels but are also the most expensive.

As noted above, Type II, III and IV pressure vessel currently require a composite overwrap over a vessel liner to give them the necessary strength to withstand the intended pressure exerted by a compressed fluid contained in the vessel. It is known, however, that the polymeric matrix of the composite wrap adds little or no strength to the overwrap. Thus, this invention also can be used with novel winding arrangements using a dry filamentous material that is disposed over a pressure vessel liner in a dry state and that remains in essentially a dry state (i.e. not bonded throughout with an impregnation of resin) for the life-time of the pressure vessel.

“Essentially” in a dry state takes into consideration that, in use, particularly for marine transport of compressed fluids, the filamentous material may inadvertently become dampened by environmental moisture and the like. That is, the dry filamentous material is intended to be disposed over the vessel dry and to be dry when the vessel is put in use. Essentially dry in this context therefore does not exclude situations where the filaments/fibres are wetted by water.

The pressure vessels used for the present invention will typically be type 3 or type 4, or another form of pressure vessel utilising a full composite overwrap and either a non structural metal liner or a non metal liner or a liner used purely for the process of manufacture, i.e. a removable liner.

The present invention has been described above purely by way of example. Modifications in detail may be made to the invention within the scope of the claims appended hereto.

CLAIMS:

1. A ship comprising a plurality of pressure vessels for the transportation and distribution of CNG, the CNG being transported at storage pressures in excess of 200 bar, the ship comprising a CNG powered electrical generator, the generator being connected to extract its fuel requirements from one or more of the plurality of pressure vessels.
2. The ship of claim 1, wherein the CNG used to power the generator is residual CNG, the residual CNG being extracted from a pressure vessel that has had its transportation quantity substantially offloaded therefrom, the residual CNG therefore being the CNG that remains therein after the offload, it being at a pressure below 100 bar.
3. The ship of claim 2, the CNG being extracted via pipework connected to the lower end of the pressure vessel.
4. The ship of any one of the preceding claims, wherein no fuel pump is provided between the pressure vessel and the generator.
5. The ship of any one of the preceding claims, wherein the pressure vessel is at a temperature of between -20° and +45°.
6. The ship of any one of the preceding claims, wherein ambient air is provided as the oxygen source for the combustion process within the generator, that air being pressurised upon entry into the generator using a compressor or turbo/supercharger.
7. The ship of any one of the preceding claims, wherein ambient air is provided as the oxygen source for the combustion process within the generator, the generator further having an air-heating mechanism for increasing the temperature of the air prior to its entry into a combustion chamber of the generator.
8. The ship of claim 7, wherein the air-heating mechanism is a heat exchanger.

9. The ship of claim 8, wherein the heat exchanges operates off the heat from exhaust gases of the generator.

5 10. The ship of any one of the preceding claims, further comprising a separate diesel powered engine for driving the propellers and for providing electrical requirements at sea.

10 11. The ship of any one of the preceding claims, wherein the pressure vessels are arranged on the ship in arrays.

12. The ship of any one of the preceding claims, wherein the pressure vessels are type 3 or type 4 pressure vessels.

15 13. The ship of any one of the preceding claims, wherein CNG is the primary cargo of the ship, with no other cargo having a greater storage volume demand compared to the CNG thereon.

14. The ship of any one of the preceding claims, wherein the pressure vessels are at least 15m long and at least 2m diameter.

20 15. A method of providing electrical power on a ship according to any one of the preceding claims, comprising powering the generator of the ship by burning CNG stored on the ship within the combustion chamber of the generator.

25 16. The method of claim 15, wherein the combusted gas exiting the combustion chamber drives a turbine/alternator for producing an electrical output.

30 17. The method of claim 15 or claim 16, wherein the turbine/alternator is connected to a compressor for compressing air as it enters the generator.