THE USE OF LIQUID NATURAL GAS AS HEAT SINK FOR POWER CYCLES

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Introduction

Gas pipelines represent the best answer to the conveyance of large quantities of natural gas provided they are technically feasible and economically justified. When producing sites are separated from the potential consuming areas by an excessive distance or by insurmountable geographical obstacles liquefaction and shipment by specialized carriers, at the present time, is the only alternative to the use of gas pipelines. The high cost of liquefaction, suggests that the best use is made, at the receiving terminal, of the peculiar thermal characteristics of liquid natural gas (LNG). Many technical processes, taking place totally or partially at cryogenic temperatures could benefit by the refrigerating capability of LNG. An alternate use of the LNG cold, or of the fraction of it that cannot be profitably employed in cryogenic processes, is as heat sink for power cycles.

LNG is stored at atmospheric pressure at a temperature of about -160°C. Its refrigerating capacity as a function of temperature depends basically on the pressure at which it is revaporized. Considering a reference upper temperature of 0°C, at atmospheric pressure 60% of the cold is available, though vaporization of the liquid, at about -160°C; the remaining 40% representing the heat required to super-heat the vapour to 0°C. At supercritical pressures the LNG refrigerating capacity is distributed continuously over the whole temperature range of heating. At 70 bar (1015 psia), for example, about 30% of the cold is available between -160 and -100° and 70% between -160 and -60°C.

The thermal characteristics of LNG employed as heat sink for power cycles can undergo wide variations owing:

a) to the pressure at which LNG is vaporized; b) to the fraction of the cold that is actually available for power generating purposes. A similarly wide variation in the thermal characteristics of the waste heat rejection process from different types of power cycles is therefore of interest.

Basic Cycles and Fluids

A limited amount of work can be generated by relying on the heat sink capability of LNG and using the ambient as hot source.

A considerably larger amount of work is obtainable at a much higher efficiency at cycle top temperatures similar to those employed in conventional power plants. The very low minimum cycle temperature (down to -130 to -140^{o}C) and the correspondingly high maximum to minimum temperature ratio τ (up to 6 to 7) are responsible for the peculiar character of these cycles. Ordinary Rankine cycles which are basically enclosed within the saturation curve are unsuited for similar operating conditions. The exponential dependence of saturation pressure on temperature entails a rapidly increasing pressure ratio as τ increases. Only cycles extended mainly in the gas-phase region can master the extreme values of τ at an acceptable level of pressure ratios.

Two main classes of cycles meet the general requirements for the proposed application: simple phase closed gas cycles and condensation cycles.

Gas cycles (Fig. 1a) are attractive for the following thermodynamic reasons: a) At the unusually high temperature ratios which