

# AN INNOVATIVE WAY OF REDUCING BOG ON EXISTING OR NEWBUILT LNG STORAGE TANKS

Damien Féger  
Vice President, LNG & Shipping  
New Generation, Natural Gas,  
Paris France  
[damien@ng-two.com](mailto:damien@ng-two.com)

## ABSTRACT

Present, state of the art, LNG storage tank use expanded silica and glass wool as insulation materials on, respectively, the tank side and ceiling. When the tank is in operation, these insulation volumes are filled with the natural gas vapors coming from the LNG, at the same pressure as the LNG.

This paper presents an innovative solution to improve the thermal performance of this insulation by filling these insulation volumes with argon gas, which has a much lower (40 %) thermal conductivity, with minimal changes in the tank design, as argon, much heavier than natural gas vapors, is simply trapped in these volumes by gravity. The required design changes are respectively negligible (to inject argon in the side insulation spaces using the existing dry nitrogen injection piping) to minute (modification of the suspended ceiling to trap argon gas), making this innovation possible as a retrofit action.

Beyond the immediate operational gains linked to the reduction of BOG rate, this innovation can generate significant capital expense savings by reducing the requirements on the BOG recompression systems.

It describes how this change can be implemented on existing and on new built tanks with:

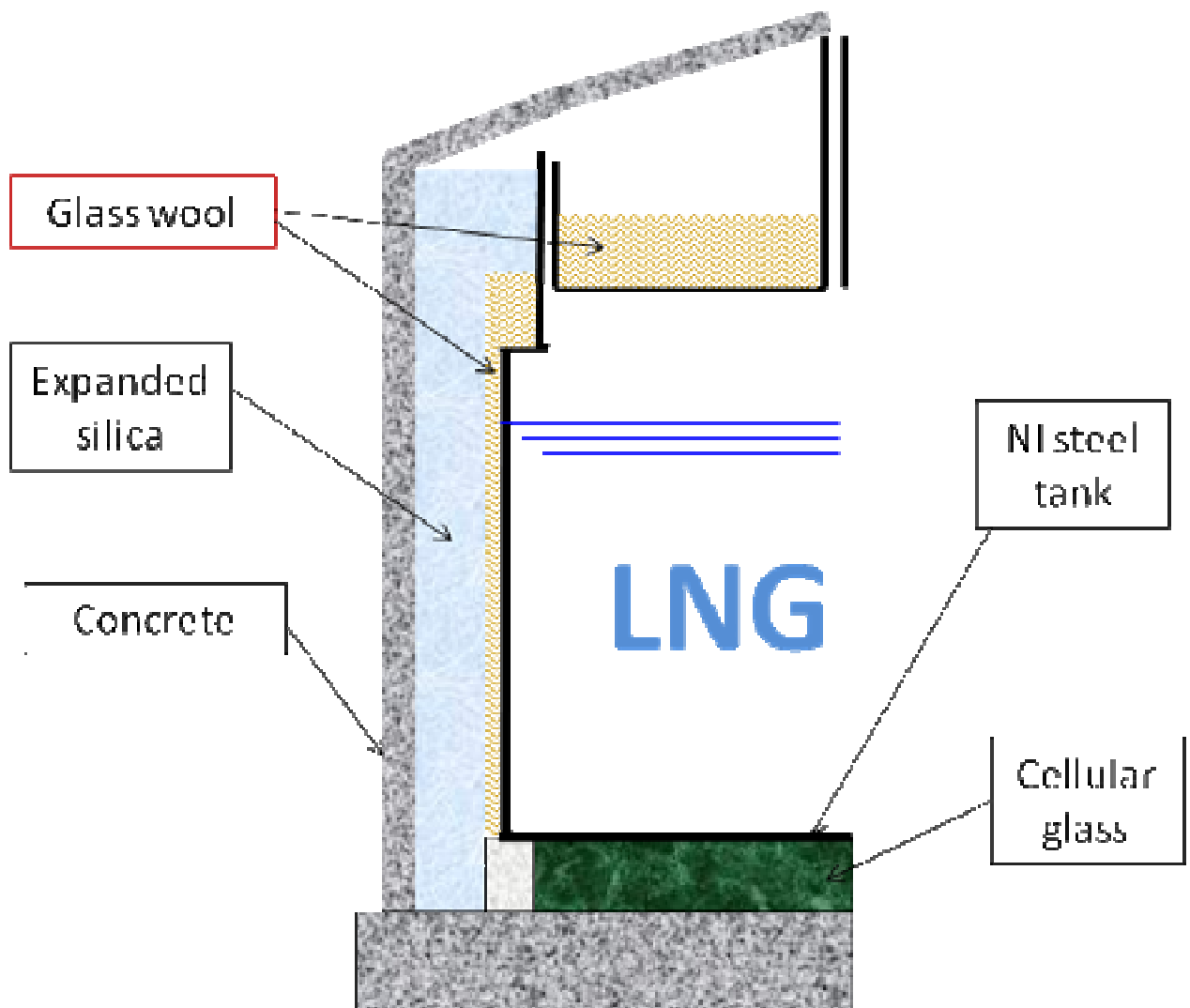
- a review of the technical requirements and operational constraints;
- a description of the argon supply system;
- an assessment of the corresponding economical and environmental benefits both for a liquefaction plant and a regas terminal;
- an analysis of the corresponding impacts and benefits on safety and on terminal operations;
- a detailed case study on a new built and an existing tank.

## ○ INTRODUCTION

### State of the art

The typical configuration of LNG land based storage tanks is given in Figure 1. The LNG is contained in an open cryogenic grade nickel steel alloy circular tank.

- The bottom of the tank is supported by a layer of pressure resistant insulation made of cellular glass blocks;
- The Side of the tank is surrounded by a layer of glass wool and a volume filled with expanded glass foam (expanded silica);
- The top of the tank is covered with a suspended roof which is insulated by a layer of glass wool;
- The whole system is surrounded with a gas tight reinforced concrete envelope.



**Figure 1: Typical LNG storage tank configuration**

When the tank is in operation, the side and upper insulation volumes are filled up with the natural gas vapors and the corresponding heat transfer can be considered to be limited to the

thermal conductivity of methane gas, convective and radiant thermal exchange being blocked by the glass wool and the expanded silica. Based on this design approach, the typical heat entries into the cargo are typically split in three equal parts:

- 1/3 through the roof insulation;
- 1/3 through the side wall insulation;
- 1/3 through the tank bottom insulation.

Depending on tank size, contract requirements and detailed design strategy, the typical boil-off rate is 0.05% per day. Although this has been considered as acceptable by the industry so far, there are, nevertheless, significant environmental and economical benefits to reduce it further and the purpose of this paper is to present an innovative solution to achieve it, by filling the side and top insulation volumes of the tank with argon instead of natural gas vapors.

## ○ PROPOSED INNOVATION

### What is argon?

Argon is the most common “rare” gas and constitutes 0.94% of ambient air composition. As such, it is a widely available industrial commodity, produced as a by-product of air separation plants, which are usually mostly aimed at nitrogen or oxygen production. It can be delivered in compressed or liquefied, bulk, form.

It is mainly used in numerous industries on a routine basis for its inert and thermal properties, such as the filling of the insulation spaces in double glazed windows.

Figure 2 illustrates the main reason of interest of argon in the present case, showing the difference of thermal conductivity of argon compared to methane and nitrogen gas.

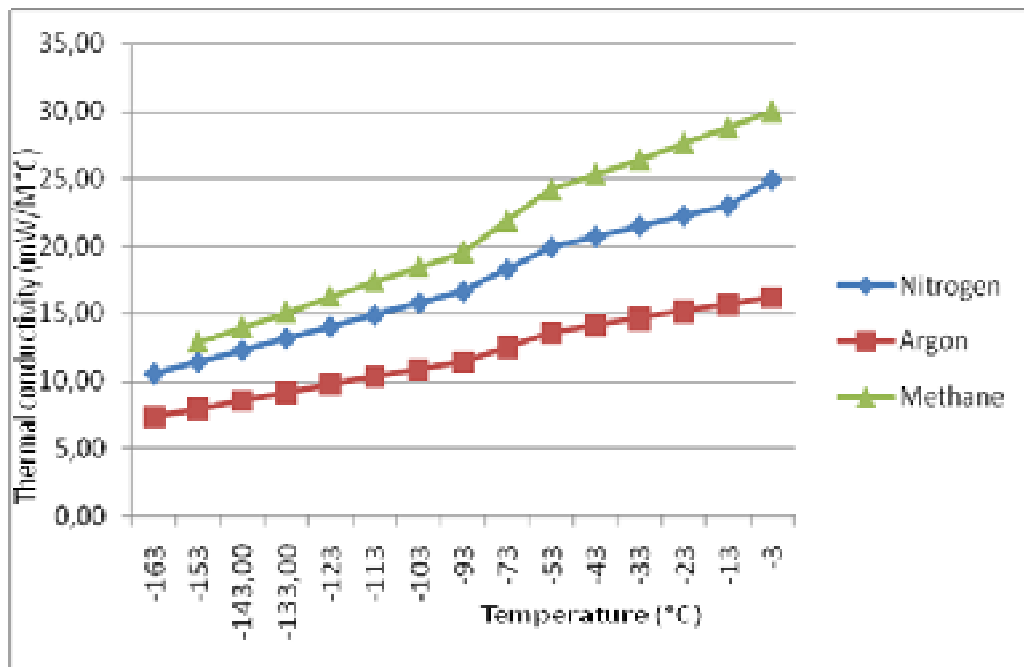


Figure 2 : Nitrogen, Methane and nitrogen thermal conductivity

Other argon properties of interest for this application are:

- like nitrogen, it is an inert gas;
- its liquefaction point ( $-185^{\circ}\text{C}$ ) is well below LNG temperature ( $-160^{\circ}\text{C}$ );
- its molecular weight (39.95 g/mole) is much heavier than the one of methane (16.04 g/mole) of nitrogen (28.01 g/mole)

Therefore, replacing natural gas vapors by argon in the side and top tank insulation volumes is possible and shall reduce their thermal conductivity by around 40%.

#### Implementation

Figure 3 shows a typical way of filling an LNG storage tank top and side insulation spaces with argon, taking benefits that argon is much heavier than natural gas vapors to trap it in these volumes by gravity effect, while, at the same time, providing an open communication between all these volumes and the tank dome, so that pressure differences remain minimal during tank operations.

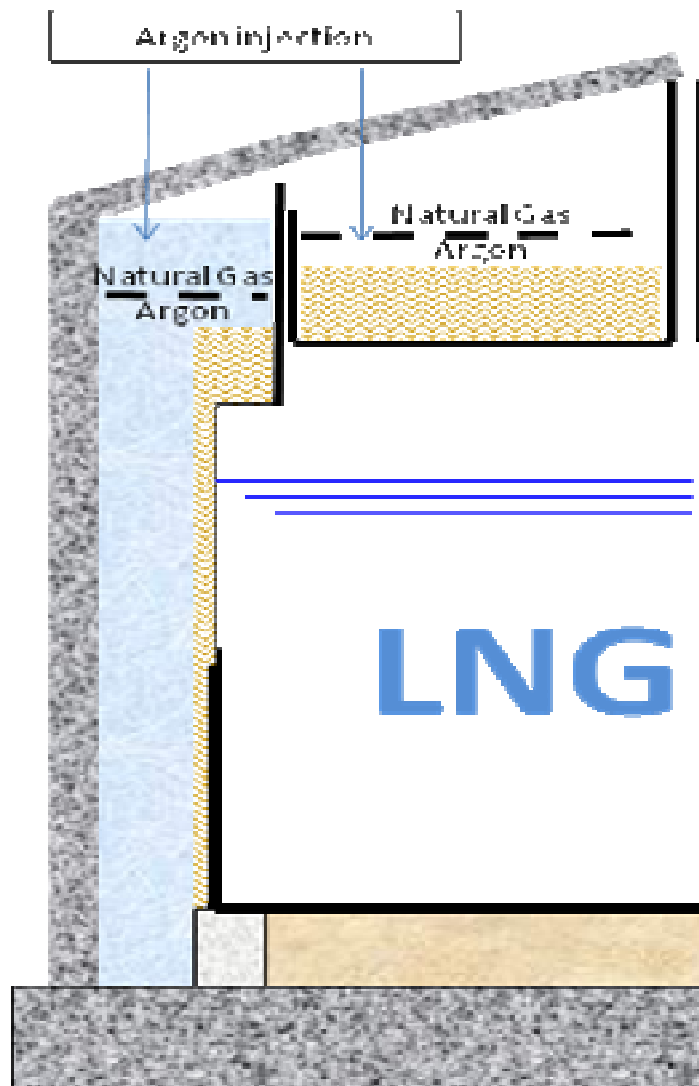


Figure 3: Typical LNG storage tank argon insulation implementation

One will note that the required tank design changes are minimal, if any:

- without any design changes side wall volume will trap argon by gravity, and existing pipes, such as the one used to flush expanded silica with dry nitrogen, prior first tank filling with LNG, could be used to inject argon in these volumes. By gravity effect, the much heavier argon will displace the natural gas vapors out of the expanded silica and glass wool volumes and remain trapped between the side concrete and the NI steel tank side walls. One will note that as no operation is needed inside the tank, this argon replacement can be performed as a retrofit action, without even interfering with tank routine operations.
- for the suspended deck insulation volume, the only design changes will be to make the suspended deck gas tight so that, here again, the argon gas will remain trapped by gravity effect inside the glass wool volume. Such modifications are expected to be straightforward for a new built case. Any existing pipe through the roof can be used to inject argon gas above the suspended deck.

During tank operations, the pressure in the gas dome and the temperature in the insulation spaces are expected to fluctuate, so the argon trapped in the insulations volumes will either contract or expand accordingly. The frontier between the volumes filled with argon and the natural gas vapor dome will therefore move up and down (or “breathe”), the upper part of the insulation volumes acting as buffer volumes.

One will note that if too much argon is injected, the excess argon, once the side and top insulation volume have been filled up, will just overflow into the gas dome and will be either vented with the BOG flow or will fall and get dissolved into the LNG contained in the open top NI steel tank, without any significant consequences as these quantities will remain negligible compared to the LNG tonnage.

### **Assessment of economical and environmental gains**

If natural gas vapors are replaced by argon in the top and side insulation volumes of a given storage tank, the resulting reduced heat entries can be estimated the following way compared to the initial conditions:

- 33% → 20% through the roof insulation;
- 33% → 20% through the side wall insulation;
- 33% → unchanged through the tank bottom insulation.

The resulting BOG rate can therefore be estimated to be reduced to around 75% of the initial one (one will note that, in the case of a retrofit case, were only the side wall insulation spaces are filled with argon, the BOG expected reduction would be down to 85%, which is already quite significant).

In the case of a liquefaction plant, storage tank BOG is a direct loss in the overall efficiency of the plant, as this BOG will be usually recycled as fuel gas rather than being delivered as export cargo to the LNG carriers.

As illustrated in figure 4, this 25% new built storage tank BOG reduction opportunity can be used in, at least, two different ways, considering an initial 0.4 % storage tank BOG:



## **Impact on safety and operations**

From safety point of view, main risk brought by argon is the risk of anoxia, but as argon presence is only expected either in open space or inside the tank itself, this risk is expected to be very remote.

Argon filling, monitoring and top up operations are very similar to the one required, for example, for inerting operations using nitrogen, so the application of the corresponding safety procedures to argon operations, should lead to a very low level of risk.

On the other side, filling the side wall insulation volume of LNG storage tank with argon inert gas brings a safety benefit to the installation with regard to the risk of creation of explosive atmosphere in case of leakage through the outer wall side concrete envelope.

In the same way, the reduce heat entries will reduce the risk of turnover, which may cause dame, among others, to the suspended deck.

Typically the initial argon charge can be delivered by one or two truck of liquefied argon in bulk. Filling operations would take, typically a week, depending, among other things, on the diameter and distribution of the pipes available for injection and the time required to displace the natural gas vapors out of the expanded silica and glass wool volumes.

During tank nominal operations, argon losses may occur, for example due to leaks through the outer concrete wall, the suspended roof or by entrainment with the NG BOG. To compensate this, argon refilling may be necessary either by a site small liquefied argon storage tank or by a set of high pressure cylinders...

Monitoring of the argon level in the insulation volumes can be done by sampling tubes which combined with a gas analyzer can be used by the terminal operator to assess on, typically, a monthly basis, the extra "top up" argon quantities required.

Due to the order of magnitude of the total argon and LNG quantities (typically around 40 tons of argon for a 70 000 tons storage tank!) entrainment of argon into the storage BOG flow or dissolution with the LNG, if it occurs, will not significantly affect the cargo composition.

## **Case study and conclusion**

Table 1 gives a summary of the estimated environmental and economical gain to be expected in the case of a liquefaction plant 175,000 m<sup>3</sup> new built LNG storage tank, assuming typical Capital and Operational expenses (including royalties to have access to this innovation) as well as, among other things, LNG and feed gas values.

It shows that return on investment can be extremely fast, typically less than a year, even without considering potential added value provided by CO2 emissions permits.

In this case, an extra capacity of 3,610 tons of LNG production per year would be generated for a capital expense of USD 330,000.

This brings the TPA/CapEx ratio to USD 91 per ton per annum, while typical values for present liquefaction project are as high as 600 USD per ton per annum...making the proposed solution an attractive, safe, and profitable solution with a very short return on investment.

Table 2 gives similar estimate for the retrofit case, were only the side wall insulation is filled with argon. Although the TPA/CapEx ratio is slightly higher, up to USD 120 per ton per annum, it is still very competitive... as illustrated by a return on investment of just above one year...

In both cases, the proposed innovation can therefore be considered as attractive both for new built and retrofit cases, from environmental and economical point of view. Not a big surprise when one consider that argon filled insulation is used on a routine and profitable basis for double glazed windows where the difference of inside and outside temperature is up to 10 times lower than in LNG storage tanks!

To meet the general requirement of reducing by 40 % CO<sub>2</sub> emissions in the coming decades, the LNG industry, like all mature industry will have to implement numerous emissions abatement solutions such as:

- increased energy efficiency;
- alternate power sources;
- CO<sub>2</sub> sequestration;
- Buying emissions permits...

No doubt that, in this context, such BOG reduction opportunity, which is both environmental friendly and cost effective, should be considered as one of the lowest hanging fruit to grab!

**Table 1. Case study for a new built 175,000 m<sup>3</sup>  
liquefaction plant storage tank**

<b>Hypothesis</b>				
LNG Storage tank		capacity	175 840	m <sup>3</sup>
		density	450	kg/m <sup>3</sup>
Insulation volume :				
	Side wall			
		Height	35	m
		Inner Diameter	80	m
		Outer diameter	82	m
		Volume	8 792	m <sup>3</sup>
	Roof			
		Surface	5 024	m <sup>2</sup>
		Thickness	0	m
		Volume	2 010	m <sup>3</sup>
total insulation volume			10 802	m <sup>3</sup>
Average side insulation temperature			200	K
Average roof insulation temperature			200	K
Average Argon vapor density			3,50	kg/m <sup>3</sup>
Average Methane vapor density			0,33	kg/m <sup>3</sup>
Quantity of required argon			37 806	kg
Quantity of displaced methane			3 601	kg
Argon cost :			800	USD/ton
Methane value :			200	USD/ton
<b>CAPEX</b>				
Argon unit CapEX			\$100 000	
Argon instrumentation			\$100 000	
Engineering			\$50 000	
Royalties			\$50 000	
Argoncost			\$30 244	
CH <sub>4</sub> Saving			-\$720	
		<b>TOTAL CAPEX</b>	<b>\$329 524</b>	
<b>OPEX</b>				
Maintenance (5% of CapEX)			\$16 476	
Royalties			\$50 000	
		<b>TOTAL OPEX</b>	<b>\$66 476</b>	
<b>Gains</b>				
Initial BOG			0,050%	/day
BOG reduction			25%	
New BOG			0,038%	/day
Reduced BOG per Year			3 610	tons/year
Feed Gas value			50	USD/ton
LNG Value			200	USD/ton
Extra Value of Exported LNG			\$541 532	/year
Net Value			\$475 056	/year
		<b>ROI</b>	<b>8,3</b>	<b>months</b>

**Table 2. Case study for a retrofit 175,000 m<sup>3</sup> liquefaction plant storage tank**

<b>Hypothesis</b>				
LNG Storage tank		capacity	175 840	m <sup>3</sup>
		density	450	kg/m <sup>3</sup>
Insulation volume :				
	Side wall			
		Height	35	m
		Inner Diameter	80	m
		Outer diameter	82	m
		Volume	8 792	m <sup>3</sup>
	Roof			
		Surface	0	m <sup>2</sup>
		Thickness	0	m
		Volume	0	m <sup>3</sup>
total insulation volume			8 792	m <sup>3</sup>
Average side insulation temperature			200	K
Average roof insulation temperature			200	K
Average Argon vapor density			3,50	kg/m <sup>3</sup>
Average Methane vapor density			0,33	kg/m <sup>3</sup>
Quantity of required argon			30 772	kg
Quantity of displaced methane			2 931	kg
Argon cost :			800	USD/ton
Methane value :			200	USD/ton
<b>CAPEX</b>				
Argon unit CapEX			\$80 000	
Argon instrumentation			\$80 000	
Engineering			\$30 000	
Royalties			\$50 000	
Argon cost			\$24 618	
CH <sub>4</sub> Saving			-\$586	
		<b>TOTAL CAPEX</b>	<b>\$264 031</b>	
<b>OPEX</b>				
Maintenance (5% of CapEX)			\$13 202	
Royalties			\$50 000	
		<b>TOTAL OPEX</b>	<b>\$63 202</b>	
<b>Gains</b>				
Initial BOG			0,050%	/day
BOG reduction			15%	
New BOG			0,043%	/day
Reduce d BOG per Year			2 166	tons/year
Feed Gas value			50	USD/ton
LNG Value			200	USD/ton
Extra Value of Exported LNG			\$324 919	/year
Net Value			\$261 718	/year
		<b>ROI</b>	<b>12,1</b>	<b>months</b>