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An Empirical Study for the Safe and Effective Operations in Membrane LNG Ships focused on the Tank Cool Down

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ABSTRACT

The most crucial factor in membrane LNG ships to ensure safe operations, is how to effectively control tank pressure at the time of excessive generation of boil off gas (BOG). When the ships carry out tank cool down with her retaining heel prior to arrival at loading port, the vessel encounters the critical situation of excessive BOG and high tank pressure that can lead to high degree of risk. This is to provide one of the best ways to secure safe and effective LNG ship operations focusing on the detailed methods of tank cool down to achieve ATR (Arrival Temperature requirement) without building up high tank pressure and excessive BOG and calculating the appropriate heel quantity to be unutilized for tank cool down and fuel during ballast voyage.

1. Introduction

The international LNG transport industry has achieved a remarkable safety record without a significant accident over four decades of operations. This record is the result of paying close attention to the quality of vessel crews as well as operation of ship and terminal facilities, which is however, now becoming more difficult to assure as the LNG sector is facing a rapid expansion, technological change, increased market competition, and potential qualified labor supply constraints.

In view of this situation of rapid expansion of LNG fleet and a short of qualified ship's staff, Every sectors in LNG circles need best practices through standardization or unification of operation procedures, we therefore sorted out "Tank Cool down", one of the most critical operation in Mem brane LNG ships that impacted on the safety of the vessel and carried out empirical tests of Tank Cool down for 3 years in order to seek safe and effective method.

We finally reached a conclusion that Tank cool down by Spray pump small nozzle was the best solution. This method presents us safe and effective operation by allowing easiness of tank pressure control, reduction in BOG generation and more room for speed adjustment.

We suppose that this method could be a standard operation procedure for Tank Cool Down

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2. Tank Cool Down

2.1 Tank Cool Down method in accordance with heel distribution

2.1.1 Distribution Method

Distributing Heel for tank cool down into all

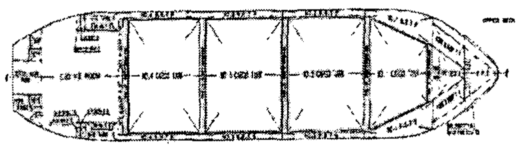

Figure 1. Heel distribution into all cargo tanks

2.1.2 Concentration Method

Gathering and retaining Heel for tank cool down into one specific cargo tank

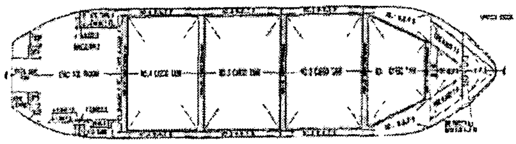

Figure 2. Heel gathering into one cargo tank

2.2. Tank Cool Down methods in accordance with technical aspects

2.2.1 Manual Cool down by Spray Pump Big Nozzle

Spray LNG on the space of No. 1, 2 & 3 tanks simultaneously by using big nozzle of Spray Pump in No.4 Tank

2.2.2 Auto Sequence Cool Down (IAS)

Carry out Cool Down with provided function of automatic sequence in IAS by using big & small nozzle of Spray Pump.

2.2.3 Manual Cool down by Spray Pump Small Nozzle

Spray LNG on the space of No. 1, 2 & 3 tanks simultaneously by using small nozzle of Spray Pump in No. 4 Tank

3. Advantage and disadvantage among methods of Tank Cool Down

3.1 Manual Cool down by Spray Pump Small Nozzle

The following disadvantages were recognized when we utilized this method.

Excessive BOG generated and Forced to increase RPM to consume BOG generated (6,700~6,800kg/h) in the Boiler.

[DSHS Dumping + BOG release into Atmosphere]

Restriction on the speed adjustment

Heavy work burden for Gas Officer

(24 hours for Tank Cool down + 1 day for loading work)

3.2 Auto Sequence Cool Down (IAS)

3.2.1 There were following advantages when we used this method.

There were reduction of generation of BOG (6,300 ~ 6,400 kg/h) [DSHS Dumping]

Free from restriction on speed adjustment

We could alleviate work burden for Gas Officer.

3.2.2 The following disadvantages were recognized

There were Ampere hunting at the time of opening/closing of spray pump big & small nozzle to keep spray header pressure set by sequence program

Dry running in heavy weather

Ill effect on tube of internal DSHS in Boiler and dumping system (DSHS Dumping)

3.3 Manual Cool down by Spray Pump Small Nozzle

We finally reached this method and there were following advantages

It was more easier for tank pressure control and ship's speed adjustment than Auto Sequence Cool Down (BOG : 5,200 kg/h)

There were neither DSHS Dumping nor possibility of releasing BOG into Atmosphere. There was no work burden imposed on the Gas Officer.

Table 1. Spray Quantity Unit : cbm/h

Pressure (Bar)	Nozzle Type	Water Flow	LNG Flow	No.1 Tank	No.2 Tank	No.3 Tank	No.4 Tank	Total Flow
1.5	Big	0.84	1.24	13.64	19.84	19.84	18.60	71.92
	Small	0.47	0.69	4.14	6.21	6.21	5.52	22.08
2.0	Big	0.97	1.42	15.66	22.78	22.78	21.36	82.59
	Small	0.54	0.80	4.78	7.16	7.16	6.37	25.47
3.0	Big	1.18	1.74	19.17	27.89	27.89	26.15	101.09
	Small	0.67	0.98	5.89	8.84	8.84	7.86	31.42
4.0	Big	1.38	2.03	22.39	32.56	32.56	30.53	118.03
	Small	0.77	1.13	6.79	10.19	10.19	9.06	36.22
Number of Nozzle in Tank			Big	11	16	16	15	58
			Small	6	9	9	8	32

* LNG Density : 460 kg/cbm,
LNG Flow/h = Water Flow/h x 1/√LNG Density

3.4 Operation procedures for Manual Cool down by Spray Pump Small Nozzle

3.4.1 Preparation of Cool Down

Before Cool Down: Confirm the quantity of Heel remained by snapshot function of CTMS

Adjust pressure of Barrier Space > Primary.: 7 mbar/Secondary : 4.0 mbar

Adjust RPM to approx. 76 (80%) and tank pressure to approx. 52 mbar

Adjust trim of the ships in order to secure smooth operation of "Spray Pump" in consideration of Weather. (2.0 meter by th stern)

3.4.2 Line Up

Liquid Spray : No.4 Spray Pump - VCS450 Spray Header VCS#55 VCS#54 VCS#51/52 BOG handling : VCG#70 VCG873 - L/D COMP(1 set) VCG927 VCG914 - NO.2 Heater VCG 875 Boiler

Release to Atmosphere : Gas Heater - VCG917/8 VCG751 VCG777 VCG771 VCG772 - Vent mast (in case of emergency)

3.4.3 Start No. 1 2 & 3 Tank Cool Down (Initial stage of Cool Down)

Start No.4 Cargo tank Spray pump by "Manual" (Pump Load Setting at 68 %, Tank Pressure : 48 mbars)

First, purge vapor in spray line by using No. 1, 2 & 3 Tank Big/Small nozzle, when VCS#51/52 covered fully with frost, then START COOLDOWN at No. 1, 2 & 3 tanks by OPENING ONLY SMALL NOZZLE. [VCS 461 Return pressure 3.6 (Manual Value 4.0%), Maintain Nozzle Pressure approx. 3.4 Bars]

The tank pressure gradually went up after starting Cool down and started No.2 L/D Compressor when the tank pressure reached 50 mbars, the gas flow at L/D load approx. 50% was approx. 3500 KG/H (Gas consumption : approx. 5,400~5,500 KG/Hour)

3.4.4 Keep Cooling in all tanks (Final stage of Cool Down)

The temperature of No.1 & No.3 tanks met ATR (130℃) and adjust the nozzle pressure of Control Valve (154/354) by manual to approx. 1.5 bars (Manual value 5%)

The temperature of No. 2 tank reached ATR (130℃) and adjust openness of VCS 461 so as to maintain nozzle pressure approx. 2.0 bars Started cool down using small nozzle at No. 4 tank 1 hour before pilot boarding by crack opening of No. 4 Cool Down valve. The cool down at No. 4 tank was completed in short period of time as the heel(- 158℃) was remained in the bottom of tank

3.4.5 Completion of Cool Down At the time of entering port

The maximum tank pressure at completion of cool down was 95 mbars, Change mode of Boiler from "GAS ONLY" to "DUAL" at the time of decrease RPM, the BOG generated after S/B Engine consumed at DSHS

Stop spray pump just before "OPENING CTS"

Table 2. Tank condition at the time of OPENING CTMS

Tank No	No. 1	No. 2	No. 3	No. 4
Tank Pressure (mbar)	155	155	155	155
Tank Temperature (deg. C)	131.5	132.1	132.6	132.7
B/Spare Temperature (deg. C)	20.8	22.1	22.8	36.7
Liquid Level Corrected (M)	0.064	0.064	0.068	0.188
Liquid Quantity (cbm)	43.7	84.3	89.6	232.9

Table 3. Tank Temperature (No. 1, 2 & 3)
Unit : degree (Celsius)

	OH	4H	8H	12H	16H	20H	24H	28H	32H
Manual B_N	9	78	107	115	121	125	134		
Auto Seq.	3	84	117	127	129	131	133	135	134
Manual S_N	6	44	75	92	105	115	122	129	133

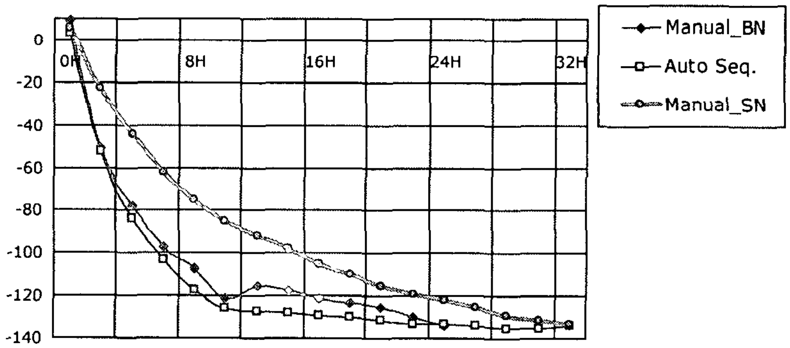

Figure 3. Tank Temperature (No. 1, 2 & 3)

Table 4. Tank Pressure

Unit : mbar

	OH	4H	8H	12H	16H	20H	24H	28H	32H
Manual B_N	55	123	122	109	81	56	118		
Auto Seq.	53	71	68	68	86	86	85	67	120
Manual S_N	53	84	90	94	91	85	83	75	125

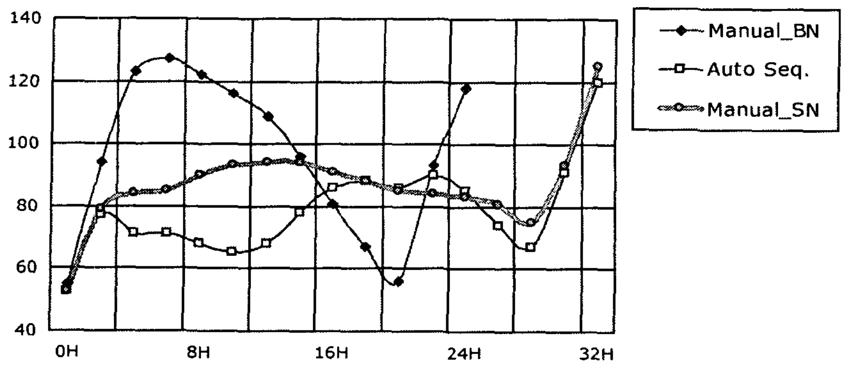

Figure 4. Tank Pressure

Table 5. Boil Off Gas

Unit: kg/hour

	0H	4H	8H	12H	16H	20H	24H	28H	32H
Manual B_N	0	6530	6510	6610	6620	6310	2330		
Auto Seq.	0	5718	5810	5867	6346	6281	6348	2000	2100
Manual S_N	0	4780	5370	5440	5620	5200	5700	5420	2100

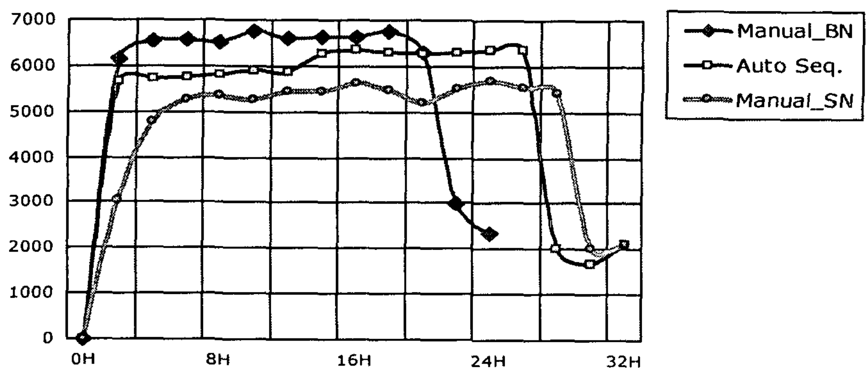

Figure 5. Boil Off Gas

Table 6. RPM

	0H	4H	8H	12H	16H	20H	24H	28H
Manual B_N	80.5	80.7	80.5	81.6	80.7	81.9		
Auto Seq.	77.0	77.5	78.0	78.6	78.3	79.0	77.5	79.8
Manual S_N	45.8	76.0	75.8	75.7	76.0	76.3	76.6	76.1

4. Calculating appropriate heel quantity

4.1 Distribution method

Table 7. Heel Comparison (Distribution)

	8 Sea Days	15 Sea Days	20 Sea Days
No. 1 Tank	220 CBM (70+150)	355 CBM	450 CBM
No. 2 Tank	315 CBM (130+185)	475 CBM	590 CBM
No. 3 Tank	315 CBM (130+185)	475 CBM	590 CBM
No. 4 Tank	460 CBM (125+175+160)	615 CBM	725 CBM
Total Heel	1,310 CBM	1,920 CBM	2,355 CBM
Cool down Time	4 Hours	5 Hours	6 Hours

4.2 Concentration method

Table 8. Heel Comparison (Concentration)

	8 Sea Days	15 Sea Days	20 Sea Days
No. 1 Tank	45 CBM	45 CBM	45 CBM
No. 2 Tank	50 CBM	50 CBM	50 CBM
No. 3 Tank	50 CBM	50 CBM	50 CBM
No. 4 Tank	1,175 CBM (125+200+850)	1,350 CBM (25)	1,475 CBM
Total Heel	1,320 CBM	1,495 CBM	1,620 CBM
Cool down Time	30 Hours	30 Hours	30 Hours

4.3 Heel Consumption Comparison

Table 9. Heel Comparison

Unit: CBM

	Manual Big Nozzle	Auto Sequence	Manual Small Nozzle
HJMC	1586	1545	1552
HJSU	1670	1595	1510
HJRL	1591	1505	1537
AVERAGE	1615	1584	1537

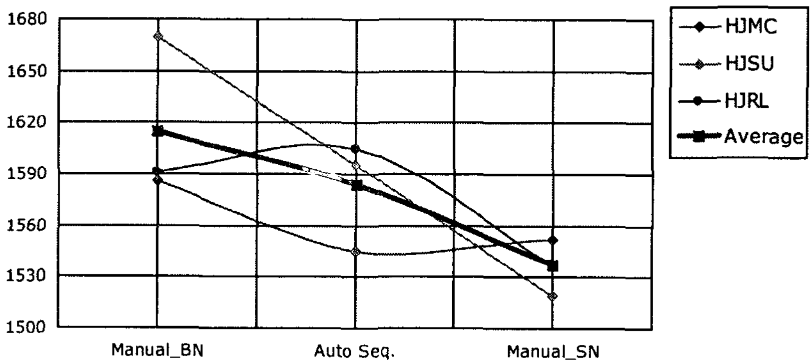

Figure 7 Heel Comparison

5. Conclusion

This study reviewed safe and effective operation in Membrane LNG ships focused on the Tank Cool down, one the most critical operations in LNG through empirical test and concluded that Tank Cool down by Spray Pump Small Nozzle provided the vessel with the safest ways of tank cool down and ultimately might be a standard practice for Tank Cool down.

This standard method may contribute to the safe and effective operation for the existence LNG operation company as well as the new comer who starts LNG operation.

Furthermore, There need efforts for unification of operational procedures among terminals in the near future to improve safety standards.