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TO STUDY THE DIFFERENCE OF TEMPERATURE (DELTA) BETWEEN THE PEAK TEMPERATURE ON LEFT SIDE AND RIGHT SIDE DURING NORMAL FIRING IN GLASS TANK MELTING FURNACE

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ABSTRACT

Glass Tank Melting furnaces utilize a cross-fired approach, with burners alternating between the left and right sides in 20-minute cycles. During normal firing, a significant temperature difference, known as delta, is observed between the peak temperatures achieved on the left and right sides. This temperature delta exceeds the permissible limit of ±2 °C, resulting in furnace process instability and energy losses. To address this issue, a two-month action plan was implemented. In the first month, various parameters were analyzed to identify the key factors affecting the temperature delta. In the second month, corrective actions were taken, following a standard Kaizen procedure. Parameters investigated included combustion air flow, air-gas ratio, batch moisture, regenerator top and bottom temperature differences, natural gas flow, combustion air flow, draft pressure, burner parameters, flue gas analysis, net calorific value variation, and more. Notably, the combustion air flow, total gas flow, and air-gas fuel ratio demonstrated a strong correlation with the temperature delta. Several issues were identified, such as excess air and equipment calibration discrepancies. Recommendations for resolving these issues included adjusting excess air ratios, calibrating burner parameters, sealing cracks and holes, and upgrading flow measurement devices. Additionally, the study suggested reevaluating the correlation between net calorific value and gas flow. This investigation seeks to enhance furnace efficiency, minimize energy losses, and ensure a consistent temperature profile during glass production.

Keywords: Glass Tank Melting furnace, Temperature Delta, Combustion Air Flow, Net Calorific Value, Furnace Energy.

NOMENCLATURE

°C Degree Celsius (Temperature)

MW Mega Watt (Furnace Energy)

Kwh/Nm^3 Net Calorific Value

Kcal/Nm^3 Net Calorific Value

Kcal/Sm^3 Net Calorific Value

Nm^3/hr Normal cubic meter flow of air or gas

Sm^3/hr Standard cubic meter flow of air or gas

1 INTRODUCTION

Glass Tank Melting furnace is a cross fired furnace where firing occurs through burners from alternate sides in alternating cycles of 20 minutes. It has been observed that there is a temperature difference between the peak temperature attained during firing. That is the peak temperature attained during left side firing is not equal to the peak temperature attained during right side firing in the normal firing schedule of the GTF. This delta value exceeds the permissible limit value of ±2°C which is responsible for causing Furnace Process instability and Energy Losses.

To address the problem, a 2 month action plan was prepared. First month was dedicated to analyse various parameters and come to a conclusion to streamline our focus to a specific and the most appropriate parameters with the greatest influence to the problem and the Second month was reserved for Corrective Actions and Measures. A Standard Kaizen Procedure was followed.

All the possible parameters that were analysed are as follows. The following reasons might possibly influence and might be the possible reasons correlating to the given problem statement:

1)Combustion air flow in B3 port
2) Air gas ratio in port 3
3) Batch moisture
4) Regenerator top and bottom temperature difference
5) Total Natural Gas flow
6) Total Combustion Air flow
7) Total Air by Total NG ratio
8) Draft Pressure
9) Combustion Air Pressure by Burner HP Ratio
10) Effectof parasitic air

11)Burner HP,L.P., flame length
12) Flue Gas Analysis
13) Net Calorific Value Variation
14) Improper Air Flow and Gas Flow due to NCV variation
15) Air-Gas Fuel Ratio or Stoichiometric Ratio with NCV variation
16) Cross Check of the Chromatograph
17) Mega Watt Set Value vs. Temp of B3 Crown.

2 ANALYSIS OF THE PARAMETERS

2.1 COMBUSTION AIR FLOW IN B3 PORT

Air itself doesn't have any calorific value , so excess air flow might contain more parasitic air , so as the air flow increase but the gas flow is controlled thus incomplete combustion occurs as a result of which the furnace temperature as well as the delta value decrease . Thus we find a negative correlation .Its also observed that air flow follows a positive correlation , that is with increased air flow , furnace temperature increases and vice versa.

2.2 AIR GAS RATIO IN PORT 3

As fuel gas flow increases , Air to Gas ratio decreases . A stoichiometric ratio of air to gas of value 10:1 is to be maintained but that isn't occurring as was evident from real time observation and recorded values from the DCS .

2.3 BATCH MOISTURE

As batch moisture is higher it will absorb more heat for evaporation thus , temperature recorded will be lower and also the fuel consumed will be more thus causing energy instability and reduce sustainability .

2.4 REGENERATOR TOP AND BOTTOM TEMPERATURE DIFFERENCE

The idea is that , higher the temperature difference between regenerator top and bottom , higher is the heat amount absorbed by the combustion air . Now if a particular regenerator shows more difference in top and bottom temperature than the other regenerator , then the firing and thus the temperature attained on the other side is higher (side opposite to the regenerator in which the temperature difference came out to be higher) . It was observed that right regenerator top in port 3 attained higher temperature than the regenerator top in the left . So this should mean that when firing from the right side occurs , temperature attained should be more as the combustion air is flowing in through the Right Regenerator so it should mean the flue gases generated should heat up the left regenerator top more , but the exactly opposite of this is what occurs .

2.5 TOTAL NATURAL GAS FLOW

A positive correlation exists , as Natural Gas flow increase , more heat is generated during combustion thus a higher temperature is recorded. Natural gas flow depends on NCV value . The flow is adjusted accordingly by the DCS . The variation in the combustion air flow is the main contributing factor as its value is more for left side firing than right side firing . As combustion air flow is calculated on the basis of gas flow . Thus there is a direct correlation between NCV value , gas flow and B3 crown temperature delta

2.6 TOTAL COMBUSTION AIR FLOW

Its observed that combustion air flow is more for on the left side than on the right side by about 500 Nm^3/hr . Thus as the combustion air is more , homogenization is assumed to be more , more oxygen than the required stoichiometric ratio is available , thus combustion is more efficient . Now as the combustion air is more , which is not taking into account the amount of parasitic air , thus flue gas volume should be higher , thus draft pressure will be higher . Subsequent observations revealed just that .

2.7 TOTAL AIR BY TOTAL NG RATIO

A negative correlation is seen for air gas ratio and the B3 crown temperature measured , as the fuel gas flow increase , air by gas flow ratio decrease , more heat is generated , thus a higher temperature is recorded . As the combustion air flow is already higher by about 500 Nm^3/hr on the left side , so the increase in gas flow ensures complete combustion thus the temperature reached is also higher

2.8 DRAFT PRESSURE

A negative correlation is found between B3 crown temperature delta and draft pressure . Draft pressure is higher during the firing in the LHS than compared to the Firing that's occurring in the RHS. This can be attributed to the higher volume of flue gas which is being generated due to higher volume of combustion air flow in the LHS to the tune of 500 Nm^3/hr .

2.9 COMBUSTION AIR PRESSURE BY BURNER HP RATIO

B3 crown delta value was found to be low for a combustion air pressure to burner HP ratio value of 0.654 for LHS .B3 crown delta value was found to be low for a combustion air pressure to burner HP ratio value of 0.642 for RHS.This shows that calibration is required to maintain similar Burner HP levels .

2.10 EFFECT OF PARASITIC AIR

Excess air that enters the furnace through coolant lines or through cracks and pores is known as parasitic air . Various sources of parasitic air in the furnace are :- 1)Cooling Air 2)Air Leaks Air Leaks can occur through cracks and holes . Cracks can occur due to wear and tear , weathering , corrosion and through thermal spalling . During regenerator raft condition checking , several cracks were observed in the regenerator bottom raft window section in both the regenerators of the furnace .All the cracks were then sealed to prevent Air Leaks through these .

2.11 *BURNER HP , LP , FLAME LENGTH*

Flame length depends on the HP , LP values . Also the inclination of the flame , whether it is parallel to the batch or at an angle to it , also is an important factor . Visually , flame during left firing is more parallel to the batch-line compared to the flame during right side firing .Since , the HP , LP values for the natural gas through the burners is comparatively more in the LHS burners than the RHS (only exception being the B3 port burners) , the flame length should be more , so should be the intensity . But due to human error , the flame length is assumed to be same . There is no arrangement to validate flame length , temperature , velocity in this furnace . But various input data (burner angle , HP , LP value of natural gas) implies , flame during the left side firing should be longer , and be of higher intensity.This assumptions should be validated and if a discrepancy is found then it should be corrected in order to obtain an uniform distribution of flame . This will also help to cut down cost and improve energy efficiency by reducing over firing and excess flow of natural gas .

2.12 *FLUE GAS ANALYSIS*

Flue Gas analysis was performed to study how the composition of the flue gas was used in calculating the amount of combustion air that is to be supplied . The volume of combustion air depends on the oxygen and CO composition of the flue gas . No such variations were found in our study from flue gas , nonetheless it is an important parameter . Flue Gas analysis is done twice a month on weekends.

Burner angle variation

Burner Angle		LHS		Burner Angle		RHS
Port 1	U/S	11.9		Port 1	U/S	12.1
	C	12.2			C	12.1
	D/S	11.9			D/S	12.15
Port 2	U/S	12.25		Port 2	U/S	12.15
	C	12.1			C	12.45
	D/S	13.35			D/S	12.3
Port 3	U/S	12.7		Port 3	U/S	11.8
	C	12.15			C	11.95
	D/S	12.45			D/S	11.55
Port 4	U/S	12.1		Port 4	U/S	12.05
	C	12.4			C	12.4
	D/S	12.45			D/S	12
Port 5	U/S	11.95		Port 5	U/S	11.8
	C	11.55			C	12.05
	D/S	12.32			D/S	11.8

Fig. 1. This Chart represents a comparison between Burner Angle on both side of the GTF.

	HP	LP	Flame Length
HP	1		
LP	0.893237	1	
Flame Length	0.850914	0.86595	1

Fig. 2. This Chart represents a correlation between HP , LP and Flame Length.

It is observed that burner angle for port 2 and 3 is a bit more for LHS . Thus the inclination of the flame will be a bit more towards the crown for the LHS as compared to the flame angle on the RHS.

	Burner Energy					Burner Energy		
LHS	Set Point MW	Total Capacity	Percent		RHS	Set Point MW	Total Capacity	Percent
B1	6.859	7.5	91.45333		B1	6.802	7.5	90.69333
B2	7.473	10.5	71.17143		B2	7.411	10.5	70.58095
B3	7.875	10.5	75		B3	7.828	10.5	74.55238
B4	7.862	10.5	74.87619		B4	7.705	10.5	73.38095
B5	4.549	7.5	60.65333		B5	4.458	7.5	59.44
B6	1.396	2.5	55.84		B6	1.396	2.5	55.84

Fig. 3. This Chart represents a comparison between burner energy.

Thus the energy capacity for burners in B1 , B2 , B3 , B4 , B5 of LHS is higher compared to that of the RHS.

2.13 *NET CALORIFIC VALUE VARIATION*

The Gas used to support combustion is Natural Gas which is supplied by GAIL. There is an instrument which calculates the NCV of the gas continuously at every 3 minutes interval. The instrument is called the Chromatograph. Depending on the Value of NCV of the Gas at each instant, the Gas Flow and the Air Flow gets changed. Too much of change in NCV is the main factor for temperature fluctuation and also Furnace energy leakage. To study this variation , Manual Data of 24hrs was collected, which contained the component Analysis of the NG captured by the chromatograph.

Methane is the main component of the NG. Normally whenever there is a decrease in the Methane %, Ethane or other hydrocarbon isexpected to increase and the NCV value gets higher and vice versa also happens. Here the opposite is happening, i.e., with Methane % increase, the NCV is increasing and with a decrease in Methane % , NCV is decreasing. Probability: Some component with lower CV is increasing with decrease in Methane %.

2.14 *IMPROPER AIR FLOW AND GAS FLOW DUE TO NCV VARIATION*

Now since there is a variation in the NCV, the Gas Flow and Air Flow gets changed accordingly. The Theoretical model suggests that whenever NCV increases, the gas flow gets decreased and the Air Flow either remains constant or there is a very slight decrease in it. Similarly whenever NCV decreases, the gas flow gets increased and the Air Flow either remains constant or there is a very slight increase in it.

Fig. 4. This graph shows the Gas Flow whenever NCV increases.

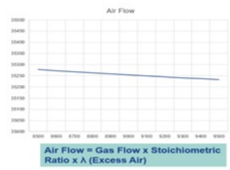

Fig. 5. This Graph shows the expected Air Flow with corresponding NCV increase.

Now we perform a check to see whether its performing properly.

2.15 AIR-GAS FUEL RATIO OR STOICHIOMETRIC RATIO WITH NCV VARIATION

With NCV Increase, Air Gas Fuel Ratio or Stoichiometric Ratio must increase and vice versa.

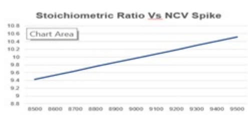

Fig. 6. Stoichiometric Ratio vs NCV spike.

2.16 CROSS CHECK OF THE CHROMATOGRAPH

The Chromatograph calculates the NCV and Composition of the Natural Gas. So, we perform few calculations by other methods to see whether the reported NCV of the gas by the Chromatograph is correct or not. We performed this by comparing the Unit Conversion Method (which occurs in the chromatograph) with other 2 methods. The other two methods are Wiley's Formula and the Formula given by Gujrat Gas Corporation Limited.

2.17 MEGA WATT SET VALUE VS TEMPERATURE OF B3 CROWN

Whenever there is any Change in the B3 Crown temperature, the MW Set Value is adjusted manually. For example, whenever temperature increases, MW Set Value is decreased by a Step Manner using a fixed value interval. Similarly if temperature decreases, MW Set Value is increased by a step manner using the same fixed value. We did a cross check to see whether the fixed value by which increase and decrease of the MW Set value is being done is correct or we need to do some changes in it.

3 EQUATIONS

3.1 CALCULATION OF EXCESS AIR

$$\text{Excess air} = \frac{\text{Measured } O_2\%}{20.9 - \text{Measured } O_2\%} \times 100$$

Overall $O_2\%$ in flue gas regenerator = 10- 12% . If measured $O_2\%$ is 1.8 then excess air = 9.4 % . If measured $O_2\%$ is 2 and above the excess air = 10 and above %.

3.2 PARASITIC AIR

$$\text{Parasitic Air} = \left[\frac{M_{\text{real } O_2} \times F_{0\%O_2 \text{ total fumes}}}{100 \times 0.21 \times \left(1 - \frac{M_{\text{real } O_2}}{100 \times 0.21}\right)}\right] - (F_{\text{CA}} - F_{\text{SA}}) \tag{1}$$

Here $F_{CA} = F_{\text{Combustion Air}}$

$F_{SA} = F_{\text{Stoichiometric Air}}$

3.3 STOICHIOMETRIC AIR

$$\text{Stoichiometric Air} = F_{\text{gas}} \times V_{\text{gas}} + F_{\text{oil}} \times V_{\text{oil}} \tag{2}$$

This function calculates the combustion air flow rate needed for the complete combustion of the injected fuel flow. The calculation depends on the fuel feature Va, the volume of air Nm^3/hr needed to burn 1 Nm^3/hr of gas or 1kg of oil and the fuel flow rate $D_gas/fuel$

3.4 MW

$$\text{MW} = \frac{\text{NCV}\,(\text{kCal/Nm}^3) \times \text{Gas Flow}}{860 \times 1000} \tag{3}$$

3.5 AIR-GAS FUEL RATIO OR STOICHIOMETRIC RATIO CALCULATION

$$\text{Stoichiometric Ratio} = 0.944051 \times \text{NCV} + 0.115472 \tag{4}$$

3.6 AIR FLOW CALCULATION

$$\text{Air Flow} = \text{Gas Flow} \times \text{Stoichiometric Ratio} \times \lambda\ (\text{Excess Air}) \tag{5}$$

3.7 UNIT CONVERSION METHOD

$$\text{GCV MJ/m}^3 \times 239.006 = \text{GCV Kcal/Nm}^3 \tag{6}$$

$$\text{NCV MJ/m}^3 \times 239.006 = \text{NCV Kcal/Nm}^3 \tag{7}$$

3.8 WILEY'S FORMULA

Find out the GCV in KJ/mol of individual components. Find out the Molar Mass of the components as well,

Calculate GCV in kwh/NM3, using the formula

$$\left[\frac{\text{CCIC}}{100}\right] \times \frac{\text{GCV in KJ/mol}}{3600 \times \text{Volume Mol}} \tag{8}$$

Here CCIC = Chromatograph Composition of individual component

Find the total adding all the individual GCV in $kWhr/Nm^3$

Calculate GCV in kwh/NM3, using the formula

$$\text{GCV Kwh/Nm}^3 - \left[\frac{\left(\frac{\text{no. of H atom}}{2} \times \text{LO } H_2O\right)}{3600 \times \text{Volume Mol}}\right] \times \text{CC} \quad (9)$$

Here CC = Chromatograph Composition.

Also sum all the individual values The total GCV and NCV in $Kcal/Nm^3$ using the following formula:=

$$\text{GCV in Kwh/Nm}^3 \times 860.42065 \quad (10)$$

$$\text{NCV in Kwh/Nm}^3 \times 860.42065 \quad (11)$$

3.9 GUJRAT GAS CORPORATION LIMITED'S FORMULA

$$\text{Molar Mass} \times (\text{Composition }\%) \quad (12)$$

$$\text{Calculate g/mol} = \sum \text{of all individual Masses} \quad (13)$$

$$\text{Calculate g/l} = \frac{\sum \text{of all individual Masses}}{22.4} \quad (14)$$

$$\text{CCVIC} = \frac{\text{CV in MJ/Kg} \times \text{Mass}}{22.4\,(\text{g/l})} \quad (15)$$

Here CCVIC = Calculate Calorific Value by Vol. for individual components

$$\text{Sum of all in KJ/l} = \sum \text{of the NCV by vol of individual components} \quad (16)$$

$$\text{Calculate NCV in Kcal/Nm}^3 = \frac{\text{NCV in KJ/l} \times 4.18}{1000} \quad (17)$$

4 FIGURES.

4.1 B3 CROWN TEMPERATURE VARIATION BETWEEN TWO CONSECUTIVE LEFT SIDE FIRING

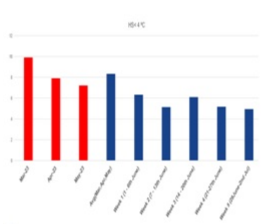

Fig. 7. B3 Crown Temp Variation between two consecutive left side firing.

4.2 THEORETICAL MODEL

This Model Suggests the behaviour of the Gas Flow , Air Flow and Air-Gas Fuel Ratio along with NCV variation.

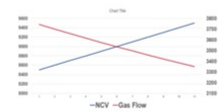

Fig. 8. NCV Spike vs Gas Flow.

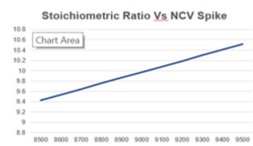

Fig. 9. Stoichiometric Ratio vs NCV Spike.

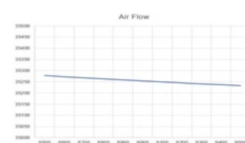

Fig. 10. Air Flow Variation.

4.3 MW SET VALUE

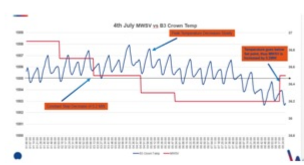

Fig. 11. MW Set Value 1

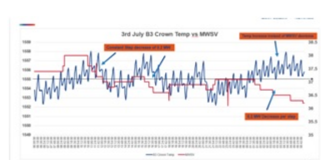

Fig. 12. MW Set Value 2.

5 TABLES.

5.1 THEORETICAL MODEL

NCV (Kcal/Nm3)	MW	Gas Flow Nm3/hr
8500	37	3743.529
8600	37	3700
8700	37	3657.471
8800	37	3615.909
8900	37	3575.281
9000	37	3535.556
9100	37	3496.703
9200	37	3458.696
9300	37	3421.505
9400	37	3385.106
9500	37	3349.474

Fig. 13. NCV Variation affecting gas flow

NCV	NCV KWH	V_a	Excess Air	Gas Flow	Air Flow	Air Gas Fuel Ratio
8500	9.86	9.423815	1	3743.529	35278.33	9.42381486
8600	9.976	9.533325	1	3700	35273.3	9.533324776
8700	10.092	9.642835	1	3657.471	35268.39	9.642834692
8800	10.208	9.752345	1	3615.909	35263.59	9.752344608
8900	10.324	9.861855	1	3575.281	35258.9	9.861854524
9000	10.44	9.971364	1	3535.556	35254.31	9.97136444
9100	10.556	10.08087	1	3496.703	35249.83	10.08087436
9200	10.672	10.19038	1	3458.696	35245.44	10.19038427
9300	10.788	10.29989	1	3421.505	35241.14	10.29989419
9400	10.904	10.4094	1	3385.106	35236.94	10.4094041
9500	11.02	10.51891	1	3349.474	35232.83	10.51891402

Fig. 14. NCV Spike effecting air flow and stoichiometric ratio

5.2 DATA COLLECTION FOR NCV CROSS CHECK

Chromatograph Reading													DCS					
Date & Time	Superior CV(GCV), MJ/Nm3	Inferior CV(NCV), MJ/M3	Sp. Gr.	%CH4	%C2	%C3	%IC4	%NC4	%IC5	%NC5	%N2	GCV_DCS (Kcal/Nm³)	NCV_DCS (Kcal/Nm³)	NG Flow in Furnace	NCV_DCS (Kcal/Sm³)	MW in Furnace	Wobbe
29-05-2023 (2:00 PM)	41.6227	37.6168	0.64379	87.0133	8.8292	1.0082	0.0351	0.0209	0	0	0.3793	9951.4	8983.2	3577.1	8499.03	37.365	11594
29-05-2023 (3:00 PM)	41.6875	37.6729	0.639161	87.5498	8.6452	0.9756	0.0358	0.0212	0	0	0.3562	9958.3	8990.1	3581.2	8505.57	37.429	11594
29-05-2023 (4:00 PM)	41.6603	37.6472	0.638582	87.5821	8.6319	0.9502	0.0333	0.0199	0	0	0.352	9951.4	8990.1	3589.3	8505.57	37.52	11594
29-05-2023 (5:00 PM)	41.6731	37.6589	0.638293	87.6184	8.5768	0.9614	0.0342	0.0205	0	0	0.3615	9958.3	8990.1	3579.3	8505.57	37.414	11594
30-05-2023 (9:00 AM)	41.5909	37.587	0.643501	87.2959	8.6673	1.0255	0.0403	0.0235	0	0	0.3853	9937.9	8983.2	3576.4	8499.03	37.357	11594
30-05-2023 (10:00 AM)	41.6539	37.6412	0.638293	87.8738	8.4437	1.0063	0.0417	0.0242	0	0	0.3943	9958.3	8990.1	3553.1	8505.57	37.365	11594
30-05-2023 (11:00 AM)	41.5884	37.5792	0.636267	88.2076	8.2056	0.9769	0.0394	0.0229	0	0	0.4184	9937.6	8969.4	3586.7	8485.95	37.418	11594
30-05-2023 (12:00 PM)	41.6671	37.656	0.641476	86.8053	8.3904	1.1202	0.0479	0.0284	0	0	3.6078	9958.3	8990.1	3567.2	8505.57	37.289	11594
30-05-2023 (1:00 PM)	41.6992	37.6829	0.63829	87.9321	8.3232	1.0816	0.0503	0.0317	0.0018	0	0.4154	9965.2	8997.1	3409.4	8512.12	35.687	11594
30-05-2023 (2:00 PM)	41.4859	37.4925	0.645816	87.2403	8.2117	1.0712	0.0488	0.0319	0.0062	0.0084	0.396	9906.4	8955.6	3624.3	8472.86	37.741	11594
30-05-2023 (3:00 PM)	41.4269	37.4361	0.643501	87.4294	8.1492	1.0359	0.0359	0.0234	0	0	0.3832	9896.1	8934.8	3645.7	8453.23	37.876	11594
30-05-2023 (4:00 PM)	41.5557	37.55509	0.638293	87.8081	8.2812	0.9973	0.0376	0.022	0	0	0.3831	9923.7	8962.5	3624	8479.4	37.497	11594
30-05-2023 (5:00 PM)	41.59	37.5824	0.638293	87.7565	8.3428	0.9976	0.0363	0.0212	0	0	0.03736	9930.7	8969.4		8485.95		11594
31-05-2023 (9:00 AM)	41.5151	37.5402	0.626719	89.4324	7.5799	0.86001	0.0237	0.0136	0	0	0.3607	9923.7	8957.5	3523.8	8474.72	36.708	11594
31-05-2023 (10:00 AM)	41.5616	37.5447	0.624115	89.7487	7.5038	0.8247	0.0266	0.0148	0	0	0.3535	9930.7	8963.3	3529.6	8480.03	36.792	11594
31-05-2023 (11:00 AM)	41.4705	37.4611	0.623826	89.7726	7.3246	0.8402	0.0241	0.0137	0	0	0.4233	9910.6	8948.7	3528.8	8466.32	36.719	11594
31-05-2023 (12:00 PM)	41.4967	37.4844	0.623247	89.8768	7.2757	0.8484	0.0241	0.0139	0	0	0.4158	9916.8	8955.6	3689.4	8472.86	37.361	11594
31-05-2023 (1:00 PM)	41.5503	37.5352	0.625272	89.5983	7.3992	0.9123	0.0261	0.0148	0	0	0.337	9924.1	8962.5	3551.7	8479.4	37.02	11594
31-05-2023 (2:00 PM)	41.5244	37.5093	0.622668	89.9222	7.2198	0.8757	0.0245	0.0144	0	0	0.3293	9918.7	8955.6	3556.9	8472.86	37.035	11594
31-05-2023 (3:00 PM)	41.5195	37.5056	0.623536	89.7816	7.2605	0.8873	0.025	0.0147	0	0	0.3913	9916.8	8955.6	3584.5	8472.86	37.318	11594
31-05-2023 (4:00 PM)	41.6085	37.5877	0.623826	89.6912	7.3926	0.9052	0.0296	0.0174	0	0	0.3397	9937.4	8969.4	3578.9	8485.95	37.318	11594
31-05-2023 (5:00 PM)	41.6399	37.6162	0.623247	89.7376	7.4625	0.8786	0.0301	0.0179	0	0	0.3372	9938.9	8983.2	3534.5	8499.03	35.321	11594

Fig. 15. Data Collection

6 CONCLUSIONS.

The following observations and suggestions can be made :

6.1 PRACTICAL SET OF CONCLUSIONS BASED ON PHYSICAL INSPECTION

1) Combustion air flow is more during left side firing, reason can be attributed to the fact that the excess air ratio setting is a bit more ports on left side which is set based on flue gas analysis of oxygen amount .

2) B3 crown delta value is observed to be low when furnace pressure is around 5.17 Pa .

3) B4 burner HP LP values for NG flow is comparatively more in the left side compared to that in the right side , calibration required .

4) B3 burner HP LP values for NG flow was observed to be comparatively less in the right side compared to the left side , calibration was done to make them equal .

5) Maximum temperature for B3 right regenerator top (Target wall) was found to be higher during left firing compared to left regenerator top (Target wall) during right firing and minimum temperature for B3 right regenerator top (Target wall) was lower during left firing compared to left regenerator top (Target wall) during right firing . Possible reasons as observed are choking in the right regenerator top in B3 port.

6) Cracks and openings were found in the regenerator bottom peep window area . Sealing and repair work was done .

7) Cracks and holes were observed in the B4 skew-line area in the left side and holes in penetration wall area was found . Repair work and sealing was done in the observed area .

8) Burner coupling for manometer attachment , used for measuring burner HP LP values was found to be faulty , needs to be replaced.

9) Burner service life is almost at its last stage , as such calibration for HP LP of NG flow becomes difficult. It needs to be replaced.

It has been observed that the rate of rise of temperature during left firing is more steep compared to the rate of rise of temperature during right firing . Since the temperature of left regenerator is lower by 40 to 60 degree Celsius compared to the temperature of right regenerator , the temperature of combustion air is also low during left firing compared to right firing . But as the combustion air volume is more during left firing the combustion process is robust and the temperature rise of the combustion end product (flue gas) is higher. Also the temperature point from which left firing temperature rise start is lower compared to the temperature point from which right firing temperature rise starts . Due to difference in combustion air volume and difference in volume in oxygen required for combustion , the nature and total energy released during the firing process is different . Due to higher combustion air volume during left firing , mixed nature of reaction of heavier hydrocarbon occurs ,that is the oxidation of N-butane , iso-pentane etc. occur which produce soot (amorphous carbon) , which is susceptive to further oxidation , which on oxidizing produce CO and CO2 . Due to comparatively lower amount of combustion air in right firing , this reaction occurs to a lesser extent , thus the amount of CO formed is lower as confirmed by flue gas analysis.

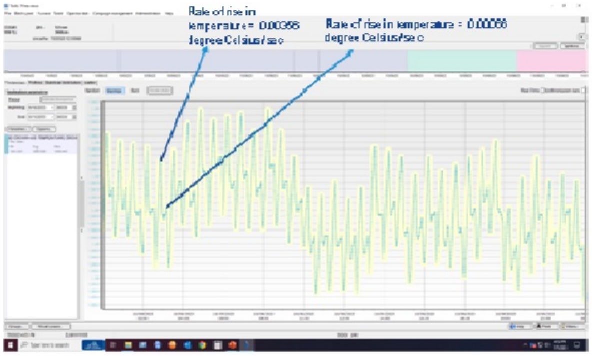

Fig. 16. DCS view of the problem statement

6.2 *ANALYSIS OF VARIOUS DATA*

1)Net Calorific Value Variation:

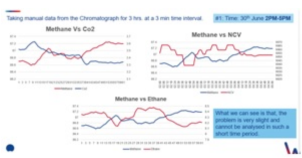

Fig. 17. Relation between different components of the NG 1.

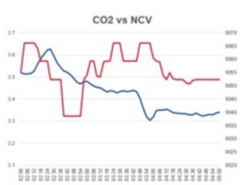

Fig. 18. CO2 vs NCV

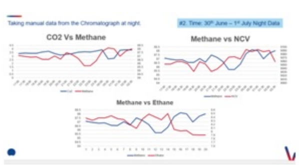

Fig. 19. Relation between different components of the NG 2.

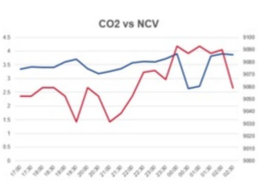

Fig. 20. CO2 vs NCV

2) From the Data Manually collected from the Chromatograph, we can say that, there is a possibility that the Directly Proportional behaviour of NCV with Methane can be due to the variationof CO2 % with Methane %.
3) Whenever there is an NCV spike CO2 % is taking Methane % thus decreasing the NCV.
4) This should not take place
Solution : We contacted GAIL authorities and discussed the issue and told to fix it.

6.3 *AIR FLOW , GAS FLOW AND STOICHIOMETRIC RELATION CHECK WITH RESPECT TO THE THEORETICAL MODEL*

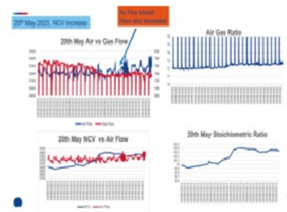

Fig. 21. NCV and other parameter variation on particular dates 1.

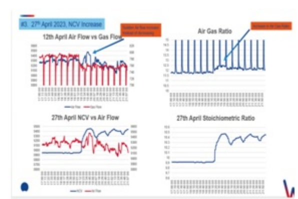

Fig. 22. NCV and other parameter variation on particular dates 2.

After Collecting Data , we can see that, with NCV increase or decrease , Gas Flow is following the theoretical model ,but Air Flow is not following the order due to which the Air Gas Fuel Ratio or Stoichiometric Ratio is also getting a bit hampered. Factors which might affect the Air Flow:
1) Flow Meter : Anuubar Flow Meter
2) Excess Air
Now, Excess Air is kept constant, on reviewing much we could see that the problem mainly lies within the Flow Meter which measures the Air Flow. The flow meter used is Annubar Flow Meter. The Annubar primary flow element is a device used to measure the flow of a liquid, gas or steam fluid that flows through a pipe. It enables flow measurement by creating a differential pressure (DP) that is proportional to the square of the velocity of the fluid in the pipe, in accordance with Bernoulli's theorem.

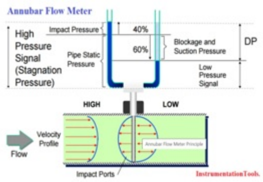

Fig. 23. Annubar Flow Meter

Thus the disadvantages of this flow meter are :
1) Single point measurement.
2) Pitot tube is fragile.
3) DP signal is low.
Suggestion: Installing a better Flow Meter with more accuracy and low cost.

Flow Meters	Approx. Price	Accuracy	Advantages	Picture
Annubar (Currently in use)	Rs. 4 Lakhs	± 0.75%	• Easy to install • Requires Less Maintenance • Simple Structure	
Ultrasonic Flow Meter	Rs. 1.5 Lakhs (India Mart)	± 0.5-0.7%	• Better accuracy • More installation flexibility • Minimal Maintenance	

Fig. 24. Comparison of other better flow meters.

6.4 CHROMATOGRAPH CROSS CHECK RESULT

Wiley's Formula :

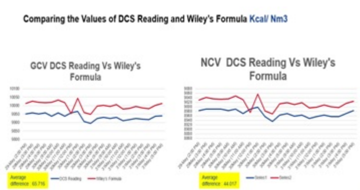

Fig. 25. Comparison of Wiley's formula with DCS reading.

GGCL Methodology :

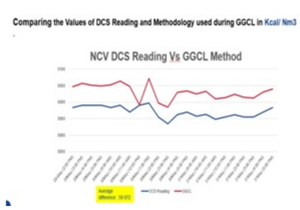

Fig. 26. NCV DCS reading vs GGCL methodology.

What we can see from both the cases that there are some differences, but that is negligible comparatively. So we focus on other issues neglecting this.

6.5 MW SET VALUE INCREASE OR DECREASE WITH RESPECT TO TEMPERATURE INCREASE OR DECREASE

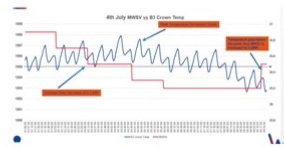

Fig. 27. MW Set Value Variation 1.

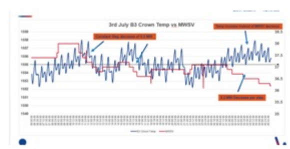

Fig. 28. MW Set Value Variation 2.

Considering the Data collected Manually :
1) We can see that the change in MW Set Value is Altered corresponding to B3 Crown Temperature Variation.
2) The adjustment of MW Set Value is done with a value of ±0.2MWin maximum of the cases.
3) This is causing a very late action on the B3 Crown Temperature.
Suggestions:
1) We can try adjusting the MWSV with a value of 0.25-0.30 MW.
2) 6th July – 7th July : Adjusting MWSV with a value of 0.25 MW.

7 REFERENCES

1) Principle of Annubar Flow Meter, LinkedIn
2) Ultrasonic Flow Meter, India Mart

**The Data and all the other work has been inherited from Saint Gobain India Private Ltd, Jhagadia, Gujrat Plant l **