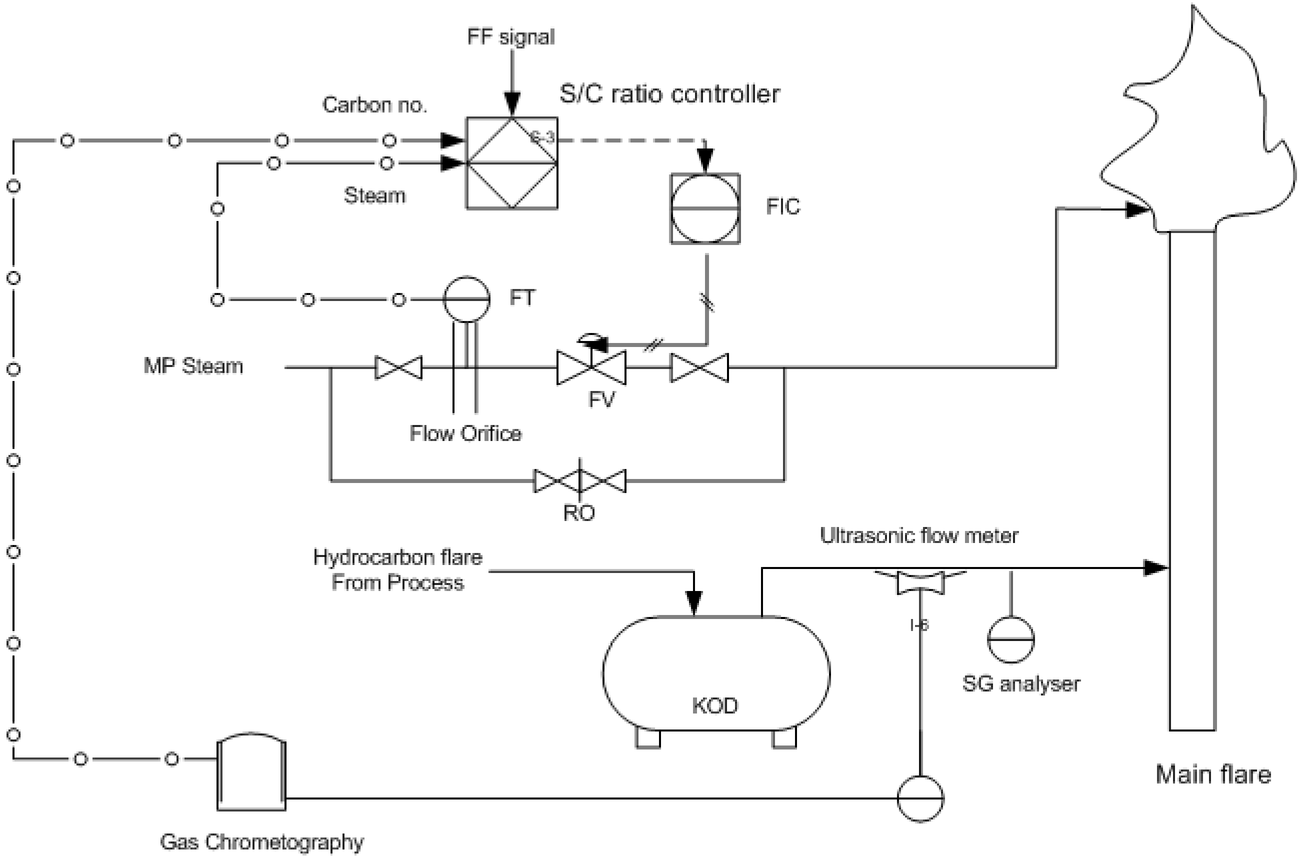

Figure 4: Automatic S/C ratio control loop with feed forward

3.1 Combustion Efficiency

Flare gases of different compositions and same heating value can have different stable flame operating envelopes when flared from the same flare. But with different quantities of steam to hydrocarbon ratio will change the combustion efficiency.

Steam to HC ratios of 3.5 to 1 or less had 98% plus Combustion efficiency.
Steam to HC ratios of 5.8 to 1 or less had 82% plus Combustion efficiency.
Steam to HC ratios of 6.7 to 1 or less had 69% plus Combustion efficiency.

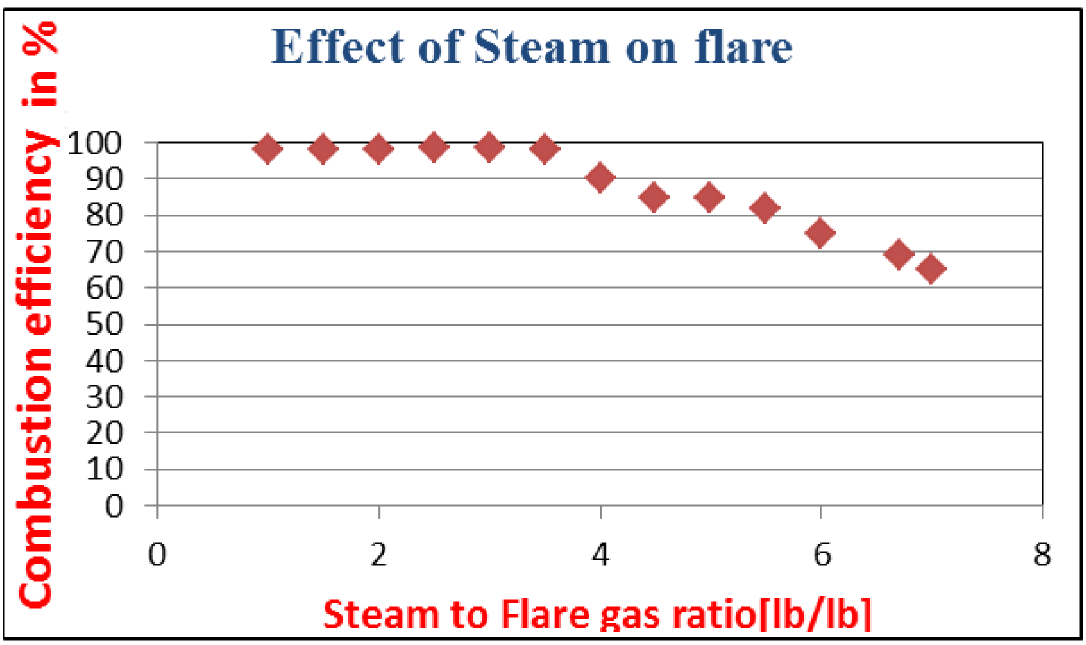

Figure 5: Impact of steam injection and combustion Efficiency

4. Simulation Results

In a typical refinery process, each unit vent gases connected to a common flare header and finally burn at flare stack tip. Here for simulation purpose each unit vent taken as 1, 2, 3…8. Each unit is having different carbon number according to process design. In simulation model any unit vent open above 0%, algorithm checks the design carbon number versus actual carbon number calculated from gas chromatography, then higher value is taken for feed forward signal for S/C ratio controller. As a normal feedback control valve, steam flow control valve will operate to maintain the desired steam flow to flame zone according to S/C ratio set point. But due to time lag from gas chromatography, feed forward signal is calculated from algorithm is directly multiply the S/C ratio set point to control quickly. Once GC gives actual carbon number steam flow will be optimized. Simulation models depict that smoke less flaring operation is possible by adopting S/C ratio control with feed forward action.

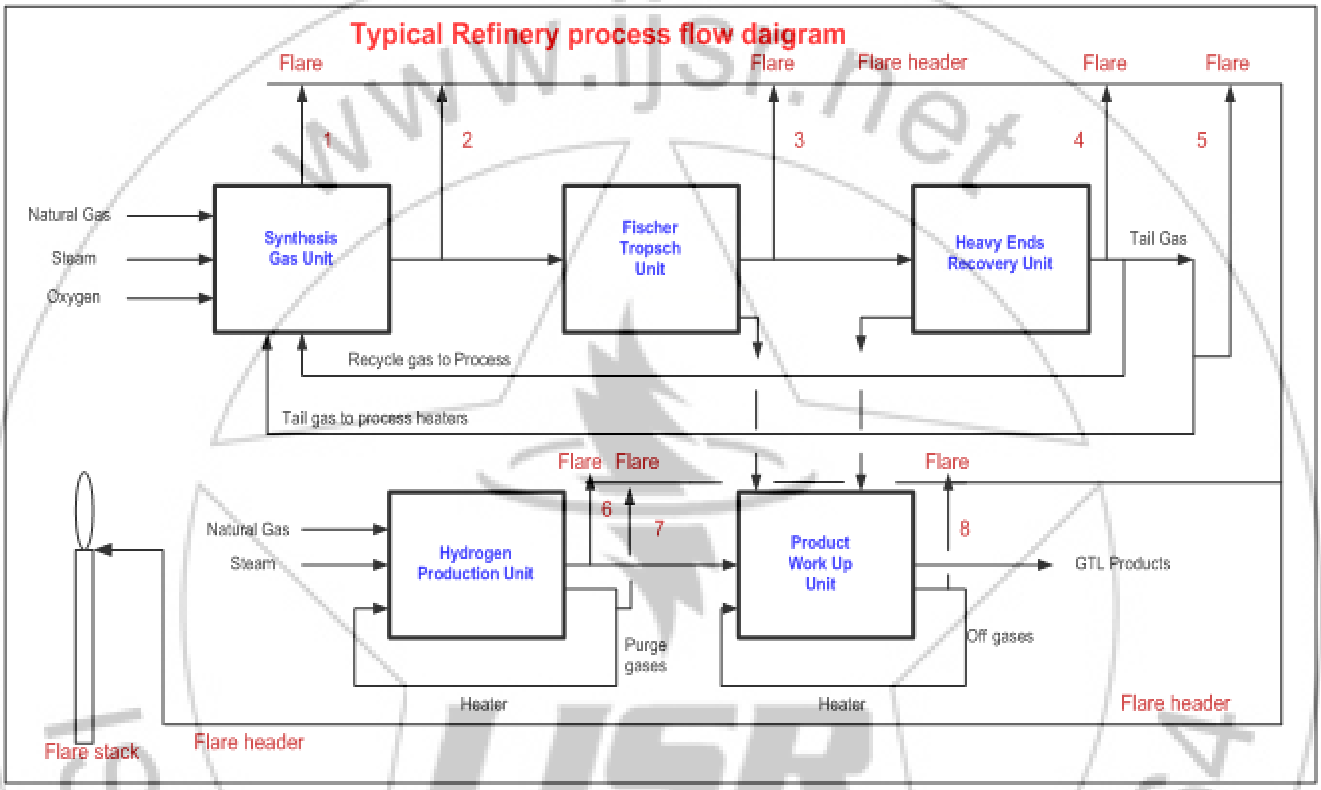

Figure 6: Typical refinery process with flare header

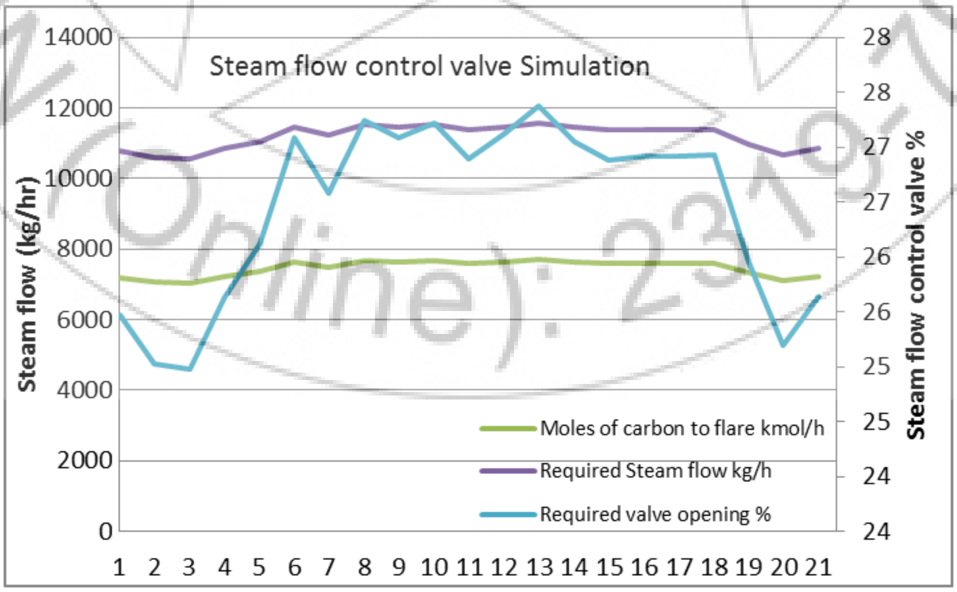

Figure 7: Steam flow control valve output vs. steam Demand [1]

Table 1: Steam requirement calculation

Start	Ratio of steam to C kg/kmol 1.5							
11/14/2013 7:00								
End								
11/14/2013 11:00								
	Steam requirement calculation				Actual valve and steam			
	Steam flow control valve				181HIC0003.OP			
	Maximum carbon number	Moles of carbon to flare	Required Steam flow	Required valve opening	MP Steam to 181-Rf-001	Estimated steam flow	Excess steam being wasted	Steam deficit
Timestamp	-	kmol/h	kg/h	%	%	kg/h	kg/h	kg/h
14/11/2013 07:00:00	3.10	7182	10773	25	15	6344	0	4430
14/11/2013 07:00:30	3.10	7057	10586	25	15	6344	0	4242
14/11/2013 07:01:00	3.10	7043	10564	25	15	6344	0	4220
14/11/2013 07:01:30	3.10	7225	10837	26	15	6344	0	4494
14/11/2013 07:02:00	3.10	7365	11048	26	15	6344	0	4704
14/11/2013 07:02:30	3.10	7636	11453	27	15	6344	0	5110
14/11/2013 07:03:00	3.10	7495	11242	27	15	6344	0	4898
14/11/2013 07:03:30	3.10	7681	11522	27	15	6344	0	5178
14/11/2013 07:04:00	3.10	7636	11454	27	15	6344	0	5110
14/11/2013 07:04:30	3.10	7675	11512	27	15	6344	0	5169
14/11/2013 07:05:00	3.10	7584	11376	27	15	6344	0	5032
14/11/2013 07:05:30	3.10	7648	11471	27	15	6344	0	5128
14/11/2013 07:06:00	3.10	7718	11578	27	15	6344	0	5234
14/11/2013 07:06:30	3.10	7626	11439	27	15	6344	0	5096
14/11/2013 07:07:00	3.10	7579	11369	27	15	6344	0	5025
14/11/2013 07:07:30	3.10	7589	11383	27	15	6344	0	5039
14/11/2013 07:08:00	3.10	7588	11382	27	15	6344	0	5038
14/11/2013 07:08:30	3.10	7594	11391	27	15	6344	0	5047
14/11/2013 07:09:00	3.10	7316	10974	26	15	6344	0	4631
14/11/2013 07:09:30	3.10	7104	10656	25	15	6344	0	4312
14/11/2013 07:10:00	3.10	7230	10844	26	15	6344	0	4501
14/11/2013 07:10:30	3.10	7209	10814	26	15	6344	0	4470
14/11/2013 07:11:00	3.10	7023	10534	25	15	6344	0	4190
14/11/2013 07:11:30	3.10	6883	10324	24	15	6344	0	3981
14/11/2013 07:12:00	3.10	6948	10422	25	15	6344	0	4078
14/11/2013 07:12:30	3.10	7177	10766	25	15	6344	0	4422
14/11/2013 07:13:00	3.10	7283	10925	26	15	6344	0	4581
14/11/2013 07:13:30	3.10	7252	10878	26	15	6344	0	4534
14/11/2013 07:14:00	3.10	7322	10983	26	15	6344	0	4639
14/11/2013 07:14:30	3.10	7673	11510	27	15	6344	0	5166
14/11/2013 07:15:00	3.10	7885	11827	28	15	6344	0	5483

5. Conclusions

Zero soot formation from the flare stack in any emergency situation by adopting automatic control with feed forward control technic. Meet or exceed government legislation, and eliminate risk of non-compliance, as flare opacity is always less than Ringlemann index#2.

Economical benefits by adopting automatic control of soot from flares are, $70/ hour saving by reducing excess steam to flares, consider that Natural gas price is $1/mmbtu and raw water price is $5/m3. International Carbon Trade: 1Carbon Credit = 1ton CO2 removed = $12 in today's market. Due to reduction of excess steam, total CO2 reduction to atmosphere is 7.45ton/day. US Environmental

Protection Agency proposal would strengthen the annual health standard for harmful fine particle pollution (PM2.5) to a level within a range of 13µg/ m3 to 12µg/m3. The current annual standard is 15µg/m3. By proposing a range, the agency will collect input from the public as well as a number of stakeholders, including industry and public health groups, to help determine the most appropriate final standard to protect public health.

6. Future Scope

Ultrasonic flow meters are very expensive and these meters are very sensitive for hydrogen gas. When there is a CO_2 gas and propane gases are in the vent gas, Gas Chromatography may not gives the proper gas composition as both gases molecular weights are same. In future cost reduction on ultrasonic flow meters installation and GC accuracy needs to consider for further research work.

7. Acknowledgment

I express my profound gratitude and sincere thanks to my research supervisor Dr KVSG Murali Krishna, Professor of Civil Engineering, JNTUK, Kakinada, Andhra Pradesh, India for his valuable and dynamic supervision throughout the progress of this work.

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Author Profile

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