Forensic investigation of catalyst performance in a large scale system

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Introduction

Consider a case study of a combined cycle gas turbine power plant with a heat recovery steam generator (HRSG) and an oxidation catalyst to control carbon monoxide and VOCs. Shortly after startup stack emissions approach permit limit. This paper describes a comprehensive forensic investigation revealing surprising and unexpected root causes.

Materials and Methods

The paper describes the design basis of this platinum on alumina oxidation catalyst. Catalyst elements were pulled from the HRSG and tested in several reactors at the design flow rate, temperature and inlet CO concentration. The catalyst performed as designed. Evidence pointed to system causes for high stack emissions. A field inspection failed to reveal a root cause. A gas sampling probe and a temperature probe were inserted upstream of the catalyst but proved inconclusive. Full simultaneous traverses were performed upstream and downstream of the catalyst measuring flow rate, temperature, and CO concentration. The paper describes the reactor equipment and the field sampling equipment.

Results and Discussion

Even after passing through the HRSG's perforated plate diffuser, superheater and HP evaporator tube bundles the turbine's CO exhaust concentration was highly maldistributed and the average was higher than the design basis translating into a higher catalyst outlet concentration. The mass flow rate was maldistributed and the average was higher than the original design spec translating into higher gas hourly space velocity and reduced catalyst performance. The single upstream temperature probe was not representative of the maldistributed temperature nor did it reflect the low temperature in most zones translating into reduced catalyst performance.

With this spatial data the performance of the entire catalyst grid was analyzed, zone by zone, using known mass flow rate, operating temperature and inlet and outlet CO concentrations. Each zone was performing as it should under those conditions, confirming reactor test results. The mass emissions of CO exiting each catalyst zone were summed to predict the value measured at the stack. The investigation explained in engineering terms how the catalyst could be performing well while the stack emissions were expectedly high.

Significance

Having complete traverse data upstream and downstream of a catalyst system is rare and very revealing. It provides a detailed look at the distribution of flow, temperature, and concentration inside a HRSG regardless of the mixing expected from perforated plates and heat transfer tubes and independent of CFD modeling predictions. It reveals the potential magnitude of maldistribution. It also reveals that taken alone, data from a stack CEMS and a single temperature probe can be very misleading when diagnosing catalyst performance.

Table 1 Carbon Monoxide Measured by Traverse Across the Inlet of the Oxidation Catalyst

	Measured CO Inlet (ppmvd)			
Level	1	2	3	4
6	50.2	49.3	48.5	45.6
5	46.5	41.8	42.1	36.7
4	34.8	27.8	27.9	27.3
3	No Data	No Data	No Data	No Data
2	No Data	No Data	18.4	16.6
1	17.7	18.7	28.8	62.5
	Average CO (RMS) – 36.1 ppmvdc			
	Average CO (weighted) – 33.8 ppmvdc			

Table 2 Exhaust Gas Temperature Measured by Traverse Across the Inlet of the Oxidation Catalyst

	Measured Temperature (F)			
Level	1	2	3	4
6	626	574	573	566
5	553	522	529	520
4	614	580	573	572
3	610	571	569	569
2	No Data	No Data	569	568
1	668	566	568	567
	Average Temperature (RMS) – 550 F			
	Average Temperature (Weighted) – 583 F			

Table 3 Exhaust Gas Velocity Measured by Traverse Across the Inlet of the Oxidation Catalyst

	Measured Velocity (ft/s)			
Level	1	2	3	4
6	43.0	24.0	25.0	26.0
5	16.0	22.0	25.0	25.0
4	16.0	21.0	25.0	28.0
3	21.0	24.0	22.0	21.0
2	No Data	No Data	16.0	21.0
1	53.0	17.0	22.0	18.0
	Average Velocity (RMS) – 24.5 ft/s			