Application of Oxidation Catalysts to Comply with South Coast Air Quality Management District (SCAQMD) Rule 1110.2 Volatile Organic Compound (VOC) Limits

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Introduction and Regulatory Background

South Coast Air Quality Management District (SCAQMD) Rule 1110.2 requires engines to meet a 30 ppm Volatile Organic Compound (VOC) limit. However, the rule allows SCAQMD, with EPA approval, to establish alternate, technologically achievable VOC limits for two-stroke engines on a case-by-case basis because the exhaust temperature on two-stroke engines is generally too low for optimum oxidation catalyst performance and to burn off combustion products on the catalyst to prevent premature fouling. Both the Southern California Gas Company (SoCal Gas) Playa Del Rey Storage Field and San Diego Gas and Electric (SDG&E) Moreno Valley Compressor Station are subject to Rule 1110.2 and conducted a two year demonstration to determine if the 30 ppm VOC limit is sustainable, and when not, to develop an appropriate alternative limit. The demonstration results are summarized below in Table 1, with additional engine data in Table 2.

Table 1
Engine and Demonstration Results

Engines	Was 30 ppm VOC sustainable?	Proposed VOC Limit (ppm @ 15% O2)
SDG&E Moreno Valley HSRA-8LEC	Yes	30
SDG&E Moreno Valley Cooper Quad	No	47
SDG&E Moreno Valley Cooper 8V-275	Yes	30
SoCalGas Playa Del Rey GMVH-10C	No	56

Table 2
Engine Information and Demonstration "Groups"

Facility / Engine Designation	SCAQMD Device ID	Rated HP	Engine Model	Group
Moreno Units 1, 2, & 3	D5, D6 & D7	995	Clark HSRA-8LEC	1
Moreno Units 8 & 9	D8 & D9	3000	Cooper 8Q155HC2 "Quad"	2
Moreno Unit 10	D10	3200	Cooper 8V-275C2	3
Playa Del Rey Units 6, 8, & 9	D14, D16, & D17	2000	Cooper GMVH-10C	4

Since there is no formal process of establishing a limit while under variance, SoCal Gas proposed the criteria for developing more stringent Best Achievable Control Technology (BACT) limits. Specifically, to demonstrate:

Reliability: All control technologies must have been installed and operated reliably for at least six months. If the operator did not require the basic equipment to operate daily, then the equipment must have at least 183 cumulative days of operation. During this period, the basic equipment must have operated: 1) at a minimum of 50% design capacity; or 2) in a manner that is typical of the equipment in order to provide an expectation of continued reliability of the control technology.

Under the Variances, a Test Plan was developed which required VOC tests on each of the engines after approximately 500, 1000, 1500, and 2000 operating hours or at least four times within a 183 cumulative days of operation (approximately every 50 operating days) for demonstrating "reliability."

Effectiveness: The control technology must be verified to perform effectively over the range of operation expected for that type of equipment. If the control technology will be allowed to operate at lesser effectiveness during certain modes of operation, then those modes of operation must be identified. The verification shall be based on a performance test or tests, when possible, or other performance data.

In accordance with the Test Plan, at least two of the four VOC tests were conducted at a lower load to demonstrate "effectiveness" over the operating range of the engines.

Commercial Availability: At least one vendor must offer this equipment for regular or full-scale operation in the United States. A performance warranty or guaranty must be available with the purchase of the control technology, as well as parts and service. Based on good engineering practices, warrantee terms of 8000 operating hours, or 3 years, whichever comes first, was selected.

"Commercial availability" would be demonstrated at the conclusion of the Test Plan when a warrantee was secured from the catalyst manufacturers.

A key assumption of the Test Plan was that the engines would operate enough to complete four tests on each engine. Unfortunately, actual operation was less than expected, so the SCAQMD extended the variance an additional 12 months. Even with the extension, three engines at Moreno Station did not reach the 2000 operating hour threshold, but the catalyst manufacturers and SCAQMD agreed that an alternative limit could be established based on the engine group. The final tests were completed in April 2012 and the final report and permit applications for alternative limits were submitted on June 6, 2012 to allow time for the SCAQMD to secure EPA approval, and issue permits as needed before the variances expires.

Initial Challenges

Commercial: Catalyst manufacturers had no experience with such high VOC destruction efficiency requirements on two-stroke engines. The procurement process included preliminary discussions with several vendors, a Request for Information, and the final Request for Proposal. In all, nine vendors were involved in, but none of them would provide a warrantee at 30 ppm. EnviroKinetics, a catalyst packager was selected as the provider for Moreno. Envirokinetics selected DCL as the primary catalyst manufacturer, and BASF as an alternative for Moreno Units 2 and 8, to satisfy a verbal request from SCAQMD to evaluate two different catalysts. Playa Del Rey's engines were already equipped with BASF catalysts that had been optimized for VOC destruction in an effort to reduce exhaust odor, so procurement of new catalyst was not needed or advised. Note that the BASF catalysts used at Moreno and Playa Del Rey are different. Playa Del Rey uses a BASF CAMET catalyst whereas the alternative catalyst evaluated at Moreno is a BASF VOCat COM-10 catalyst.

Test Methods: Across the country, air agencies regulate VOCs as Non-methane, Non-Ethane Hydrocarbons (NMNEHC) as measured by gas chromatograph using EPA Method 18. Method 18 measures individual hydrocarbon, i.e., methane, ethane, ethylene, propane, and butane. This data is useful to the catalyst manufacturer since temperature has an effect on the reduction efficiency of individual VOCs; and especially at the lower exhaust temperatures typical of two-stroke engines. However, SCAQMD specifies the use of SCAQMD Method 25.3 which complicated the catalyst manufacturer's analysis because:

- Method 25.3 measures VOCs as a bulk value without speciation, except for ethylene.
- Method 25.3 includes formaldehyde as a VOC. While formaldehyde is a VOC, all other air agencies ignore it since it is not detected by EPA Method 18.
- Method 25.3 analytical results are biased by 1.086. This 8.6% increase was included during method development so that Method 25.3 matched SCAQMD Method 25.1 results. Note that SCAQMD Method 25.1 is very similar to EPA Method 25, which is known to be biased high.

Therefore, the catalyst manufacturers had to conduct catalyst performance calculations and life projections using EPA Method 18 results, and then make adjustments for SCAQMD Method 25.3.

Group 1 Engines – Moreno Clark HSRA: Prior to replacement of the turbocharger, there was concern that these engines would not be able to meet the 30 ppm VOC limit due to low exhaust temperature. Even after the turbocharger replacement, several early measurements were over 30 ppm VOC. Although the final turbocharger configuration resulted in a higher exhaust temperature, time was needed to evaluate long term catalyst performance.

Group 2 Engines – Moreno Cooper Quads: Low exhaust temperature and historically higher VOC test results indicated that these engines would have a difficult time meeting the 30 ppm limit. These engines also exhibit an uncommon behavior; due to matching of turbocharger and engine designs, exhaust temperature goes down at higher loads. This made it necessary to manipulate pipeline conditions to achieve near maximum engine load during tests.

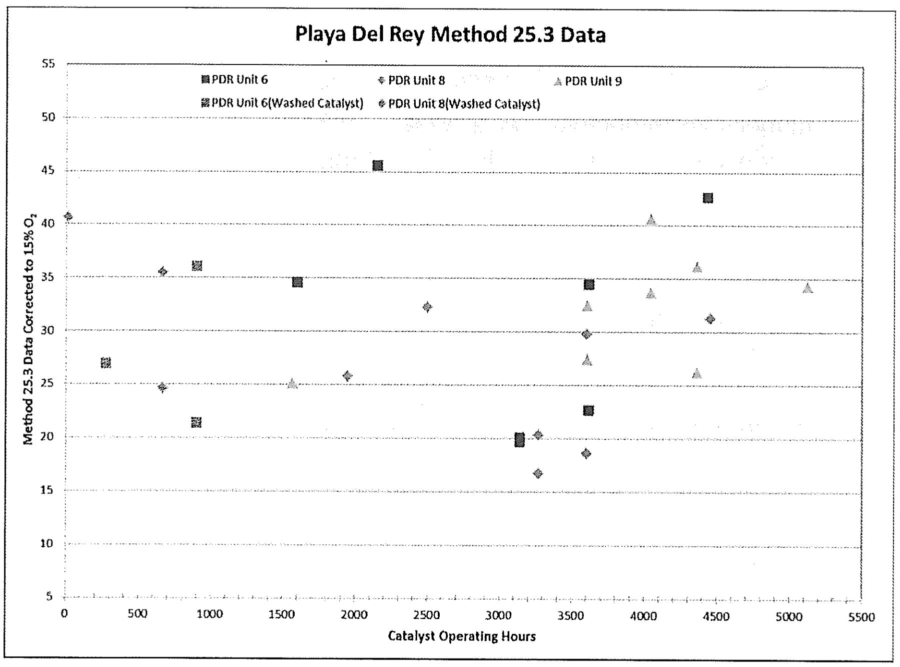
Group 3 Engine – Moreno Cooper 8V-275: Moreno Unit 10 was known to have low VOC emissions, but the original catalyst was not very effective at reducing VOCs. This could have been due to the catalyst being formulated primarily for CO reduction, but it also could have been due to fouling. Since SoCal Gas had never trended the degradation of VOC reduction over time, the exact life of the catalyst was unknown.

Group 4 Engines – Playa Del Rey GMVH-10: Low exhaust temperature and historically higher VOC test results indicated that these engines would have a difficult time meeting the 30 ppm limit. This was particularly apparent since the existing catalyst were oversized and were "heavy loaded" with precious metals for maximum reduction of VOC. The catalyst had been installed in 2007 to successfully eliminate odor complaints; SoCal Gas was not interested in changing the proven catalyst design.

General Findings

Scatter in VOC Concentration Caused Significant Uncertainty: There was considerable variation in the VOC concentration which created uncertainty in the catalyst vendors' life projections and warranty determinations, and made it difficult to make correlations between catalyst performance and engine operating conditions. The variation appears to be a natural behavior of these 2-stroke engines but is also attributable to test method accuracy and catalyst performance within the exhaust temperature range of 2-stroke engines. Inaccuracy in the test method may also have contributed to the scatter. Figure 1 below shows the scatter in Playa Del Rey data.

Figure 1
Normal Scatter in Engine VOC Emissions



Propane Predominate VOC / Catalyst Effectiveness Low for Propane: Reduction of propane was extremely low, typically 20–40 %, and as low as 0%-14% on the engines with lowest exhaust temperature. Since propane is about 40% of the VOC downstream of the catalyst, inadequate propane reduction was the major reason why the 30 ppm limit was challenging. More reactive unsaturated hydrocarbons like formaldehyde and ethylene afford much better conversion. As a result, the real impact on air pollution is much larger than the data implies. According to the Statewide Air Pollution Research Center, propane has a Maximum Incremental Reactivity (MIR) of 0.49 grams ozone formed per gram vs. an MIR of 9.46 and 9.00 for formaldehyde and ethylene, respectively. (http://www.cert.ucr.edu/~carter/SAPRC/) Future regulations should make allowances for high propane sources, and research is needed to develop catalysts that do a better job reducing propane.

Washing Catalyst had Negligible Effect in Improving Catalyst Performance: Washing the catalyst did not support the sustainability of the 30 ppm VOC limit. As shown in Table 6, measurements on PDR D14 and D16 using washed catalyst did not consistently result in VOC concentrations under 30 ppm. In fact, the range of VOC concentration measured on Playa Del Rey Units 6 and 8 is very similar to that of PDR D17 which used unwashed catalyst, ~25–40 ppm. Figure 1 above also depicts similar performance of washed and unwashed catalyst. (This is not to say that washing does not improve catalyst performance. Rather, washing a catalyst with less than 2000 operating hours, did not have enough affect on catalyst performance to make 30 ppm achievable.)

BASF VOCat COM-10 Catalyst Not Found Affective on Group 2 Engines: SCAQMD requested that Moreno evaluate more than one catalyst make, so a BASF VOCat COM-10 catalyst was installed in D6 and D8. Although the BASF VOCat COM-10 catalyst performed similar to the DCL catalyst in the Group 1 engines, that was not the case for Group 2 engines because the exhaust temperature was too low. As a result, the BASF VOCat COM-10 catalyst was removed from D8 and replaced with a DCL catalyst. Note that this does not imply BASF is an inferior catalyst, but rather the VOCat COM-10 was not appropriate for Group 2 engines. The BASF VOCat COM-10 catalyst will be an option for Group 1 engines. Also note that a different model, BASF CAMET, which is used at Playa Del Rey, performed well at lower temperatures.

Technical Approach

PDR Strategy: A lot of thought and effort went into accomplishing an alternative VOC limit for this station. Due to the nature of the engine operation and the scatter observed in the data; the catalyst manufacturer had to conduct catalyst performance studies and make engineering assumptions to propose a warranted representable VOC stack emission limit based on SCAQMD Method 25.3(M25.3).

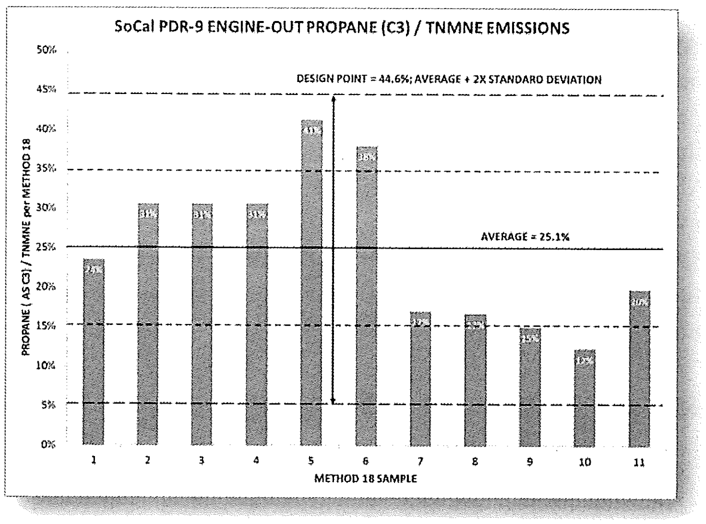
The oxidation catalyst installed at Playa Del Rey Unit 9 has operated in continuous service without maintenance for over 5,000 hours and for over 3 calendar years. As such, having satisfied the calendar durability terms of the warranty, it offers the best characterization of an end-of-warranted life catalyst subjected to the operating and aging environment specific to the Playa Del Rey engines. Although good engineering practices call for an 8000 hour / 3-year warrantee period, the engines at Playa Del Rey are only permitted to run 2100 operating hour/year in order to maintain status as a Large Source under a NOx trading program. Therefore, BASF conducted further analysis on the PDR historical data for the purposes of determining a revised, proposed warranted VOC stack emission per M25.3 enforced for a period of 3 calendar years or 6,300 operating hours, whichever occurs first.

When BASF establishes a warranty position, the intent is to have all installations meet or exceed the warranty requirements. In this particular installation, there are a number of factors that make the determination of the warranty limit more difficult. In particular, it is asked of BASF to subsume all risks associated with the quantity and relative constituent profile of the engine emissions inlet to the catalyst as well as the risk associated with field measurement uncertainty as well as the risk of premature catalyst deactivation under actual engine operating conditions, including frequent start-up and shutdown operation, to the degree manifested in the field data.

In consideration of these risks, BASF has analyzed the Playa Del Rey data set with specific focus on three issues with the intent of formally characterizing and describing the catalyst operating environment in a manner that is consistent with the historical data set for the Playa Del Rey site:

1. The historical data set for Playa Del Rey Unit 9, depicted in Figure 2 below, is used to describe the uncontrolled engine exhaust conditions inlet to the oxidation catalyst with respect to total non-methane non-ethane hydrocarbons (TNMNE) and that portion of the TNMNE that are propane.

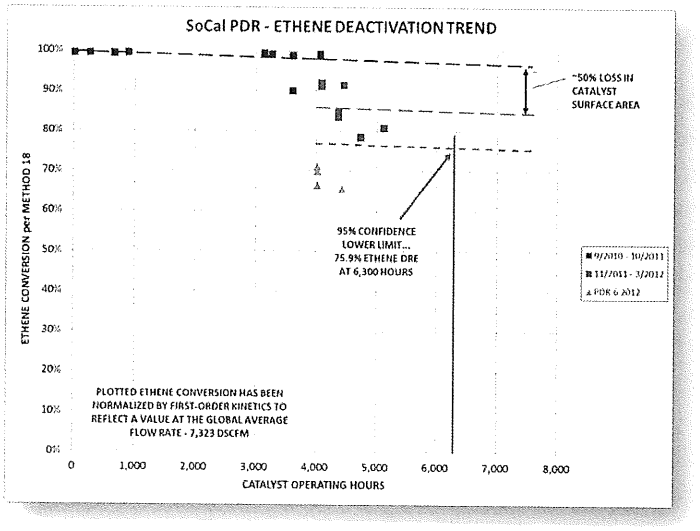
Figure 2
Engine Propane fraction of TNMNE Emissions



2. The catalyst activity trends demonstrated by Playa Del Rey Unit 9 through March 2012 may define the "end of warranted catalyst life," on a compound by compound basis, based on a warranty timeframe of 3 calendar years or 6,300 operating hours (2,100 hours/year), whichever occurs first.

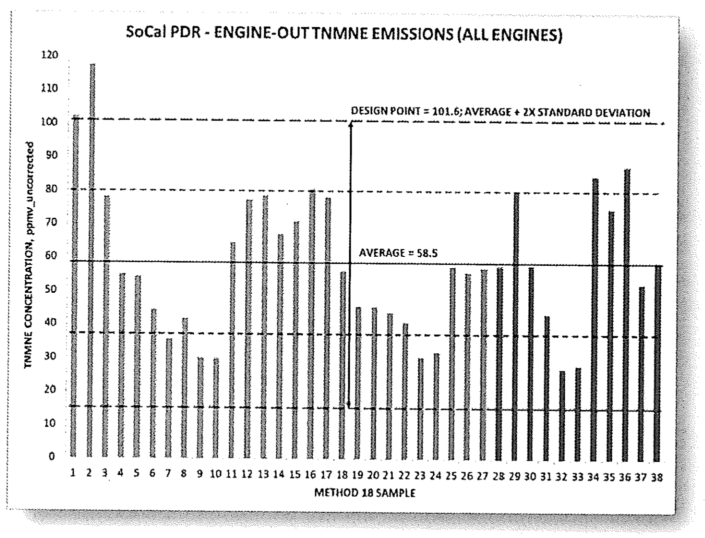
   The observed step-change in ethene deactivation over time for the entire Playa Del Rey population is shown as the difference between the blue dashed line and the red dashed line and is consistent with a 50% loss in catalyst surface area. Figure 3 is one of the approaches that BASF followed to verify the "end of warranted catalyst life".

Figure 3
Catalyst Ethene Deactivation and Projection



3. Contextualization of Playa Del Rey Unit 9 among the greater station engine population with specific interest as to whether the use of Unit 9 as a "representative" engine is valid. Unit 9 (red) values are shown in Figure 4 with those values from Unit 6 (blue) and Unit 8 (green).

Figure 4
Engine TNMNE Emissions



To constrain and define the level of risk associated with the scatter in the field data, BASF chose to describe the scatter in terms of an average value +/- 2 standard deviations from the average value. This defines a range of values in which 95% of the given population would fall if it were assumed to possess a normal distribution of values. BASF has selected from the extents of these ranges those values that would best constrain the risk of non-performance.

DCL Strategy: Four out of the six units at the Moreno station met the SCAQMQ 30ppm VOC limit with the DCL catalyst. The other two units, Unit 8 and 9, did not meet that limit due to a lower exhaust temperature and a significant combustion characteristics difference from the other units which contributed a higher VOC inlet concentration.

A summary of Unit 8 and 9 catalyst efficiency and post catalyst emissions are provided in Figure 5 and 6 below. An alternative VOC limit was projected to cover a warranty of 8000 hours or 3 calendar years, whichever occur first based on only 2200 hours of engine operation. Figure 5 shows minor deterioration in the catalyst conversion efficiency using EPA method 18 results; whereas Figure 6 shows that there was no deterioration in the post catalyst emissions observed with M25.3 concentration.

Figure 5
Catalyst Efficiency Moreno Unit 8 & 9

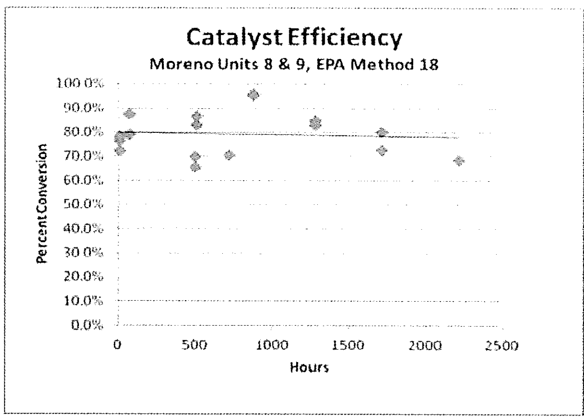
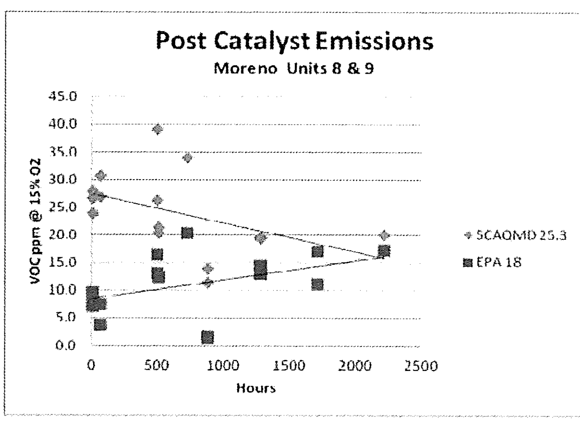


Figure 6
Post Catalyst Emission Moreno Unit 8 & 9



Although no significant post catalyst emissions deterioration was observed with M25.3, DCL thought that it is prudent to assume that deterioration will occur over time. Therefore, DCL recommended a catalyst deterioration factor of 72% after 8000 operating hours based on engineering judgment.

Results

Test results are summarized in Tables 3, 4, 5, and 6, respectively for Engine Groups 1, 2, 3 and 4.

Group 1 Engines – Moreno Clark HSRA Warranted at 30 ppm VOC: Several early measurements attributed to problems during turbocharger commissioning or which could not be repeatable during the final tests were not used in the DCL's warrantee determination. The Group 1 engines exhibited the highest exhaust temperature of all the engines, consistently over 650° and often over 700°. This improved overall catalyst performance, and ultimately DCL provided a 30 ppm VOC warrantee.

Group 2 Engines – Moreno Cooper Quads Warranted at 47 ppm VOC: There were several measurements on each engine near or over 30 ppm VOC. Although there does not appear to be any degradation over time in the SCAQMD Method 25.3 data shown in Table 4, EPA Method 18 results did show some catalyst degradation had occurred. DCL accounted for this degradation and provided a 47 ppm VOC.

Group 3 Engine – Moreno Cooper 8V-275 Warranted at 30 ppm VOC: This is the "work horse" of the station and completed its Test Plan a full year before the other groups. None of the VOC measurements on D10 were over 30 ppm, and with ample compliance margin. Although D10 has the coolest exhaust of all the engines at Moreno, consistently under 600°F, its catalyst did not need to provide as much reduction because engine VOC emissions are about 40 to 60 ppm less than the other engines. DCL provided a 30 ppm VOC warrantee.

Group 4 Engines – Playa Del Rey GMVH-10 Warranted at 56 ppm VOC: Early analysis by BASF showed that engine emission variability, and high levels of propane added significant uncertainty to the point where BASF was only willing to warrantee 80 ppm VOC. Prior to the final tests, SoCal Gas conducted in-house tests to better characterize engine propane emissions, and were unable to re-create the high propane observed on Unit 6 and 8 in March 2013. Therefore, SoCal Gas instructed BASF to exclude these high propane levels in their final analysis. Also, since these engines can only operate 2100 hours per year to maintain status as RECLAIM Large Sources, BASF set the warrantee terms as 3 years or 6300 hours, whichever comes first, instead of 8000 hours. As a result, BASF provided a 56 ppm VOC warrantee for these engines.

Current Catalyst Status: Shortly after completion of the tests, two oxidation catalysts due to exceeding or potentially exceeding the permitted VOC limit: the Group 3 engine catalyst had over 9000 hours before it exceeded the permitted 30 ppm VOC limit, and one Group 4 engine had over 5000 hours in a 4 years period when it approached its 89 ppm CO limit. Both replaced catalyst will be washed and re-commissioned as soon as a new catalyst replacement is needed. When re-installed, the washed catalyst performance will be monitored to determine if washing is cost effective. Although previous tests demonstrated that washing did not help the catalyst meet 30 ppm VOC, there was an improvement in performance.

The need to replace catalyst at near the end operating hours given in the warrantee indicates there is virtually no compliance margin in the VOC limits. Although project goals were met, other catalysts in the SoCalGas system have performed well beyond warrantee terms. Replacing catalyst every 8000 hours is not a practical or economical solution to meet the new VOC limit requirement, so further research is needed to develop a better understanding of the application of oxidation catalyst to two strokes and even four strokes lean burn engines typically used in the natural gas pipeline industry.

Conclusion

Over 2 years of trending VOC emissions on two-stroke lean burn engines revealed that 30 ppm VOC is not always sustainable. An appropriate VOC limit must be developed on a case-by-case basis to account for engine specific emissions, operating conditions and ranges, and exhaust temperature. More details regarding the technical development of the alternative limits are available in reports provided by the catalyst manufacturers, DCL for Moreno Valley and BASF for Playa Del Rey. Final warranted limits provided by the manufacturers are shown in Table 1.

Propane was found to be the most significant VOC downstream of the catalyst and will be a concern as lower VOC limits are accepted by other air agencies. In fact, propane could be a problem on some four-stroke lean burn engines at low load or with low exhaust temperature. Research should be performed to better understand and/or improve propane reduction, as well as lobbying efforts to treat propane differently since it is a less reactive VOC.

It should be noted that these results may not be easily applied to other applications. Most notable, the limits were established based on SCAQMD Test Method 25.3 which is not applicable outside of the SCAQMD. Moreover, these engines may not be representative of other engines found in the pipeline industry due to additional scrutiny under the Regional Clean Air Incentive NOx Market (RECLAIM) which has led to a higher-than-normal level of performance monitoring including:

- Engines are equipped with better than average Air Fuel Ratio (AFR) control.
- Engines condition is continuously monitored. RECLAIM Major Source engines have Continuous Emission Monitoring Systems (CEMS) to assure NOx stays within the CEMS range, and smaller RECLAIM Large Sources have AFR controller alarms.
- All engines have Continuous Pressure Monitoring (CPM) of the main chamber and some also have ion sensing of pre-combustion chambers. This technology allows the operator to quickly identify and correct combustion problems that may affect NOx, and also cause catalyst overheating.
- Engines are equipped with high outlet temperature shut downs.

This, coupled with appropriate lubrication of the engine, and high exhaust temperature shut downs at the catalyst outlet helped minimize catalyst degradation and damage to assure maximum catalyst life. However, even with these high levels of monitoring, catalyst manufacturers did state that washing may be needed under the warrantee.

Over the next few years, catalyst performance will be watched carefully. Quarterly or every 2000 operating hour portable analyzer checks for CO are required under Rule 1110.2. However, CO may not provide a direct indicator of VOC reduction. SoCal Gas will develop a strategy to internally monitor and to observed catalyst performance and project the need for washing or replacement.

Although project goals were met, further research is needed to better understand the application of oxidation catalyst to two stroke engines, and even four stroke engines used in the pipeline industry.

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Table 3

Test Results Summary Moreno Valley Engine Group 1

	Catalyst Installed (mfg)	Test Results VOC (ppmv)	Exhaust Temp When Tested (deg F)	Load When Tested (%)	Test Date or Projected Date	Catalyst Operation (Hours)
	SDG&E Moreno/Fac. ID 004242/Clark HSRA-8LEC Device D5					
Initial Test	DCL	52.6	698	87	8/23/10	3
Re-Test	DCL	17.7	728	96	1/27/11	70
Re-Test	DCL	18.2	703	86	1/27/11	70
First Test - High	DCL	12.9	699	96	10/4/11	392
First Test - Low	DCL	16.2	655	84	10/4/11	392
Second Test - High	DCL	11.9	711	96	2/2/12	957
Second Test - Low	DCL	21.5	693	78	2/2/12	957
Third Test - High	DCL	8.4	735	91	4/9/12	1454
Third Test - Low	DCL	10.95	743	75	4/9/12	1454

	SDG&E Moreno/Fac. ID 004242/Clark HSRA-8LEC Device D6					
Initial Test	BASF	16.7	755	89	6/22/10	4.8
First Test - High	BASF	20.0	731	95	3/1/11	477
First Test - Low	BASF	36.4	688	78	3/1/11	477
Second Test - High	BASF	14.6	727	95	10/5/11	977
Second Test - Low	BASF	19.6	695	84	10/5/11	977
Third Test - High	BASF	11.7	740	96	2/2/12	1623
Third Test - Low	BASF	12.6	763	79	2/2/12	1623

	SDG&E Moreno/Fac. ID 004242/Clark HSRA-8LEC Device D7					
Initial Test	DCL	17.1	747	91	5/19/10	25.1
First Test - High	DCL	21.0	685	96	3/1/11	646
First Test - Low	DCL	53.4	603	75	3/1/11	646
Second - High	DCL	11.2	707	92	9/16/11	1184
Second - Low	DCL	16.1	701	79	9/16/11	1184
Third Test - High	DCL	13.2	701	92	10/5/11	1323
Third Test - Low	DCL	18.2	676	78	10/5/11	1323
Fourth Test - High	DCL	11.54	688	91	4/9/12	2157
Fouth Test - Low	DCL	16.29	695	75	4/9/12	2157

Table 4

Test Results Summary Moreno Valley Engine Group 2

	Catalyst Installed (mfg)	Test Results VOC (ppmv)	Exhaust Temp When Tested (deg F)	Load When Tested (%)	Test Date or Projected Date	Catalyst Operation (Hours)
	SDG&E Moreno/Fac. ID 004242/Cooper 8Q155HC2 Device D8					
Initial Test	BASF	78.5	558	76	5/27/10	12.4
Re-tests on BASF VOCat COM-10	BASF	51.2	624	88	9/10/10	14.5
	BASF	39.0	663	70	11/18/10	14.5
Initial Test - High	DCL	23.9	635	92	2/2/11	7.5
Initial Test - Low	DCL	26.7	643	76	2/2/11	7.5
First Test - High	DCL	30.8	621	90	11/23/11	76
First Test - Low	DCL	26.9	624	77	11/23/11	76
Second Test - High	DCL	21.4	602	95	2/1/12	511
Second Test - Low	DCL	20.1	628	77	2/1/12	511
Third Test - High	DCL	34.0	559	96	4/10/12	721
	SDG&E Moreno/Fac. ID 004242/Cooper 8Q155HC2 Device D9					
Initial Test	DCL	28.0	597	80	5/26/10	6.5
First Test - High	DCL	39.1	603	93	2/2/11	498
First Test - Low	DCL	26.3	647	73	2/2/11	498
Second Test - High	DCL	14.0	683	78	10/4/11	881
Second Test - Low	DCL	11.5	683	70	10/4/11	881
Third Test - High	DCL	19.4	638	91	2/1/12	1282
Third Test - Low	DCL	19.6	651	78	2/1/12	1282
Fourth Test - High	DCL	20.2	594	95	4/10/12	2218

Table 5

Test Results Summary Moreno Valley Engine Group 3

	Catalyst Installed (mfg)	Test Results VOC (ppmv)	Exhaust Temp When Tested (deg F)	Load When Tested (%)	Test (Date)	Catalyst Operation (Hours)
	SDG&E Moreno/Fac. ID 004242/Cooper 8V-275C2 Device D10					
Initial Test	DCL	20.3	520	95	5/26/10	112
First Test - High	DCL	21.7	520	94	9/20/10	836
First Test - Low	DCL	24.8	538	77	9/20/10	836
Second Test - High	DCL	20.9	543	99	1/5/11	1765
Second Test - Low	DCL	18.3	596	74	1/5/11	1765
Third Test - High	DCL	12.9	527	99	1/31/11	2301
Third Test - Low	DCL	13.3	551	87	1/31/11	2301
Fourth Test - High	DCL	18.6	529	97	4/26/11	3392
Fourth Test - Low	DCL	17.2	590	74	4/26/11	3392

Table 6

Test Results Summary Playa Del Rey Engine Group 4

	Catalyst Installed (mfg)	Test Results VOC (ppmv)	Exhaust Temp When Tested (deg F)	Load When Tested (%)	Test Date or Projected Date	Catalyst Hours When Tested (Hours)
	SoCalGas Playa Del Rey Storag/Fac. ID 008582/Cooper GMVH-10 Device D14					
Historical Test	BASF CAMET	34.6	600	96	9/8/09	~1600
Historical Test	BASF CAMET	45.6	662	97	1/14/10	~2150
First Test -High	BASF CAMET (washed)	26.9	618	96	9/13/10	277
Second Test - High	BASF CAMET (washed)	21.4	611	97	3/3/11	903
Second Test - Low	BASF CAMET (washed)	36.1	580	88	3/3/11	903
Third Test - High	BASF CAMET (used)	20.1	590	93	8/4/11	3143
Third Test - Low	BASF CAMET (used)	19.7	584	89	8/4/11	3143
Fourth Test - High	BASF CAMET (used)	42.7	585	97	3/15/12	4433
	SoCalGas Playa Del Rey Storag/Fac. ID 008582/Cooper GMVH-10 Device D16					
Historical Test	BASF CAMET	25.8	595	96	9/8/09	~1950
Historical Test	BASF CAMET	32.3	673	97	1/14/10	~2500
First Test - High	BASF CAMET (washed)	40.6	593	94	9/13/10	18
Second Test -High	BASF CAMET (washed)	24.6	596	97	3/3/11	670
Second Test - Low	BASF CAMET (washed)	35.5	587	90	3/3/11	670
Third Test - High	BASF CAMET (used)	16.7	631	96	8/4/11	3274
Third Test - Low	BASF CAMET (used)	20.3	622	92	8/4/11	3274
Fourth Test - High	BASF CAMET (used)	31.3	613	96	3/15/12	4457
	SoCalGas Playa Del Rey Storag/Fac. ID 008582/Cooper GMVH-10 Device D17					
Historical Test	BASF CAMET	25.1	627	97	9/8/09	1570
First Test - High	BASF CAMET	32.5	659	96	9/30/10	3608
First Test - Low	BASF CAMET	27.4	654	93	9/30/10	3608
Second Test - High	BASF CAMET	33.7	632	96	2/1/11	4064
Second Test - Low	BASF CAMET	40.6	626	92	2/1/11	4064
Third Test - High	BASF CAMET	26.2	620	97	11/30/11	4491
Third Test - Low	BASF CAMET	36.2	605	88	11/30/11	4491
Fourth Test - High	BASF CAMET	32.4	619	96	3/15/12	5125