1. EXECUTIVE SUMMARY

Clean Air Engineering (CleanAir) has been contracted by Marathon Petroleum Company (MPC) to generate this test report for the drift emissions testing of Cooling Tower 76 also known as the Coker Tower located at the MPC Refinery in Detroit, MI.

The objective of the test effort was to accurately quantify the drift emission rate of the cooling tower to assess compliance with regulatory requirements. Two drift test runs were completed on cell 76F202 of Cooling Tower 76.

This document addresses the specifics of testing of Cooling Tower 76 on August 9, 2020. All drift emissons testing was conducted in accordance with the site specific drift test plan written by CleanAir under the guidelines of the CTI ATC-140 (2011), Isokinetic Drift Test Code.

Based on the test data collected during August 9, 2020, the drift emission rate for Cooling Tower 76 was 0.00120% of the circulating water flow rate based on calcium and magnesium as the chosen tracer elements.

In the unlikely event that changes to this report are required, the changes will be documented in the revision log and resubmitted to MPC for distribution to the appropriate parties.

End of Section

2. TEST OVERVIEW

Scope of Work

CleanAir was retained by MPC to perform drift emissions testing on Cooling Tower 76 located at the MPC Refinery in Detroit, MI.

All drift emissions testing was conducted in accordance with the site-specific drift test plan written by CleanAir under the guidelines of the CTI ATC-140 (2011), Isokinetic Drift Test Code.

The objective of the test effort was to accurately quantify the drift emission rate of the cooling tower to assess compliance with regulatory requirements. Two drift test runs were completed on one cell.

Cooling Tower Descriptions

Cooling Tower 76 consists of 4 counterflow cells with three circulating water pumps available to circulate the water to the plant process equipment. Each cell of the tower is equipped with a single fan. The tower was configured in normal summertime operation during testing.

All of the cooling tower cells contain the same components and cool the same circulating water. Thus, for cells with consistent components and in the same state of repair, it is reasonable to test one cell and consider it representative of the entire tower.

Test Schedule

The schedule of events for the testing is shown in Table 2-1. A list of personnel participating on site during the test is shown in Table 2-2.

Table 2-1: Test Schedule

Date	List of Activities
August 9, 2020	Finished setup Drift equipment on Cooling Tower 76 and performed 2 drift test runs.

Table 2-2: Test Participants

Name	Company	Role
Jacob Ortman	CleanAir Engineering	Test Director
James M. Sutton	CleanAir Engineering	Test Engineer
Skyler Turner	CleanAir Engineering	Test Technician
Cody Spoon	MPC	Witness

End of Section

3. METHODOLOGY

Test Instruments and Execution

CleanAir performed two drift emissions tests on Cooling Tower 76. The performance instruments used for the testing were supplied and calibrated by CleanAir at the CleanAir calibration facility in Powell, TN. The instruments used for the testing met the requirements set forth in the governing test plan and ATC-140.

The circulating water flow rate to the tower was measured by a plant annubar. MPC provided the data trend for the entire day of testing on August 9, 2020.

Barometric pressure was taken with a Testo hand held barometer once at the start of the test day.

An ambient air sample was collected with a high volume air sampler. The sampler was placed upwind of the cooling tower near the air inlet to the test cell. One filter was exposed during the duration of the test runs. The objective of this sampling was to provide guidance as to the selection of tracer elements.

During the execution of the drift tests, the airflow speed and direction were measured at each of the sampling locations in order to set the "target" sampling velocity at the inlet to the glass bead pack. The air speed and direction measurements were made with an S-type "double" pitot consisting of two pitots positioned at 90 degrees to each other and mounted on the end of the sampling boom near the sampling nozzle. The differential pressure of the angle sensing pitot was measured locally with a Magnahelic gauge. The velocity pressure of the flow measuring pitot was measured with an inclined manometer. The angle of rotation of the sample train was directly measured with a protractor after the sample train was aligned with the flow.

The flow rate through the sampling train was measured with a certified orifice in a dimensional flow section. Differential pressure across the orifice was also measured with an inclined manometer. Barometric pressure, inlet temperature (stack temperature) and flow section temperature were measured to correct for the density difference between the air at the sampling probe inlet and the air flowing through the orifice. After assembly in the field, the sampling train was leak checked under a strong vacuum to ensure the integrity of the sampling train.

The primary collection media for the HGBIK test is a Teflon cylinder containing tightly packed Pyrex beads. Exhaust air from the cooling tower containing the mineral bearing drift droplets are drawn through the bead pack and backup filter by a large vacuum pump. The outside of the cylinder is heated so that when drift droplets impact the heated beads, moisture is driven off and the non-volatile solids present in the drift (metallic salts) are deposited on the beads. The backup filter captures any mineral mass which escapes the bead pack. The drift rate is a function of the collected mineral mass as explained below. One glass bead cylinder and one backup filter are used per test.

Six locations on each of four radii were sampled for each test run. Table 3-1 contains the radial sampling stations at the stack exit plane.

Sample Locations

The sampling locations was based on the net area and located at the centroids of equal area, annular sample zones with a minimum of 4 radii and 6 points per radius. The position of the sampling locations is calculated by:

$$X_i = \frac{D_s}{2} - \sqrt{\left[\left(\frac{2N-2i+1}{8N}\right)(D_s^2 - D_h^2)\right] + \left(\frac{D_h}{2}\right)^2} \quad \text{(Eq. 1)}$$

Where:

X_i	=	sample location i, distance from wall
D_s	=	stack diameter at the sampling plane
D_h	=	effective hub diameter
N	=	number of sampling points on a single radius
i	=	sampling point number

CleanAir measured the diameter of the fan stack and the effective hub diameter at the exit plane while deploying the test equipment.

Six locations on each of four radii were sampled for each test run. Table 3-1 contains the radial sampling stations at the stack exit plane.

Table 3-1: Radial Sampling Positions

Sampling Position	Inches
1	7.8
2	24.6
3	43.2
4	64.7
5	90.7
6	126.9

Performance Conditions

On test day, a water sample was taken and labeled for further testing of surface tension. The sample was measured upon return of the test crew with a CSC Precision DuNouy Tensiometer. The typical lower limit for acceptable surface tension is 63 dynes/cm. The surface tension measurement is included in Table 3-2.

Table 3-2: Surface Tension Measurements

Date	Dynes/cm
8/9/20 (Tower 76)	69.6

A summary of the selection criteria and target values for the candidate tracers are presented in Tables 3-3. Target values were assigned by CleanAir in the drift emissions test plan.

Table 3-3: Elemental Tracer Selection Criteria Tower 76 Cell 76F202

August 9, 2020 Tower 76 Cell 76F202 Test Run 1	Target	Ca	Mg
Ratio of bead pack concentration to RDL	>5	14.15	4.31
Ratio of bead pack concentration to procedural blank	>5	39.47	NA
Ratio of stack concentration to ambient concentration	>5	0.94	0.82
August 9, 2020 Tower 76 Cell 76F202 Test Run 2	**Target**	**Ca**	**Mg**
Ratio of bead pack concentration to RDL	>5	18.88	7.49
Ratio of bead pack concentration to procedural blank	>5	47.68	NA
Ratio of stack concentration to ambient concentration	>5	1.16	1.31

The results listed as "NA" in Table 3-3 are due to the fact that analyses of the procedural blank returned a non-detect for the tracer element. Non-detect means the concentration was below the detection limit of the analysis technique. In this case, "NA" indicates that these criteria are acceptable. In all cases the ratios of the bead pack concentration to the detection limit and the procedural blank were within the acceptable values.

The ratio of concentration of the tracer elements in the stack gas to that in the ambient air is lower than the target value for both potential tracer elements. For all of the tests, the concentration of calcium and magnesium in the ambient air is greater than the concentration in the stack. This can be caused by vehicles driving near the tower or any nearby earth moving activities in the immediate area.

CTI ATC-140 dictates that an ambient air sample be collected during each drift test run to evaluate the amount of the tracer element in the air in the vicinity of the tower. Substantial amounts of the tracer in the ambient air may lead to a reported drift rate that is artificially high. This positive bias occurs when mineral bearing ambient air enters the tower and the minerals are not scrubbed by the falling water within the tower, but the minerals are captured by the drift sampling equipment. Since the scrubbing effect of individual cooling towers is unknown, as indicated in ATC-140, a correction for the ambient concentration cannot be applied.

The governing test plan states that the tower is to be configured in normal summertime operation with respect to the circulating water flow rate, fan speed, and tower bypass. A summary of the target conditions as well as the corresponding test conditions are presented in table 3-4.

Table 3-4: Operating Conditions Tower 76 Cell 76F202

Description	Target Range	Test	Test Value
Circulating Water Flow Rate (per cell)	Normal Summertime Operation	1 and 2	11,001 gpm
Fan Motor Power	Normal Summertime Operation	1 and 2	Normal Summertime Operation
Circulating Water Chemistry	Ca > 200 ppm Mg > 100 ppm	1 and 2	Ca: 172 ppm Mg: 51 ppm

Because the objective of this testing is to quantify the tower emissions during normal summertime operation, current "normal" operation may be different than the original thermal design specifications. The drift testing was conducted in accordance with the site test plan and the tower was operated in manner consistent with normal operation during the summer.

End of Section

4. CALCULATIONS

Air Velocity Calculations

Air Velocity with Flow Sensing Portion of Double "S-type" Pitot

$$V_{stack} = 1097 * C_{pitot} * \sqrt{\frac{\Delta P_{pitot}}{\rho_{stack}}} \quad \text{(Eq. 2)}$$

Where:

V_{stack} = stack air velocity at measurement point, ft/min
C_{pitot} = coefficient for S-type pitot tube, dimensionless
ΔP_{pitot} = manometer deflection for pitot tube, inwg
ρ_{stack} = density of saturated air at stack temperature and pressure, lbm/ft^3

The density is a function of the barometric pressure, the stack temperature and stack gas composition. The composition of the stack gas is assumed to be saturated air.

The velocity of the air entering the sampling nozzle is adjusted by valve manipulation to match, as closely as possible, the air velocity at each of the sampling stations.

Mass Air Flow Rate through Metering Section

$$\dot{m}_{air} = C_D * \sqrt{\rho_{meter} * \Delta P_{orifice}} \quad \text{(Eq. 3)}$$

Where:

$\dot{m}_{air}$ = mass air flow rate through sampling train, lbm/min
C_D = discharge coefficient for metering section, (lbm/min)/(inwg-lbm/ft^3)$^{.5}$
$\Delta P_{orifice}$ = differential pressure measurement for metering orifice, inwg
ρ_{meter} = density of saturated air at orifice temperature and pressure, lbm/ft^3

Air Velocity at HGBIK Tube Inlet

$$V_{tube} = \frac{\dot{m}_{air}}{\rho_{stack} * A_{tube}} \quad \text{(Eq. 4)}$$

Where:

V_{tube} = velocity of the air entering the HGBIK tube inlet, ft/min
A_{tube} = area of HGBIK tube inlet, ft^2

Drift Emissions Calculations

Exiting Tracer Mass

The test apparatus is used to collect an integrated sample of the exiting tracer mass from across the stack.

$$W_T = (M_{GB} - M_{GBB}) + (M_F - M_{FB}) \quad \text{(Eq. 5)}$$

Where:

W_T = the net mass recovered from the glass bead pack and the back-up filter for the selected tracer element (e.g. µg magnesium)

M_{GB} = mass recovered from the glass bead pack for the selected tracer element (e.g. µg magnesium)

M_{GBB} = mass recovered from the glass bead field blank for the selected tracer element (e.g. µg magnesium)

M_F = mass recovered from the back-up filter for the selected tracer element (e.g. µg magnesium)

M_{FB} = mass recovered from the back-up filter field blank for the selected tracer element (e.g. µg magnesium)

Total Circulating Water Emitted as Drift

$$\%Drift = 100 * K_1 * \frac{A_{SP}}{A_N} * \frac{w_T}{A_N * Q_{WT} * t_s * C_{TC}} \quad \text{(Eq. 6)}$$

Where:

A_N = nozzle area, m^2

A_{SP} = sample plane area, m^2

C_{TC} = circulating water tracer concentration, mg/L

K_1 = 0.001 mg/µg for SI units

Q_{WT} = water flow rate during test, L/s

t_s = total sample time, s

Although the equations listed above are for one element, when available in enough concentration, multiple elements are analyzed and used in parallel as a quality assurance step. This is beneficial since an unexpectedly high concentration in a blank or ambient sample for one element may not be present for other elements. A sample calculation is included in Appendix C.

The test samples were brought to CleanAir for chemical recovery. The glass bead packs were rinsed with multiple rinses of ultrapure hydrochloric acid and water solutions. The chemical mass on the filters were recovered by digestion in an acid solution. The samples were sent to a laboratory for chemical analyses by Inductively Coupled Plasma (ICP) which provides a highly accurate analysis of a relatively small sample.

End of Section

5. DRIFT EMISSONS SUMMARY

Performance Evaluation

Table 5-1 summarizes the results of the tests conducted on Cooling Tower 76 on August 7, 2020.

Table 5-1: Drift Emissons Test Results

Cell #	Test ID	Date	Drift Rate Ca	Drift Rate Mg
76F202	Test 1	8/9/20	0.00101%	0.00084%
76F202	Test 2	8/9/20	0.00143%	0.00153%
Tower Average	**0.00120%**			

The calculated drift emission rate for Cooling Tower 76 was 0.00120% of the circulating water flow rate. Composite results were based on calculations using calcium and magnesium as the chosen tracer.

Laboratory analyses are included in Appendix D. Drift test data and calculations are included in Appendix B.

End of Section