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May 23, 2024

VIA U.S. MAIL

Mr. Steve Kahl
Executive Secretary Director
North Dakota Public Service Commission
600 E. Boulevard, Dept. 408
Bismarck, ND 58505-0480

RE: SCS Carbon Transport LLC
Midwest Carbon Express Project
Case No. PU-22-391

Dear Mr. Kahl:

Enclosed herewith, please find the following documents for filing with the North Dakota Public Service Commission ("Commission") in the above-referenced case:

1. Response of SCS Carbon Transport LLC to the Interrogatories and Requests for Production (Set 4) from Intervenors Represented by Knoll Leibel LLP and Jorde/Domina Law Group; and
2. Certificate of Service.

An original and seven (7) copies of the foregoing are enclosed herewith. This letter and the above-described documents have been electronically filed with the Commission by e-mailing copies of the same to ndpsc@nd.gov.

Should you have any questions, please advise.

Sincerely,

LAWRENCE BENDER

LB/tjg
Enclosures

#82586759v1

577 PU-22-391 Filed 05/23/2024 Pages: 141
Response to the Interrogatories and Requests for Production (Set 4) from Intervenors Represented by Knoll Leibel LLP and Jorde/Domina Law Group

SCS Carbon Transport LLC
Lawrence Bender, Fredrikson&Byron, P.A.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF NORTH DAKOTA

IN THE MATTER OF THE APPLICATION OF SCS CARBON TRANSPORT LLC FOR A CERTIFICATE OF CORRIDOR COMPATIBILITY AND ROUTE PERMIT FOR THE MIDWEST CARBON EXPRESS PROJECT IN BURLEIGH, CASS, DICKEY, EMMONS, LOGAN, MCINTOSH, MORTON, OLIVER, RICHLAND AND SARGENT COUNTIES, NORTH DAKOTA	CASE NO. PU-22-391 OAH FILE NO. 20230002

Response of SCS Carbon Transport LLC to the Interrogatories and Requests for Production (Set 4) from Intervenors Represented by Knoll Leibel LLP and Jorde/Domina Law Group

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SCS Carbon Transport LLC ("Summit"), by and through its attorneys of record, responds to the Interrogatories and Requests for Production submitted by Intervenors represented by Knoll Leibel LLP and Jorde/Domina Law Group ("Intervenors") on May 9, 2024 in the above-captioned proceeding (each a "Discovery Request" and collectively, the "Discovery Requests"). *See* Docket No. PU-22-391. Summit's response is made without waiving or intending to waive any objection as to relevance, privilege, or admissibility of any information provided in response to the Discovery Requests in any subsequent proceeding of this or any other action on any ground. A partial answer to any Discovery Request that has been objected to, in whole or in part, is not intended to be a waiver of the objection. By responding to the Discovery Requests, Summit is not admitting that any aspect of the Discover Requests is factually accurate or relevant to this proceeding.

GLOBAL OBJECTIONS

The following Global Objections apply to each of the Discovery Requests—even if not separately restated below in response to a particular Discovery Request.

Summit objects to all Discovery Requests to the extent they seek the discovery of documents and/or information which are privileged for the reasons that they (a) are subject to the attorney-client privilege; (b) are covered by the "work product" doctrine; and/or (c) were prepared in anticipation of litigation or for trial by or for Summit or its representatives, including its employees, consultants, or agents.

Summit objects to all Discovery Requests to the extent they are beyond the scope of discovery allowed pursuant to Rules 26, 33, 34, and 36 of the North Dakota Rules of Civil Procedure.

Summit objects to all Discovery Requests to the extent they seek identification or production of "all documents" of a particular description. It is impossible to guarantee that all such documents have been identified or located. Summit states, however, that in response to these requests, it has made a diligent search of records kept in the ordinary course of business in those locations likely to contain relevant information.

Summit objects to Intervenor's definitions and instructions to the extent such definitions and instructions exceed or are inconsistent with the requirements imposed upon Summit under the North Dakota Rules of Civil Procedure, Chapter 28-32 of the North Dakota Century Code, or Section 69-02-05-12 of the North Dakota Administrative Code.

Summit objects to the Discovery Requests because they are unduly burdensome and disproportionate to the needs of this proceeding because they seek irrelevant information.

Summit objects inasmuch as the Discovery Requests seek information relating to anything other than Summit's pipeline facilities in North Dakota. Only Summit's North Dakota pipeline facilities are covered by its permit application in this proceeding.

Summit objects inasmuch as the Discovery Requests seek information that contains proprietary or confidential business information or is subject to trade-secret protections or that contains information for which Summit owes a third party an obligation of confidentiality or privacy, whether contractual or under any federal or state laws or regulations.

Summit objects to all Discovery Requests that seek, and disclaims any obligation to identify or furnish, documents or information that Intervenor actually or constructively possesses or to which Intervenor has access through alternative means.

Summit objects inasmuch as the Discovery Requests seek information from third parties and information that is not within Summit's possession, custody, control, or personal knowledge of Summit.

Summit objects and responds to the Discovery Requests based upon information and documents available as of the date hereof and reserves the right to supplement and amend the responses.

Subject to the foregoing objections and conditions, and subject to the specific additional objections made with respect to each request, Summit responds to Intervenor's Discovery Requests as follows:

RESPONSE TO INTERROGATORIES

INTERROGATORY NO. 1:

Is it true you or an affiliated entity will own the CO2 molecules proposed to be transported from the Tharaldson Ethanol Plant on your proposed hazardous pipeline?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true.

INTERROGATORY NO. 2:

Is it true you or an affiliated entity will own the CO2 molecules proposed to be transported from the Iowa Ethanol Plants on your proposed hazardous pipeline?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true with respect to some of the Iowa Ethanol Plants and not true with respect to others.

INTERROGATORY NO. 3:

Is it true you or an affiliated entity will own the CO2 molecules proposed to be transported from the South Dakota Ethanol Plants on your proposed hazardous pipeline?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true with respect to some of the South Dakota Ethanol Plants and not true with respect to others.

INTERROGATORY NO. 4:

Is it true you or an affiliated entity will own the CO2 molecules proposed to be transported from the Nebraska Ethanol Plants on your proposed hazardous pipeline?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true with respect to some of the Nebraska Ethanol Plants and not true with respect to others.

INTERROGATORY NO. 5:

Is it true that you take title to CO2 proposed to be transported on your proposed hazardous pipeline at the "title transfer point" which is the intersection of the ethanol plant and your carbon capture equipment?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true with respect to some of the ethanol plants and not true with respect to others.

INTERROGATORY NO. 6:

Is it true that you or your affiliate will own the carbon capture equipment proposed to be utilized by you or your affiliate at the Tharaldson Ethanol Plant?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true.

INTERROGATORY NO. 7:

Is it true that you or your affiliate will own your proposed pipeline?

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that this is true.

INTERROGATORY NO. 8:

Do you agree that PHMSA does not require your plume models, dispersion analysis, risk assessment or analysis, or similar be confidential? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Summit further objects to this Request as irrelevant to the subject matter at issue. Whether a federal agency does or does not require Summit's plume models, dispersion analyses, risk assessments or analyses be "deemed confidential" has no bearing on Summit's treatment of these materials because the PSC has already granted a protective order over these materials, finding that such information constitutes a "security system plan for critical infrastructure", and that the disclosure of such information "could provide information on where damaging or vandalizing the pipeline by a bad actor would have a debilitating impact on security and state public health and safety." PSC-22-391, Order on Protection of Information, Aug. 4, 2023 at ¶¶ 7, 12.

Moreover, Summit objects to this Request as being vague and ambiguous, and seeking legal conclusions that are not subject to discovery. This Request does not define the meaning of "confidential," nor does it specify what is meant by the statement that the listed materials "be deemed confidential" or whether its reference to a requirement of confidentiality is intended to apply to a federal agency itself, Summit, or other entities.

Subject to and without waiving the foregoing objections, Summit does not agree. The United States Department of Transportation ("DOT") has established regulations that specify how it and its constituent operating administrations (including PHMSA) are to respond to a request for information from the public, including whether or not the requested material is exempt from disclosure under the Freedom of Information Act ("FOIA"). Under these regulations, PHMSA, a federal agency, is required to withhold from disclosure to the public certain information that is exempted from disclosure under FOIA. See 49 C.F.R. § 7.23(c), (d). Summit believes that the plume modeling, dispersion analysis, and risk analyses and assessment it has conducted are exempted from disclosure under FOIA, namely as constituting confidential commercial information and information compiled for law enforcement purposes that, if disclosed, could reasonably be expected to endanger the life or physical safety of an individual, and are within the scope of information that PHMSA is required to withhold from public disclosure pursuant to the above regulation.

In addition, the Transportation Security Administration ("TSA"), a federal agency within the US Department of Homeland Security, has established regulations at 49 C.F.R. Part 1520 that provide for the protection of Sensitive Security Information ("SSI") from disclosure or availability to the public. Under these regulations, covered persons, including an operator who possesses SSI, are prohibited from disclosing or otherwise providing access to SSI except for limited other covered persons with a need to know, unless otherwise authorized by the TSA, the Coast Guard, or the DOT. 49 C.F.R. § 1520.9(a)(2). Moreover, if a covered person receives a request for SSI from a non-covered person, they are required to refer that request to the TSA or the applicable agency within DOT, which in this case would be PHMSA. 49 C.F.R. § 1520.9(a)(3). Summit's plume modeling, dispersion analysis, and risk analyses and assessment may qualify as SSI, rendering them as subject to the limitations on disclosure as provided in 49 C.F.R. Part 1520, and empowering federal agencies, including the TSA and PHMSA, to potentially restrict disclosure of these materials.

INTERROGATORY NO. 9:

Do you agree that no federal agency requires your Plume Models, dispersion analysis, risk assessment or analysis, or similar be deemed confidential? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Summit objects to this Request as irrelevant to the subject matter at issue. Whether a federal agency does or does not require Summit's plume models, dispersion analyses, risk assessments or analyses be "deemed confidential" has no bearing on Summit's treatment of these materials because the PSC has already granted a protective order over these materials, finding that such information constitutes a "security system plan for critical infrastructure", and that the disclosure of such information "could provide information on where damaging or vandalizing the pipeline by a bad actor would have a debilitating impact on security and state public health and safety." PSC-22-391, Order on Protection of Information, Aug. 4, 2023 at ¶¶ 7, 12.

Moreover, Summit objects to this Request as being vague and ambiguous, and seeking legal conclusions that are not subject to discovery. This Request does not define the meaning of "confidential," nor does it specify what is meant by the statement that the listed materials "be deemed confidential" or whether its reference to a requirement of confidentiality is intended to apply to a federal agency itself, Summit, or other entities.

Subject to and without waiving the foregoing objections, Summit does not agree. The DOT has established regulations that specify how it and its constituent operating administrations (including PHMSA) are to respond to a request for information from the public, including whether or not the requested material is exempt from disclosure under FOIA. Under these regulations, PHMSA, a federal agency, is required to withhold from disclosure to the public certain information that is exempted from disclosure under FOIA. *See* 49 C.F.R. § 7.23(c), (d). Summit believes that the plume modeling, dispersion analysis, and risk analyses and assessment it has conducted are exempted from disclosure under FOIA, namely as constituting confidential commercial information and information compiled for law enforcement purposes that, if disclosed, could reasonably be expected to endanger the life or physical safety of an individual, and are within the scope of information that PHMSA is required to withhold from public disclosure pursuant to the above regulation.

In addition, the TSA, a federal agency within the US Department of Homeland Security, has established regulations at 49 C.F.R. Part 1520 that provide for the protection of SSI from disclosure or availability to the public. Under these regulations, covered persons, including an operator who possesses SSI, are prohibited from disclosing or otherwise providing access to SSI except for limited other covered persons with a need to know, unless otherwise authorized by the TSA, the Coast Guard, or the DOT. 49 C.F.R. § 1520.9(a)(2). Moreover, if a covered person receives a request for SSI from a non-covered person, they are required to refer that request to the TSA or the applicable agency within DOT, which in this case would be PHMSA. 49 C.F.R. § 1520.9(a)(3). Summit's plume modeling, dispersion analysis, and risk analyses and assessment may qualify as SSI, rendering them as subject to the limitations on disclosure as provided in 49 C.F.R. Part 1520, and empowering federal agencies, including the TSA and PHMSA, to potentially restrict disclosure of these materials.

<u>INTERROGATORY NO. 10</u>:

Do you agree that a release of CO2 from an 8-inch diameter CO2 pipeline, as you intend to construct in North Dakota, has the potential to produce CO2 at 40,000 ppm concentration levels at least as far as 1,855 feet from the rupture site? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Specifically, Summit objects to the Discovery Request because the information sought by the requested admission relates to Summit's dispersion modeling which is protected information pursuant to the Commission's August 4, 2023, Order (Docket No. 364).

INTERROGATORY NO. 11:

Do you agree that a 24-inch diameter pipeline can transport 15 times as much CO2 by volume than an 8-inch diameter pipeline of similar length? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Without waiving the foregoing objections, Summit disagrees with this request because there are too many variables not specified in the request for Summit to agree.

INTERROGATORY NO. 12:

Do you agree a release of CO2 from a 24-inch diameter CO2 pipeline, as you intend to construct in North Dakota, has the potential to produce CO2 at 40,000 ppm concentration levels at least as far as 3,800 feet from the rupture site? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Specifically, Summit objects to the Discovery Request because the information sought by the requested admission relates to Summit's dispersion modeling which is protected information pursuant to the Commission's August 4, 2023 Order (Docket No. 364).

INTERROGATORY NO. 13:

Do you agree that a release of CO2 from a 24-inch diameter CO2 pipeline, as you intend to construct in North Dakota, has the potential to produce CO2 at 40,000 ppm concentration levels at least as far as 4,500 feet from the rupture site? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Specifically, Summit objects to the Discovery Request because the information sought by the requested admission relates to Summit's dispersion modeling which is protected information pursuant to the Commission's August 4, 2023 Order (Docket No. 364).

<u>INTERROGATORY NO. 14</u>:

Do you agree that if an Ethanol Plant were to process only corn produced from farms utilizing a winter cover crop, it could reduce its CI Score between an average of 20.4 to 39.1 points? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that it can neither agree nor disagree with the CI Score range referenced. The Argonne National Laboratory GREET model utilizes the Feedstock CI Calculator (FD-CIC) to calculate dynamic feedstock CI values. This model is based on county level averages and only includes four counties from North Dakota (Burleigh, Emmons, McLean, and Morton). Additionally, the results for cover crop impacts require other farm specific assumptions including the energy used to plant cover crops, cover crop herbicide applications, and cover crop yield, as well as base assumptions on the farm operations, for example corn yield and nitrogen rates. Utilizing the 2023 FD-CIC, the average CI reduction for the use of cover crops across the four available North Dakota counties, utilizing default values for the farm specific assumptions, is 6.5 points. Additionally, it should be noted that CI reductions from farm level activities would be additional to carbon capture and storage and are not a mutually exclusive decision.

<u>INTERROGATORY NO. 15</u>:

Do you agree that if an Ethanol Plant were to process only corn produced from farms utilizing manure application, it could reduce its CI Score between average of 5.5 to 28.0 points? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that it can neither agree nor disagree with the CI Score range referenced. The Argonne National Laboratory GREET model utilizes the Feedstock CI Calculator (FD-CIC) to calculate dynamic feedstock CI values. This model is based on county level averages and only includes four counties from North Dakota (Burleigh, Emmons, McLean, and Morton). Additionally, the results for manure application impacts require other farm specific assumptions including the type of manure (swine, dairy cow, beef cattle, and/or chicken), energy from manure application, manure transportation distance and manure transportation energy, as well as base assumptions on the farm operations, for example corn yield and nitrogen rates. Utilizing the 2023 FD-CIC, the average CI decrease for the use of manure across the four available North Dakota counties, utilizing default values for the farm specific assumptions, is 1.5 points. Additionally, it should be noted that CI reductions from farm level activities would be additional to carbon capture and storage and are not a mutually exclusive decision.

<u>INTERROGATORY NO. 16</u>:

Do you agree that if an Ethanol Plant were to process only corn produced from farms implementing no-till practices, it could reduce its CI Score between an average of 3.4 to 6.5 points? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that it can neither agree nor disagree with the CI Score range referenced. The Argonne National Laboratory GREET model utilizes the Feedstock CI Calculator (FD-CIC) to calculate dynamic feedstock CI values. This model is based on county level averages and only includes four counties from North Dakota (Burleigh, Emmons, McLean, and Morton). Additionally, the results require base assumptions on the farm operations, for example corn yield and nitrogen rates. Utilizing the 2023 FD-CIC, the average CI decrease for the use of no-till practices across the four available North Dakota counties, utilizing default values for the farm specific assumptions, is 3.7 points. Additionally, it should be noted that CI reductions from farm level activities would be additional to carbon capture and storage and are not a mutually exclusive decision.

<u>INTERROGATORY NO. 17</u>:

Do you agree that if an Ethanol Plant were to utilize renewable natural gas (RNG) for 40% of the plant's natural gas needs, it could reduce its CI Score by on average 21 points? If you do not agree, explain why.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Subject to and notwithstanding the objections, Summit states that it can neither agree nor disagree with the CI Score referenced. But according to the Renewable Fuel Association commissioned study completed by Informed Sustainability Consulting, LLC in February of 2022, the CI reduction benefit from switching from natural gas to bio-methane from manure would be 13.6 points. The link to the study can be found at: https://d35t1syewk4d42.cloudfront.net/file/2146, with the relevant commentary in section 2.4.1.3 (page 12) and relevant value in table 10 (page 24). Additionally, it should be noted that CI reductions from bio-gas switching would be additional to carbon capture and storage and are not a mutually exclusive decision.

INTERROGATORY NO. 18:

List the names, contact information, and titles as applicable to any person who attended any of your so-called safety meetings, including but not limited to any such meeting with any Emergency Managers, first responders, city or county officials of any kind and identify the location and date of such meetings.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Summit further objects to this request as vague to the extent that "so-called safety meetings" is not defined and Summit has held numerous meetings throughout the development of the project at which safety issues have been discussed. Subject to and notwithstanding the objections, and to the extent that this request relates only to specific safety-related meetings held with emergency managers and first responders from North Dakota counties from November 2023 through May 2024, the dates and locations of such meetings and the names of attendees at each meeting are reflected in Summit's Response to Request for Additional Information filed with the PSC on May 10, 2024 (Docket No. 562) and Summit's Supplemental Response to Request for Additional Information filed with the PSC on May 17, 2024 (Docket No. 569).

INTERROGATORY NO. 19:

For each document, study, report, and similar data discussed or shown to any non-Summit employee during any safety meeting or similar anywhere within North Dakota, state the name or *title of such document, study, report, or similar data, the amount of pages, the date it was created, and the author.*

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Summit further objects to the request as vague to the extent the phrase "any safety meeting or similar anywhere within North Dakota" is undefined, and Summit has held numerous meetings throughout the development of the project at which safety issues have been discussed. Subject to and notwithstanding the objections, Summit states that safety-focused meetings open to the general public were conducted at various locations. Although the Power Point slides were presented in poster board form, a .pdf copy of those poster boards is produced herewith. Answering further, and to the extent that this request relates only to specific safety-related meetings held with emergency managers and first responders from North Dakota counties from November 2023 through May 2024, see Response to Request for Production No. 1, below.

RESPONSE TO REQUESTS FOR PRODUCTION

REQUEST NO. 1:

For any safety meetings or any meetings where Summit or its employees or agents discussed safety, CO2 release, CO2 dispersion, CO2 hazard distances, CO2 plume modeling, CO2 plume or dispersion study, or CO2 dispersion modeling of any kind with any non-Summit employee, produce a true and accurate copy of the records, documents, and data used by Summit at those meetings or shown to the participants of such meetings, or discussed at such meetings.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Summit further objects to this request as vague to the extent that the term "safety meetings" is undefined and overbroad and unduly burdensome to the extent that the term "any meetings where Summit or its employees or agents discussed safety" could encompass hundreds of meetings at which safety-related topics were discussed. Subject to and notwithstanding the objections, and to the extent that this request relates only to specific safety-related meetings held with emergency managers and first responders from North Dakota counties from November 2023 through May 2024 Summit states that information discussed at meetings with Emergency Managers and/or Emergency Response personnel varied but comprehensively were limited to the following documents (and/or excerpts therefrom):

- American Petroleum Institute: Carbon Dioxide (CO_2) Emergency Response Tactical Guidance Document
- Department of Transportation, CFR 49, Part 195: Transportation of Hazardous Liquids by Pipeline
- American Petroleum Institute / CTEH: Indoor Carbon Dioxide Loading Following Simulated Carbon Dioxide Pipeline Release
- Power Point Summary developed by Summit Carbon Solutions (submitted to the North Dakota PSC as "confidential")

Although reviewed and/or discussed, no documentation or other materials were provided to or left with meeting attendees. Excluding the Power Point Summary, which was provided to the PSC confidentially, and Part 195 of Title 49 of the Code of Federal Regulations which is readily available to Intervenors, the remaining documents presented are produced herewith.

<u>REQUEST NO. 2</u>:

Produce true and accurate copies of every request for information and for equipment made by any county, city, township, first responder, Emergency Management personnel, fire department, or similar person or entity.

RESPONSE:

Summit incorporates by reference its Global Objections set forth above. Summit further objects to this request as overly broad, unduly burdensome, and disproportionate to the needs of this proceeding to the extent that the phrase "every request for information and for equipment" could encompass hundreds of communications. Subject to and notwithstanding the objection, Summit states that it has had formal and informal discussions with emergency managers and emergency response personnel on various occasions regarding information about the project and equipment in the event a response is required, and Summit is committed to working with local first responder organizations to determine their equipment resources and assist such organizations with supplementing their equipment where necessary to respond to a hypothetical emergency situation on the pipeline system.

AS TO THE ANSWERS TO THE INTERROGATORIES AND REQUESTS FOR PRODUCTION (SET 4) FROM INTERVENORS REPRESENTATED BY KNOLL LEIBEL LLP AND JORDE/DOMINA LAW GROUP:

SCS CARBON TRANSPORT LLC

By: DocuSigned by: James Powell
FBDF5E4B03C74A2...
James Powell
Its: Chief Operating Officer

Subscribed and sworn to before me
this ____ day of May, 2024.

____

My commission expires:_________________

AS TO OBJECTIONS:

Dated this 23rd day of May, 2024.

FREDRIKSON & BYRON, P.A.

By: ______________________________

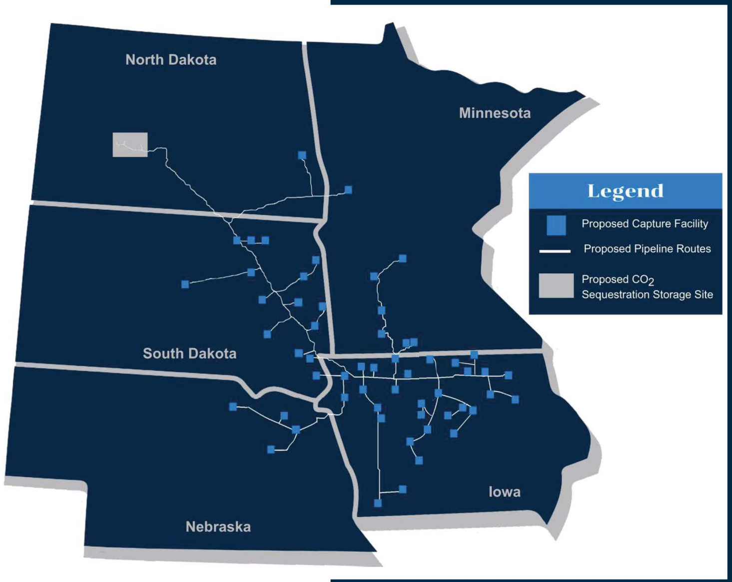
LAWRENCE BENDER, ND Bar #03908
1133 College Drive, Suite 1000
Bismarck, ND 58501
(701) 221-8700
lbender@fredlaw.com

Attorneys for SCS Carbon Transport LLC

SUMMIT CARBON SOLUTIONS

Project Overview

Summit Carbon Solutions is applying proven technology to develop the Midwest Carbon Express carbon capture transport and storage project to help its industrial partners enhance profitability, which sustains the demand for corn, helps buoy land values, and bolsters the general agriculture & energy economy.



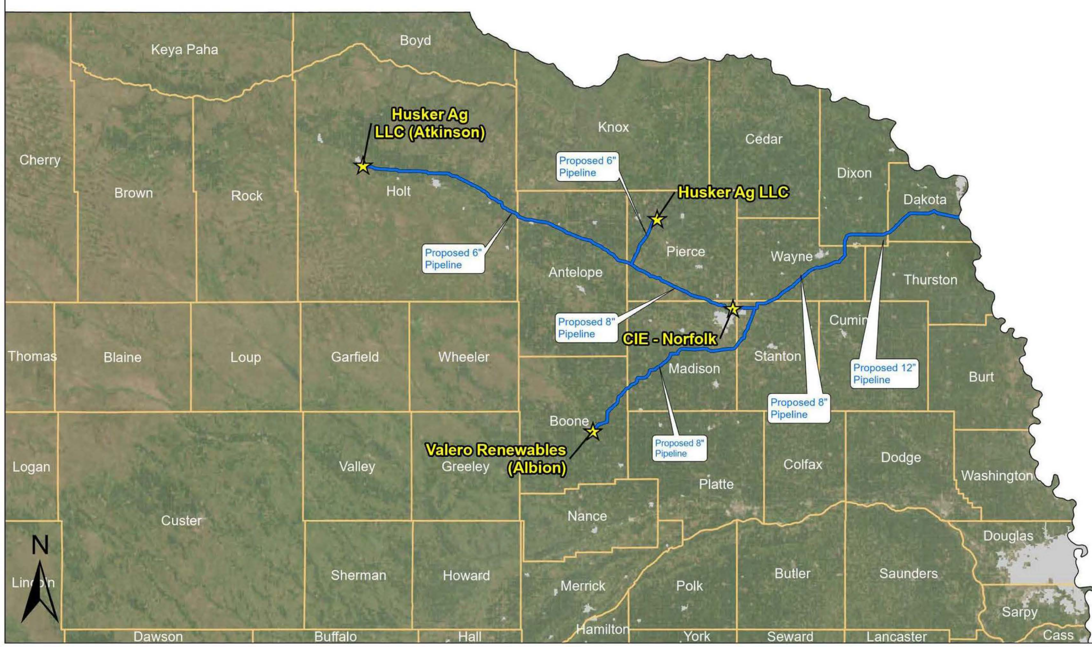
The project will capture CO2 from the fermentation process of biorefineries, such as ethanol plants. The CO2 will then be compressed into a supercritical fluid and transported to North Dakota, where it will be permanently and safely stored underground.

Safety of the landowners, communities, and our workers is ingrained in our corporate values and is reflected in all we do.

Planning	Construction	Operations
2021	2025	2026

SUMMIT CARBON SOLUTIONS

Nebraska



★ Participating Ethanol Plant
Route
State Boundary
County Boundary
Highly Populated Areas

216.10 MILES OF ANTICIPATED PIPELINE ROUTES IN NEBRASKA

Nebraska Pipeline Mileage Overview

COUNTY: MULTIPLE
STATE: NEBRASKA

ISSUED FOR REVIEW

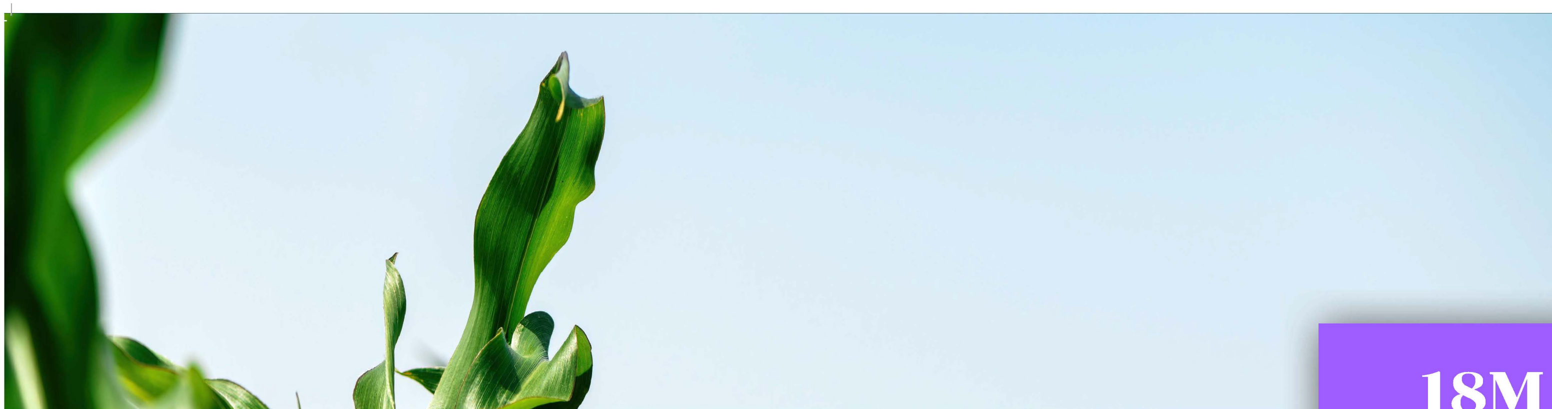
PRELIMINARY ROUTE SUBJECT TO CHANGE

DATE: 3/6/2024 | PROJECTION: NAD 83

SUMMIT CARBON SOLUTIONS

0 5 10 20 30 40 Miles

DWG: | SHEET: 1



Project Benefits

Summit Carbon Solutions' carbon capture, transportation, and storage project will help sustain a strong agricultural market, drive job creation and job growth in critical Midwest-based industries.

This multibillion-dollar investment will provide opportunities for CO2 sources such as ethanol plants, fertilizer plants, and others to enter existing and emerging low carbon intensity fuel markets such as the production of sustainable aviation fuel.

SUMMIT CARBON
SOLUTIONS

18M
Tons Of CO2 Captured Annually

57
Midwest Ethanol Plants

$8B
Initial Investment

$930K
Avg. per county Property Taxes Annually

11,500
Initial Jobs

1,100
Permanent Jobs

Sustainable Aviation Fuel Opportunity

SUMMIT CARBON SOLUTIONS

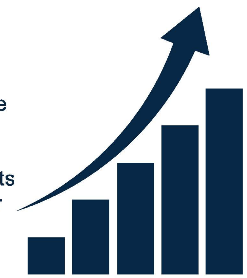
Ethanol is projected to be the single largest feedstock for production of Sustainable Aviation Fuel (SAF)

What is Sustainable Aviation Fuel?

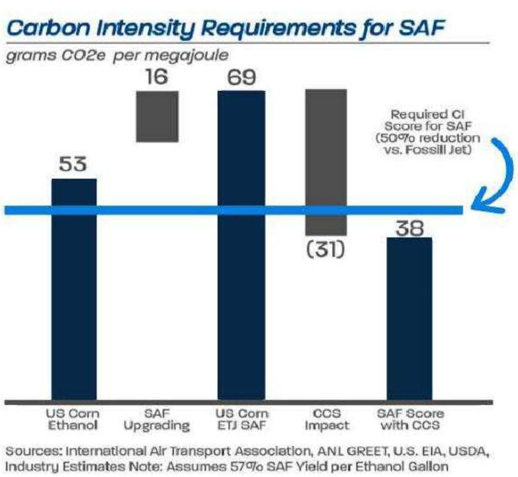
Ethanol-based sustainable aviation fuel (SAF) is used by airlines in their effort to become more carbon neutral. With limited alternatives to power today's modern aircraft, SAF is expected to make up the majority of emissions reductions for the aviation industry. In 2022, global production of SAF amounted to just ~80 million gallons with additional capacity being planned around the globe to meet growing demand.

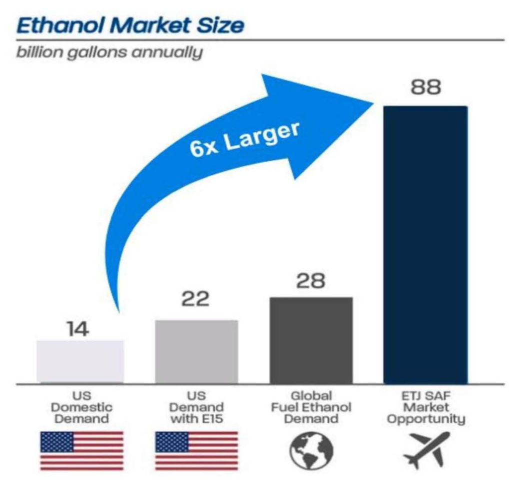
Growing Demand for SAF

Countries and companies around the world are planning to increase SAF usage, setting the stage for industry development and expansion. Corporate targets of SAF usage amount to 3.3 billion gallons annually by 2030. Governments are also incentivizing or requiring SAF usage through targets (U.S. – 3 billion gallons), mandates (EU, Japan) or various credits (Canada's Clean Fuels program, state level low-carbon markets, state level tax incentives, Clean Fuel Production Credit – 45Z).



CCS is the most efficient way to produce low CI ethanol required for SAF production





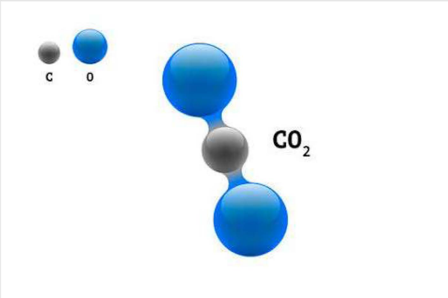
SAF expected to add value to ethanol of at least $1.25 to $2.00 per gallon

CO2 Explained

SUMMIT CARBON SOLUTIONS

Naturally Occurring

CO2 is a colorless, odorless, non-combustible, non-flammable gas that is naturally present in the Earth's atmosphere. Like natural gas, it is a simple asphyxiant that is heavier than air but it's not flammable, and CO2 can be corrosive when exposed to water.

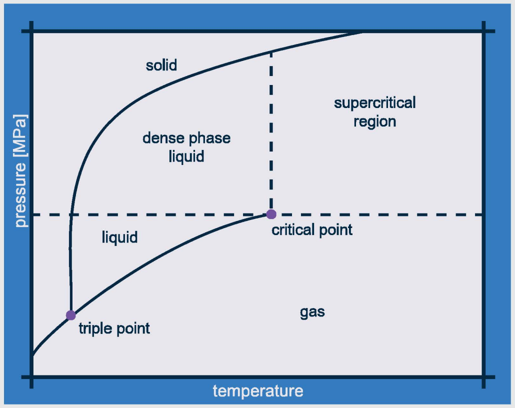


Byproduct

CO2 is a byproduct of industrial processes like the production of ethanol. The project will capture CO2 (>98% pure) from the ethanol plant scrubbers before it's released into the atmosphere.

Transport State

CO2 will be compressed from a gas to a supercritical fluid for transportation in the pipeline system.



Midwest Carbon Express System Architecture

SUMMIT CARBON
SOLUTIONS

Capture & Compression

At Summit's partner facilities, equipment will be installed to capture, compress, dehydrate, and inject CO2 into the pipeline transportation system.

Carbon capture technology is proven; in use at more than 40 industrial plants in the U.S.

Pipeline Transporation

The ~2,500 mile pipeline system will be comprised of various sized pipeline laterals that feed into a 24" diameter mainline that delivers CO2 to the permanent sequestration injection sites.

Storage and Sequestration

The sequestration and storage area will be located on more than 100 acres and include multiple injection sites.

Each injection site will be comprised of surface facilities (pumping and measurement equipment) connected to a cased well that will carry the CO2 subsurface.

Sequestration

SUMMIT CARBON SOLUTIONS

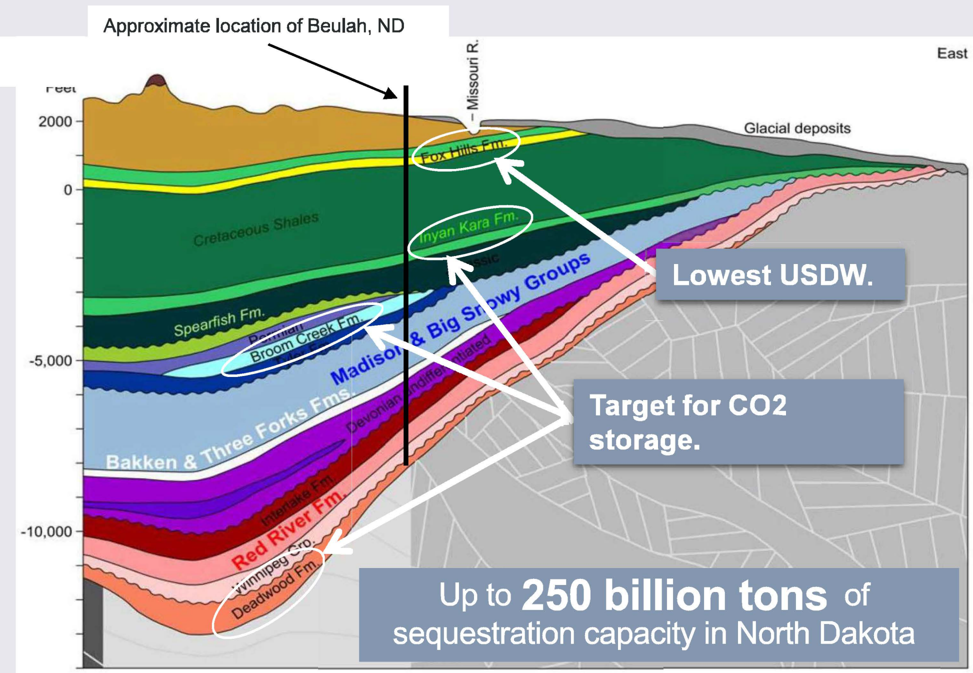
North Dakota Williston Basin Geologic Cross Section

SCS will inject supercritical CO_2 deep into saline reservoirs for permanent storage.

CO_2 will be injected underneath an **impermeable rock layer** into saline formations for permanent sequestration.

Pore space is leased from landowners that own the **surface rights.**

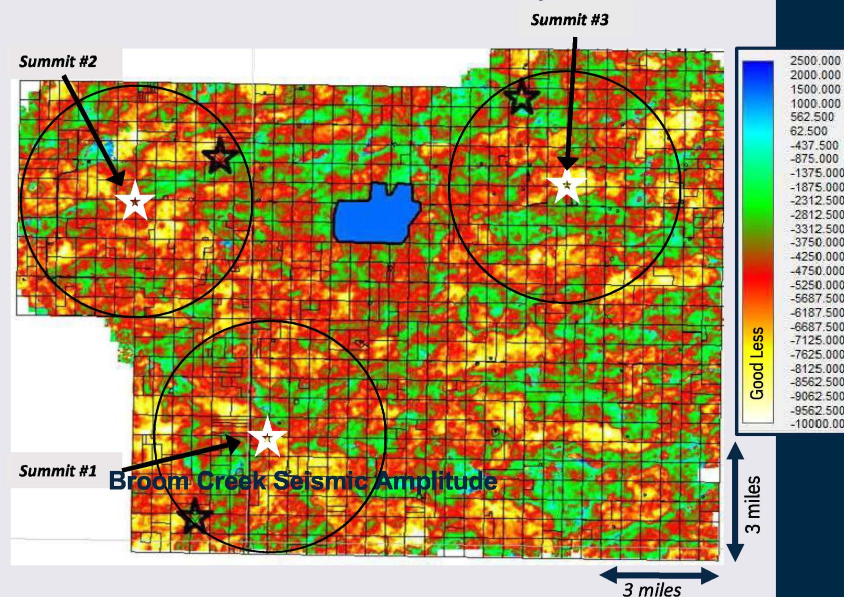
Over a 100-year injection period, **SCS will utilize less than 1%** of North Dakota's total sequestration capacity.



SCS Site Characterization

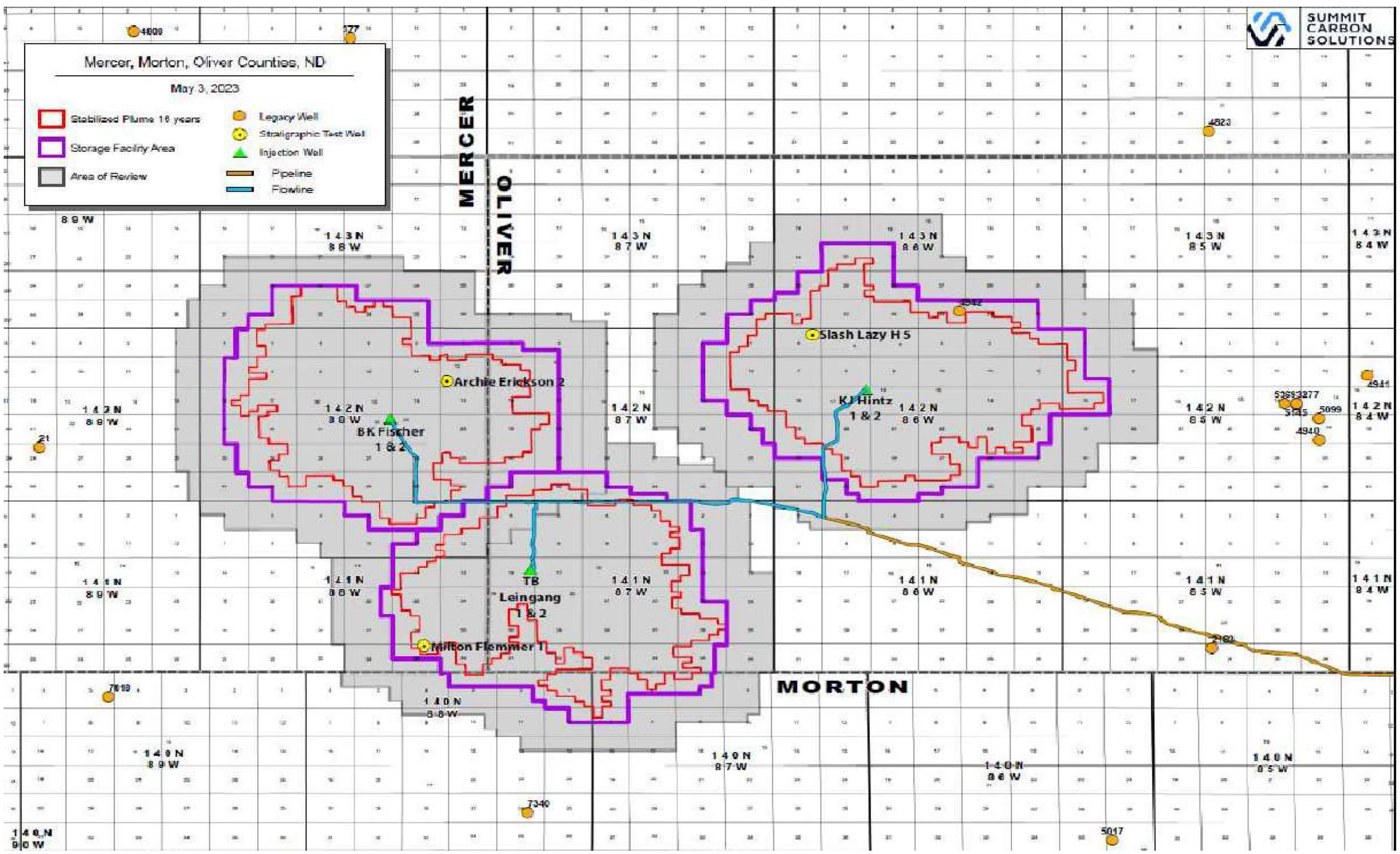
Seismic Survey Program

Collected 3-D Seismic across ~200 square miles



Sequestration

Three SCS Class 6 Storage Facility Permit Applications Submitted



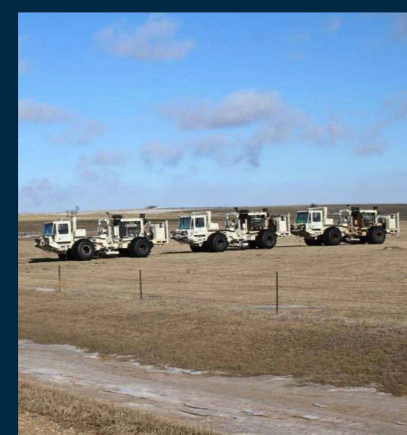
SUMMIT CARBON SOLUTIONS

Three Broom Creek Formation Storage Areas - Separate permits containing ~30,000 acres each

Two injection wells per site that are located on the same pad

Storage of three SFPs modeled at approximately 350 million tons over 20 years

Individual sites ranging from 100 million to 130 million tons over 20 years



SUMMIT CARBON SOLUTIONS

Regulatory Oversight

Summit will comply with applicable regulations and employ industry best practices to protect the environment and communities in which Summit will operate.

DOT PHMSA Regulations

The U.S. Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) has established stringent requirements for the safe design, construction, and operation of CO2 pipelines.

With dozens of PHMSA regulations, CO2 in its supercritical phase, is regulated under 29 CFR 195. The hazardous liquid standard.

Scan the code to learn more about some of the specific CO2 pipelines regulations.

SCAN ME

Additional Regulations

Constructing a carbon dioxide transportation pipeline also requires extensive permits from the following entities:

FEDERAL

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- Natural Resources Conservation Service

STATE

- Iowa Utilities Board
- South Dakota Public Utility Commission
- North Dakota Public Service Commission
- Minnesota Public Utilities Commission
- Nebraska (county jurisdiction)

As part of the permitting process, we'll complete field surveys to identify the potential impact to environmental, biological, and culturally sensitive areas.

Designed for Safety

Project Construction

Construction is a multi-step process that begins after state and federal permits are issued and easements are secured.

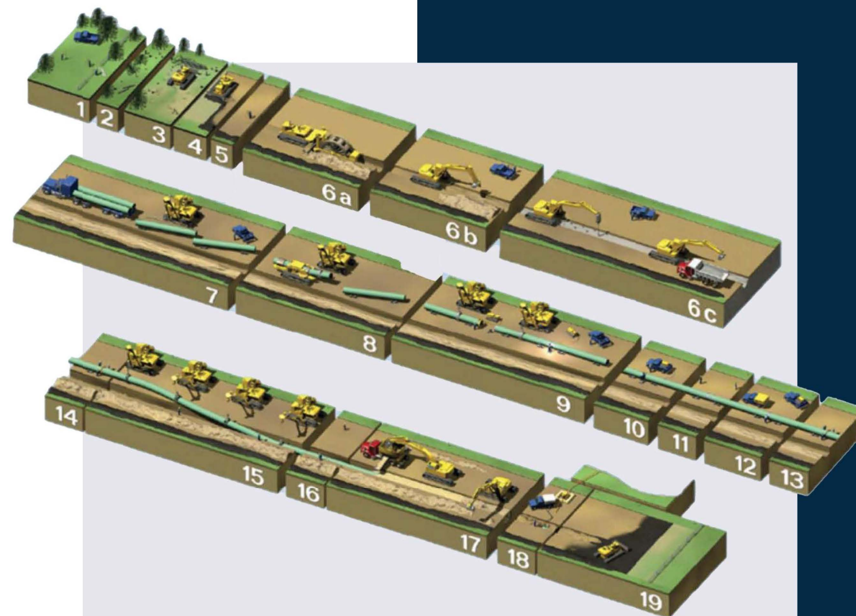
During construction, rigorous processes are followed to ensure safety and efficiency, as well as minimizing environmental impact.

Top soil and subsoil will be segregated (double-ditching) to minimize the impacts of construction on crop or pasture grass production.

The construction right-of-way will be restored to as good or better condition.

To minimize disruption, Summit will complete a majority of welding prior to trenching to reduce the time of open ground from weeks to days.

SUMMIT CARBON SOLUTIONS



1. Survey and Staking
2. Clearing
3. Front-End Grading
4. ROW Topsoil Stripping
5.Re-staking Trench Centerline
6. Trenching
   - Trenching (Wheel Ditcher)
   - Trenching (Excavator)
   - Trenching (Rock)
7. Stringing Pipe
8. Field Bending Pipe
9. Line-Up, Initial Weld
10. Fill & Cap, Final Weld
11. Weld Mapping
12. X-Ray Inspection, Weld Repair
13. Coating Field Welds
14. Initial Inspection & Repair of Coating
15. Secondary Coating Inspection, Lowering Pipe Into Trench
16. As-Built Survey
17. Pad, Backfill, Rough Grade
18. Hydrostatic Test, Final Tie-In
19. Replace Topsoil, Final Clean up, Full Restoration

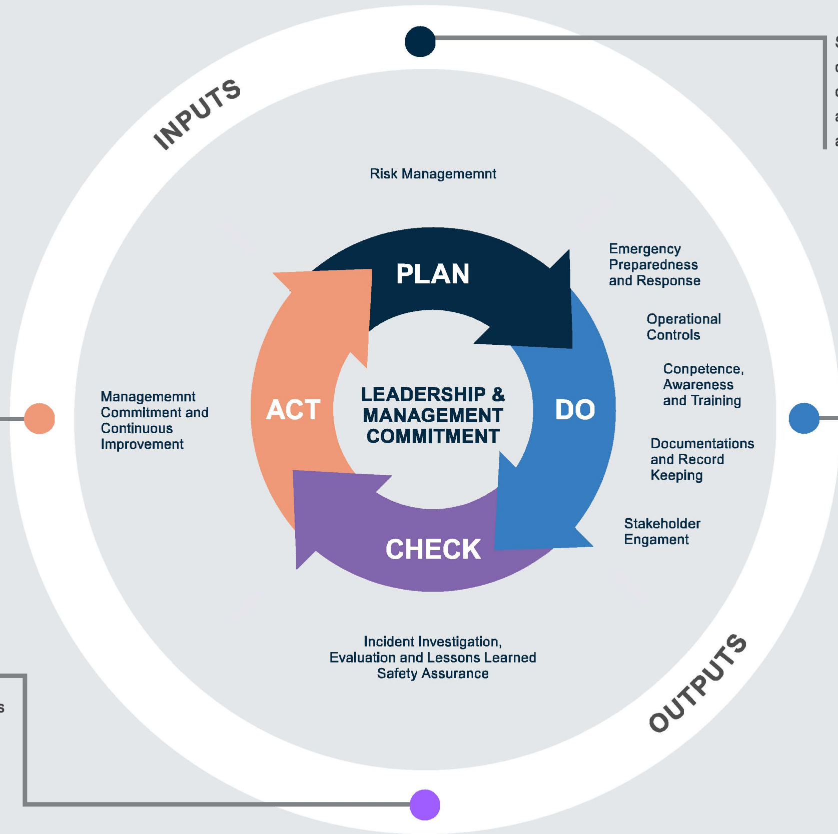
*This visual is a representation of a typical construction process.

Managing Safety

SUMMIT CARBON SOLUTIONS

The “Pipeline Safety Management Systems” (API 1173) is a guideline that offers a comprehensive approach to pipeline safety. It combines different activities like risk management, effective decision making, performance monitoring, fostering a safety culture, audits, and enhancing communication. The system surpasses existing safety programs by encouraging ongoing improvement through a “Plan-Do-Check-Act” cycle.

Summit will create processes based on our policies and expected outcomes. By defining what results to expect, it also aims to improve the thoroughness and accuracy of the process.



Summit will execute the plan.

Summit will continuously improve our operations. This includes fixing discrepancies between real and expected results, identifying why these differences occurred, and deciding where to make changes to enhance the process or product.

Summit will check the results against the set goals. It's about identifying any differences by seeing if the implementation strayed from the plan.

Emergency Preparedness

SUMMIT CARBON SOLUTIONS

We've designed an Emergency Response Plan (ERP) that covers multiple factors and scenarios over the entire project route.

PLANNING & PERMITTING → PERMITS RECEIVED → PRIOR TO OPERATIONS → OPERATIONS

Planning

Summit's planning efforts are underway, including meeting with PHMSA's technical staff and conducting initial discussions with local Emergency Managers (EMs). Summit will broaden the communication to include first responders and continue to engage throughout the lifecycle of the Project.

Preparedness Training

Once state permits have been issued and the construction schedule is confirmed, Summit will meet EMs again to discuss equipment needs, and initiate preparedness training with first responders.

Topics for Training:

1. Chemical SDS
2. Pipeline specifications
3. Pipeline operation
4. Dispersant analsys
5. High Consequence Areas (HCAs)
6. Responding procedures
7. Initial Response Tactical (IRT) plans

Preparedness Tabletop Exercise

Summit pipeline operations personnel will conduct training exercises for first responders to ensure the appropriate level of awareness and alignment of responsibilities in the event of a release.

A schedule will be developed for the first responders and Summit pipeline operations to complete tabletop exercises before the pipeline is placed into operation.

Ongoing Effort

Once in operation, emergency responders will be trained annually which is compliant with the Pipeline and Hazardous Materials Safety Administration (PHMSA) regulation 49 CFR Part 195.403.

If new emergency personnel are brought on, or the department deems additional training necessary, Summit will be there to lead.

Leak Detection and Prevention Measures

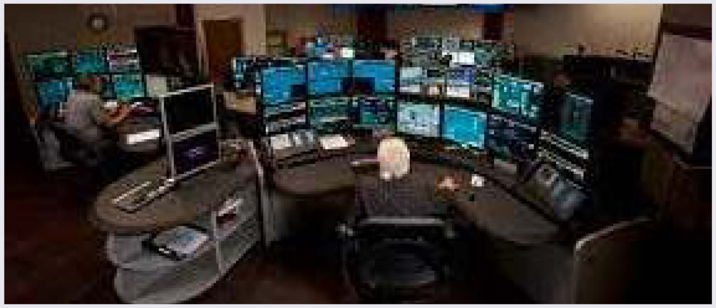
SUMMIT CARBON SOLUTIONS

For optimized leak detection and control, Summit will utilize technology and processes to create a real-time transient model (RTTM) in alignment with API RP 1130/1175.

System Oversight

24/7 Control Room

- Real-time, in-person monitoring of the entire Summit system.
- Enabled remote operation when necessary, incorporating surge protection and automatic valve shutdown in the event of significant pressure fluctuations.



This is a stock image of a pipeline control room. Construction on the Summit control room will occur during the construction phase.

Onsite Technology

Computerized Pipeline Monitoring System

- Industry leading technology installed on more than 1,500 pipeline systems worldwide.
- Monitors pressure across the entire system with instrumentation located at capture facilities, valve sites, pump stations, and sequestration sites.
- Ability to detect the smallest leak even during changes in operation.
- Provides real-time information to the Control Room.

Metering

- State of the art metering equipment used at all capture, pipeline, and sequestration sites.
- Monitors system balance to identify potential differences.
- Managed by skilled Summit technicians ready to act when necessary.

The Real-Time Transient Model (RTTM)

Simulates the behavior of a pipeline using computational algorithms. The model, which is driven by the field instrumentation, monitors discrepancy between the measured and calculated values potentially caused by a leak.

SUMMIT CARBON SOLUTIONS

Public Awareness

Summit's Public Awareness Program (PAP) will enhance ongoing SCS safety practices and contribute to a reduced likelihood of a pipeline release. Assisting the public to remain informed helps reduce emergencies caused by third-party damage.

Key stakeholder groups for public awareness are:

- Residents located in the vicinity of a high consequence area
- Local and state emergency response and planning agencies
- Public officials
- One-Call system

What you need to know about CO2:

CO2 is heavier than air and can gather in enclosed or low-lying areas if there's inadequate ventilation. It can reduce oxygen levels in environments where its concentration surpasses typical atmospheric standards.

You may see:

- White vapor cloud
- Frost covered area of ground
- Bubbling in standing water

You may hear:

- Sound of de-pressuring

How safe are pipelines

- Pipelines are the safest mode of transportation (safer than truck or rail)
- The incident rate for oil & gas pipelines is .001% and CO2 pipelines are even safer

Dispersion Modeling

Dispersion modeling is intended to highlight areas where enhanced integrity management approaches may be necessary to further mitigate risks, and inform our emergency response plans.

Summit has completed and periodically updates a dispersion model and risk analysis to ensure compliance with the Pipeline and Hazardous Materials Safety Administration's (PHMSA) regulations.

The dispersion model and risk analysis aim to identify potential impacts to High Consequence Areas (HCAs) following the Integrity Management section of 49 CFR 195.452 guidelines. Less than 1% of the pipeline route is located in direct affect population derived HCAs, yet Summit is going above and beyond the regulatory requirement by completing this across the project footprint.

Our dispersion model is extremely conservative. We took the dispersion inputs and modeled them at their worst-case state. Summit utilized both vapor dispersion modeling and terrain-aided modeling for a comprehensive analysis to fully incorporate the vapor dispersion and overland flow potential of CO2.

Factors considered in Summit's dispersion models:

- Topography
- Weather conditions
- Size of release
- High Consequence Areas
- Modeled at Max Operating Pressure (higher than normal operating pressure)
- Terrain-Aided Dispersion

Summit Carbon Solutions is going above and beyond modeling the entire route as a HCA, which will incorporate additional integrity measures across the entire system.

Defining High Consequence Areas

Dispersion modeling is intended to highlight areas where enhanced integrity management approaches may be necessary to further mitigate risks, and inform our emergency response plans.

- Densely populated zones
- Commercially navigable waterways
- Environmentally sensitive areas

SUMMIT CARBON SOLUTIONS

INDOOR CARBON DIOXIDE LOADING FOLLOWING A SIMULATED CARBON DIOXIDE PIPELINE RELEASE

Sponsored by: American Petroleum Institute (API), Denbury Inc., E3 Environmental

Prepared By

Michael Lumpkin, PhD, DABT
Senior Toxicologist

Angie Perez, PhD, CIH
Senior Toxicologist

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Cole Ledbetter, CIH, CSP
Senior Industrial Hygienist

Report Date
June 7, 2023

CTEH Project 021614

Executive Summary

Denbury, Inc. (Denbury) and American Petroleum Institute (API) requested CTEH, LLC (CTEH) to design and conduct a carbon dioxide (CO_2) exposure simulation study. The purpose of the study was to provide data to determine whether shelter-in-place (SIP), versus mandatory evacuation, is a viable option for protecting residents in proximity to a catastrophic CO_2 release from a pipeline or associated infrastructure. A Denbury CO_2 pipeline pump station served as the study site. Two towable camper trailers representing residential structures were placed inside a large, sealed tent into which CO_2 from the pump station pipeline was manually introduced. Thus, the overall scope of this study was to identify the magnitude and repeatability of ratios of indoor-to-outdoor CO_2 and O_2 concentrations in camper trailers after a controlled release from a CO_2 pipeline over a range of toxicologically relevant concentrations.

Real-time instruments that measured and transmitted airborne CO_2 and O_2 concentrations were deployed inside the tent (representing a simulated outdoor area), inside the trailers (representing a residential indoor area). Instruments also measured temperature, relative humidity, and barometric pressure inside and outside of the trailers. A test for indoor CO_2 loading due to human occupants occurred for one trailer. Four study participants occupied one trailer for approximately 90 minutes, resulting in a maximum breathing zone CO_2 concentration of approximately 3,800 ppm. A mathematical model was fitted to measurements of CO_2 leakage from both trailers to calculate air change rates of approximately 0.5 and 0.2 per hour, which would represent relatively tightly sealed residential structures.

The novel CO_2 test system was put through iterative trials to optimize the ability to introduce and control set CO_2 concentrations inside the tent using various CO_2 valve flow rates, ventilation fan placement, and CO_2 supply piping configurations. Four tests were run for approximately four hours to establish relatively constant in-tent CO_2 concentrations of 10,000 ppm, 20,000 ppm, 30,000 ppm, and 40,000 ppm at breathing zone height. A fifth test was attempted to rapidly fill the tent with CO_2 and decrease O_2 concentrations to 15% or less. Indoor and outdoor CO_2 and O_2 concentrations were measured and data logged throughout the test period.

Indoor breathing zone and floor level CO_2 concentrations increased similarly for the 10,000 ppm and 20,000 ppm tests, reaching maximums of less than 10,000 ppm. Floor level and breathing zone CO_2 concentrations in the 30,000 ppm and 40,000 ppm tests increased at different rates, with maximum breathing zone CO_2 concentrations of less than 30,000 ppm. In all 10,000 to 40,000 ppm tests, the indoor breathing zone CO_2 concentrations at two hours were below 5,000 ppm. The O_2 concentration never decreased below 19.5% throughout the 10,000 to 40,000 ppm tests. The ratio of indoor-to-outdoor breathing zone CO_2 concentrations over time increased approximately linearly for the 10,000 ppm and 20,000 ppm tests, but not for the 30,000 ppm and 40,000 ppm tests. The fifth test was aborted early due to a leak in the tent enclosure. However, the rapid increase of the tent CO_2 concentration to approximately 90,000 ppm resulted in a decrease of O_2 to 18.2% within the tent. The minimum indoor O_2 concentration for the 50,000

ppm test was 19.3 % and occurred in the breathing zone of trailer 2 which had windows open during the test.

The study and resulting data described herein present a novel approach to investigate potential residential SIP exposures over time and across various outdoor CO_2 plume densities. The results indicate that SIP for several hours provide reduced CO_2 exposure relative to outdoor concentrations, with breathing zone concentrations remaining below 5,000 ppm for at least two hours into a simulated incident.

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1.0 Introduction and Background

Denbury, Inc. (Denbury) and American Petroleum Institute (API) asked CTEH, LLC (CTEH) to design and conduct a carbon dioxide (CO_2) exposure simulation study. The purpose of the study was to provide data to determine shelter-in-place (SIP), versus mandatory evacuation, is a viable option for protecting residents in proximity to a catastrophic CO_2 release from a pipeline or associated infrastructure. Specifically, CTEH was asked to develop data to help first responders better determine whether evacuation or SIP orders represent the safer of two actions for the public in the event of a major CO_2 release event.

The United States Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) Emergency Response Guidebook (ERG)* provides first responders with guidance on best practices, based on scientific evidence, to respond to hazmat transportation accidents within the first 30 minutes of the incident. Current ERG guidance recommends isolation of the spill or leak area for at least 100 m (330 ft) in all directions in the event of a small liquid spill (less than 55 US gallons, approximately 208 liters) and evacuation for at least 100 m (330 ft) in the initial downwind direction for a large spill of inert gases.(USDOT, 2020) However, evacuation orders may introduce other public safety hazards, both physical, logistical, and psychological, especially for people with limited bodily mobility, visual impairment, unaccompanied children, those who may not receive evacuation notices in a timely manner, or those without access to transportation. Physical barriers may present hazards for evacuation such as stairs, road closures, or limited visibility in the case of dense fog. Additionally, changes in weather patterns, incident conditions, and delays in communication, may result in inaccurate or outdated evacuation instructions causing residents to evacuate into, instead of away from, hazardous conditions. The lack of a suitable communicated evacuation route may also leave certain residents without a sufficient path of egress. Therefore, the need for safe SIP options, based on scientifically tested exposure scenarios, is paramount.

The overall scope of this study was to identify the magnitude and repeatability of ratios of indoor-to-outdoor CO_2 and O_2 concentrations in camper trailers placed inside if a sealed tent enclosures during and after controlled CO_2 pipeline stream releases over a range of toxicologically relevant concentrations. Secondary study goals were to identify durations of time in which indoor levels of CO_2 and O_2 remain at levels below levels identified by scientific bodies as health hazardous, compared to outdoor levels. The data from this study may be used to inform decisions to either evacuate members of the public or have them SIP during and following a CO_2 pipeline release in a residential community. Specific study aims included the determination of infiltration and exfiltration rates of CO_2 into a residential dwelling and whether these rates are concentration dependent.

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* *ERG. 2020. Guide 120 Gases – Inert. United States Department of Transportation. Pipeline and Hazardous Materials Safety Administration.*

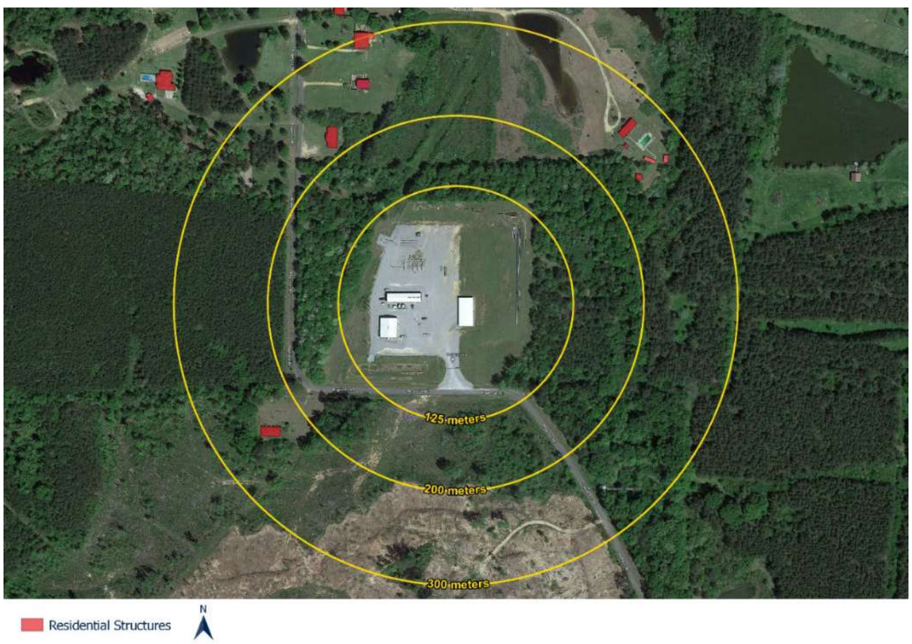
2.0 Materials and Methods

This report describes the results from a simulation study conducted on December 6 to 8, 2022 in Brookhaven, Mississippi. The study was conducted under the safety supervision of a Denbury Site Safety Officer working in conjunction with a CTEH Certified Industrial Hygienist and Certified Safety Professional serving as the Study Safety Officer. Details of the study hazards, safety measures, and Health and Safety Plan (HASP) may be found in Appendix A.

2.1 Study Area

The study was conducted at the Denbury CO_2 pipeline pump station located at 332 Rogers Lane Northeast, Brookhaven, Mississippi. Use of this location allowed for controlled release of pipelined CO_2 within a secure, fenced-enclosed area (Figure 2.1). The study tent enclosure, described below, was erected in a large gravel space approximately 50 meters from the nearest on-site building.

Figure 2.1 Brookhaven Study Location



2.2 Tent Enclosure Design

The CO2 exposures were performed inside a tent enclosure comprised of two large party-style tents sealed together. Each of the two connected tents were 40 ft long x 20 ft wide x 8 ft high with 13 ft roof peaks, providing a total exposure volume of 16,800 ft3. The tents were constructed of a metal frame with a fire-retardant exterior material (e.g., fire-retardant polyethylene sheeting). The enclosure was constructed and sufficiently sealed with polyethylene sheeting taped to the exterior tent walls to reduce gas leakage as well as the time required to raise the CO2 concentration within the enclosure to test-specific target levels. Weighted sandbags were used to hold the bottom of the tent close to the ground surface and tape was used on the exterior walls to seal pinpoint holes. Six electric fans were placed at each of the four corners and the North and South sides of centerline within the tent enclosure to facilitate rapid mixing of the CO_2 to a uniform concentration.

The tent enclosure was designed to facilitate ventilation of the interior between each test using fans to reduce interior CO_2 and H_2S concentrations to an amount safe for entry into the enclosure and diminish test reset time. Resealable openings on opposite sides of the tent enclosure were opened during clearance phases of the study and electric and pneumatic fan ventilation was used between tests to return concentrations of CO_2 within the enclosure and trailers to ambient (approximately 400 ppm).

2.3 Camping Trailer Designs

Two unmodified camping trailers (2018 Keystone Hideout and a Keystone Bullet Ultra Lite) were placed inside the tent enclosure approximately 6 feet apart. The trailers served as surrogates for residential structures within which occupants would SIP in the event of a nearby CO_2 release. Trailer configurations inside the tent enclosure and dimensions are shown in **Error! Reference source not found.** and **Error! Reference source not found.**. The trailer frames were approximately 27 inches to 29 inches above the ground surface which is similar to the height above ground surface of a typical manufactured home. According to the U.S. Department of Housing and Urban Development, ground level must be at least 18 inches below the wood floor joists (USDHUD, 2007, Chapter 5).

Figure 2.2 Trailer Positions within Tent Enclosure (Top View)

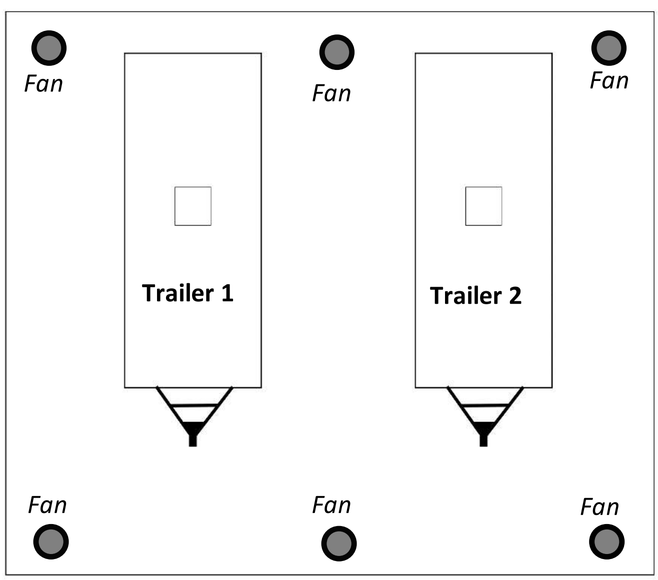


Table 2.1 Tailer Dimensions

	Space	Length (ft)	Width (ft)	Height (ft)	Volume (ft³)
Trailer 1	Main interior	26	7.7	6.4	1,281
	Slide-out section	11	3.2	5.6	197
Trailer 2	Main interior	26	7.8	6.4	1,298

Slide-out section	12	3.0	5.6	202

In a typical home, there are many differences in structural design, building materials, and materials quality that may impact the permeability of indoor and outdoor air. Camper trailers were selected for use in this study as surrogates for residential dwellings due to their mobility and ability to fit within the tent enclosure. The passive air turnover rate for the camper trailers calculated in Section 2.9 may be used to compare findings presented herein with single story building structures with different air turnover rates.

2.4 CO_2 Source Description

A gas mixture (dry CO_2) provided by Denbury was supplied to a sealed tent enclosure via pipe from a manually actuated manifold (Figure 2.3). The supply of CO_2 (

Table 2.2) was introduced to the tent using a choke and valve manifold capable of providing a flowrate between 69 to 12,222 cubic feet per minute (cfm). A certificate of analysis for the gas mixture was provided by Denbury and is shown in Appendix D.

Figure 2.3 CO_2 Manifold and Pipe Inlet to Tent Enclosure.

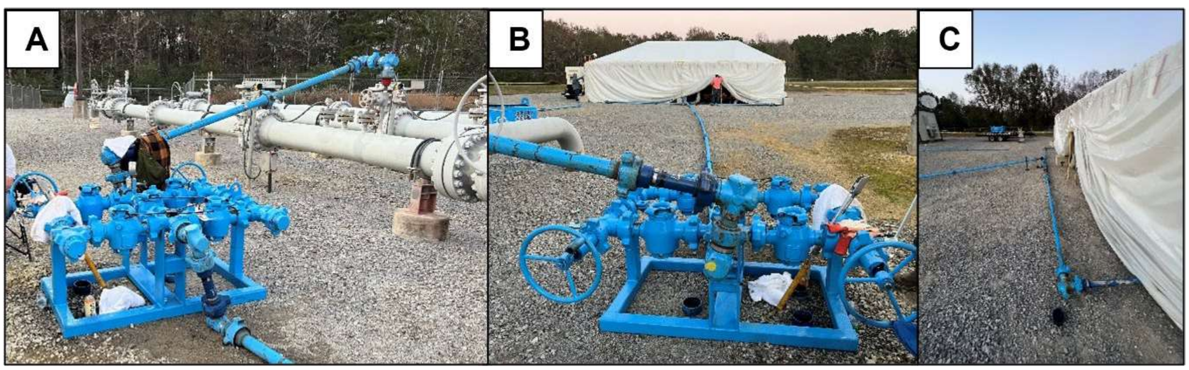


Photo A: CO_2 manifold showing tie-in to primary CO2 pipeline.
Photo B: CO_2 manifold showing leading pipeline to tent enclosure.
Photo C: Pipeline inlet to the front and back of the trailers inside of the tent enclosure.

Table 2.2 Supplied Gas Mixture

Carbon Dioxide (CO_2)	≥ 99.3%	≥ 993,000 ppm
Hydrogen Sulfide (H_2S)	< 0.001 %	< 10 ppm
Methane (CH_4)	0.30%	3,000 ppm
Nitrogen (N_2)	0.30%	3,000 ppm

The gas supply manifold was connected to the enclosure using ground-level two-inch carbon steel piping. Outside the tent enclosure, the supply pipe was bifurcated at ground level and ran parallel gas streams to opposite sides of the tent perpendicular to the trailers. Two-inch diameter riser pipes up to heights of approximately 3 ft were installed into the supply piping perpendicular to pipe length such that CO_2 gas exited vertically toward the tent ceiling. The gas supply at the supply manifold was turned on and off as needed to maintain, as much as practicable, a CO_2 concentration within ±500 ppm of each test's target

CO_2 concentration at the breathing zone height within the tent. The ability to control test target levels was determined prior to running each study test. To allow for safe emergency shutoff, the valve was positioned in a location where it could be safely operated during study events.

Figure 2.4. CO_2 Pipe Outlets Inside of the Tent Enclosure During Setup.

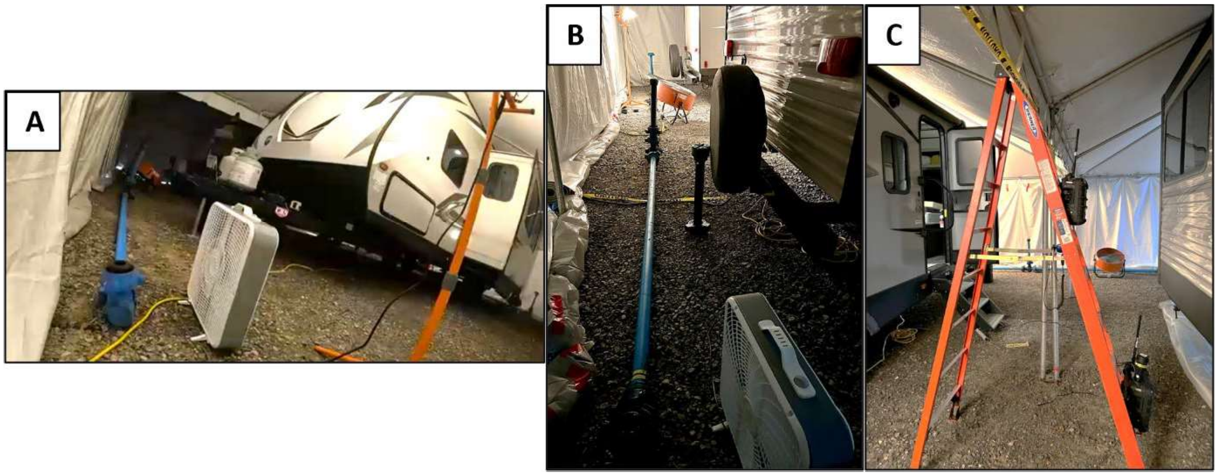


Photo A: CO_2 pipe outlets near the front (South) of the trailers.
Photo B: CO_2 pipe outlets near the front (North) of the trailers.
Photo C: Air monitoring station in between the two trailers at ground level and in the breathing zone.

2.5 Monitoring Equipment and Placement

2.5.1 Remote Telemetering/Datalogging Equipment

Data was logged directly to equipment or transmitted to remote machines approximately one to twenty second intervals. All remote data telemetering was transmitted over radio channels.

Remote telemetering and datalogging equipment consisted of Honeywell AreaRAE Pros and/or Honeywell MultiRAE Pros equipped with nondispersive infrared (NDIR) [*] CO_2 and O_2 electrochemical sensors were placed within the tent and trailers. For site safety monitoring purposes, an AreaRAE was located halfway between the enclosure exterior and the staging area and four AreaRAEs with sensors for VOC, CO_2, O_2, H_2S and %LEL measurement were located at the property fence line corners.

Sensors for The CO_2 sensors had a measuring range of 0 ppm to 50,000 ppm. Each morning prior to study commencement and between each study scenario, a two-point calibration was conducted for each chemical sensor using calibration gases. Carbon dioxide sensors were calibrated with 5,000 ppm CO_2 and O_2 sensors were calibrated with 20.9% O_2.

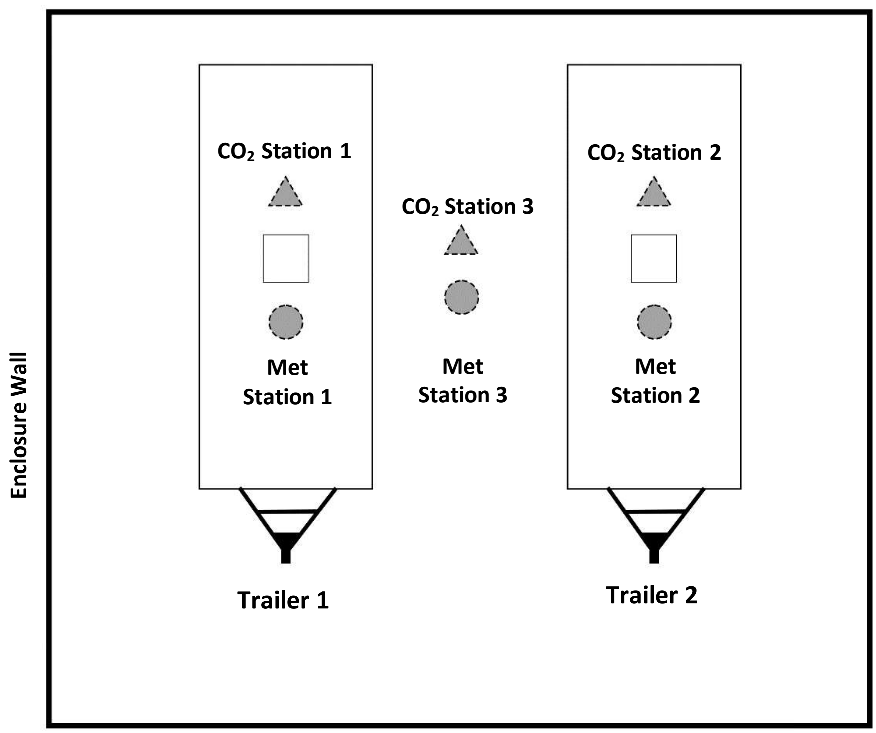
Temperature, relative humidity, and atmospheric pressure were recorded using AreaRAE meteorological sensors as these parameters had the potential to impact the behavior of the gas in the tent enclosure,

[*] Honeywell NDIR carbon dioxide (CO_2) Non-Dispersive Infrared (NDIR) sensor part number C03-0961-000. See Tech Notes TN-114 and TN-169 in in Appendix E for additional sensor information.

including infiltration into the trailers and mixing within the trailers. These parameters were measured at one location (denoted in **Error! Reference source not found.** and Figure 2.6 as a Met station) within each trailer and at one location within the tent enclosure.

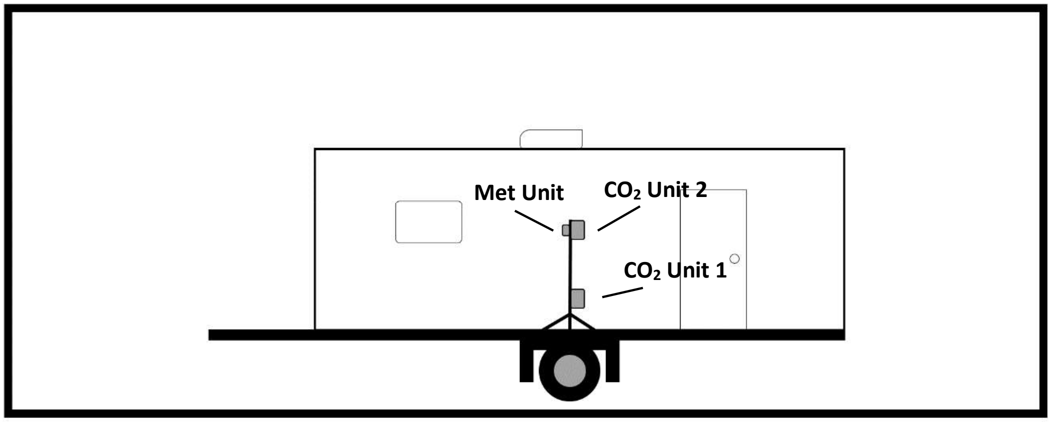
For the exposure simulation tests, gas monitoring was conducted at four monitoring stations: one station inside of each trailer, one station on each trailer exterior roof, and one station placed between the two trailers (**Error! Reference source not found.** and Figure 2.6). For interior trailer monitoring stations, one instrument was placed at a height of approximately 2-feet above ground/floor level (to simulate infant/toddler exposures) and one instrument at a breathing zone height of approximately 63-inches to 69-inches above ground/floor level (to simulate standing adult exposures). The monitoring station located between the trailers within the tent enclosure had one instrument placed at similar ground and breathing zone heights. Data from monitoring stations inside the tent and on trailer roofs were used to inform mixing of the CO_2 atmosphere as each test progressed.

Figure 2.5 Remote/Data Logging Monitoring Locations (Top View)



Met stations consist of instruments capable of measuring temperature, relative humidity, and ambient pressure.

Figure 2.6 Trailer Interior Remote Data/Logging Monitoring Locations (Side View)



Met stations consist of instruments capable of measuring temperature, relative humidity, and ambient pressure. Monitoring stations within both trailers and the enclosure were deployed.

2.6 Test System Performance Optimization

The tent enclosure /CO_2 pipeline exposure system used in this study was a novel experimental system. Therefore, several trials were conducted to optimize the system so that the in-tent CO_2 concentration was as uniform as possible from ground to roof, the desired target CO_2 level could be rapidly achieved and maintained over a 4-hour test period, and the tent and trailers could be safely and rapidly ventilated with fresh air at the conclusion of each test iteration. The following steps were performed to optimize the test system:

1. Background CO_2 and O_2 levels were monitored for 15 minutes.

2. One or two persons with handheld instruments roamed the tent exterior to identify tent leaks or on-site gas deposition hotspots.

3. CO_2 gas was introduced into the tent enclosure for a pre-calculated duration and shut off flow; exterior roamers began looking for leaks and noting exterior gas concentrations.

4. To maintain tent concentrations of ±500 ppm of target concentrations, CO_2 concentration decreases (from tent leakage) were observed and iteration combinations of manual input of supply manifold $CO_{2,}$ tent sealing, and fan location movements were performed.

2.7 Estimation of Occupant CO_2 Loading of Trailer Interior

Occupant CO_2 loading of Trailer 1 was monitored to estimate the proportion of indoor CO_2 contributed by trailer occupants. Four adult study participants occupied Trailer 1 for approximately 1.5-hrs sitting, standing, walking, and talking, while CO_2 concentrations were measured at breathing zone height.

2.8 Estimation of Trailer Air Change Rates

The camper trailers used in this study were similar in build and size but may differ in their indoor/outdoor air exchange rates compared to residential homes or other types of modular homes designed for permanent occupancy. Knowledge of these differences may be useful in extrapolating indoor CO_2 profiles observed in this study with potential profiles in other types of dwellings. The Air Changes per Hour (ACH) of each trailer was estimated by measuring the loss of indoor CO_2 over time using well established mathematical models for estimating concentration decay in a well-mixed space using the Python language. To accomplish this, overnight CO_2 measurements were recorded with doors and windows closed for trailer 1 following the conclusion of the occupant loading test described in Section 2.8 and following the conclusion of the 40,000 ppm test for trailer 2. The concentration of a gas at any point in time during which it is being lost from a well-mixed space may be calculated by Equation 2.1.

Equation 2.1 Gas Concentration Loss from a Well Mixed Space

$$C_r = (C_0 - C_{in})e^{\left(\frac{-Q(t-t_0)}{V}\right)} + C_{in}$$

Q = Air exchange flow rate between indoors and outdoors in $m^3\ min^{-1}$.
C_r = CO_2 concentration inside the trailer at time t in $mg\ m^{-3}$.
C_{in} = CO_2 concentration in air outside the trailer in $mg\ m^{-3}$.
C_0 = The initial CO_2 concentration inside the trailer at start of the decay phase in $mg\ m^{-3}$.
V = Volume of the trailer in m^3.
t = Time of the measured CO_2 concentration in minutes.
t_0 = Time at the start of the decay phase in minutes.

Solving Equation 2.1 for the air exchange flow rate (Q, m^3/minute) between indoors and outdoors results in Equation 2.2.

Equation 2.2 Indoor/Outdoor Air Exchange Flow Rate

$$Q = -\left(\frac{ln\left(\frac{C_r - C_{in}}{C_0 - C_{in}}\right)V}{t - t_0}\right)$$

Q = Air exchange flow rate between indoors and outdoors in $m^3\ min^{-1}$.
C_r = CO_2 concentration inside the trailer at time t in $mg\ m^{-3}$.
C_{in} = CO_2 concentration in air outside the trailer in $mg\ m^{-3}$.
C_0 = The initial CO_2 concentration inside the trailer at start of the decay phase in $mg\ m^{-3}$.
V = Volume of the trailer in m^3.
t = Time of the measured CO_2 concentration in minutes.
t_0 = Time at the start of the decay phase in minutes.

The air exchange flow rate (Q) was derived separately for each trailer from each CO_2 concentration (C_r)measured overnight inside the trailers and known values for the initial CO_2 concentration inside the trailers, the CO_2 concentration outside the trailers (C_{in}), and the volume (V) of the trailers using Equation 2.2. The underlying probability distribution of the flowrates was then identified using the Kolmogorov-Smirnov test* and the descriptive parameters of the identified distribution were used in subsequent calculations. Equation 2.1 was then fit† to the measured CO_2 concentration inside the trailer using least squares regression with constants C_0 and C_{in}. The volume of the trailer (V) was permitted to vary by 10% and the air exchange flow rate (Q) was permitted to vary between the 90% upper and lower confidence limits of the identified underlying distribution. The air exchange flow rate (Q) for the fitted equation was then used to determine the ACH using Equation 2.3.

Equation 2.3 Air Changes per Hour

$$ACH = \frac{Q\ x\ 60}{V}$$

ACH = Air Changes per Hour
Q = Air exchange flow rate in m^3 min^{-1}.
V = Volume of the trailer in m^3.

2.9 Study Tests

Four study tests were conducted to explore indoor CO_2 and O_2 changes in response to 4-hour outdoor CO_2 environments of up to the National Institute for Occupational Safety and Health (NIOSH) immediately dangerous to life and health (IDLH) level of 40,000 ppm (**Error! Reference source not found.**). To provide comparable results for each study event, both trailers had doors, vents, and windows fully closed, except for Test #5, which was conducted with windows open on Trailer 2. No active ventilation of trailers occurred during any other planned study tests.

Figure 2.7 CO_2 Study Tests

	CO_2 Concentration (ppm)
Test 1	10,000
Test 2	20,000
Test 3	30,000
Test 4	40,000
Test 5	≥50,000

Test 5 (CO2 ≥ 50,000 ppm) was conducted to understand the extent of indoor and outdoor O2 depletion during a "catastrophic release" in which the CO2 supply was allowed to fill the tent non-stop until the tent

* *See Python scipy.stats.kstest for additional details.*
† *See Python scipy.optimize.curve_fit for additional details.*

internal O2 level fell to 15%. Due to the high-CO2 in-tent levels expected to be generated in Test #5, a safety-based test abort trigger was employed: If tent wall leakage exceeded 20,000 ppm CO_2 in any one spot, the test would be aborted and the tent immediately ventilated into a pre-determined, fan-directed direction away from the study participants.

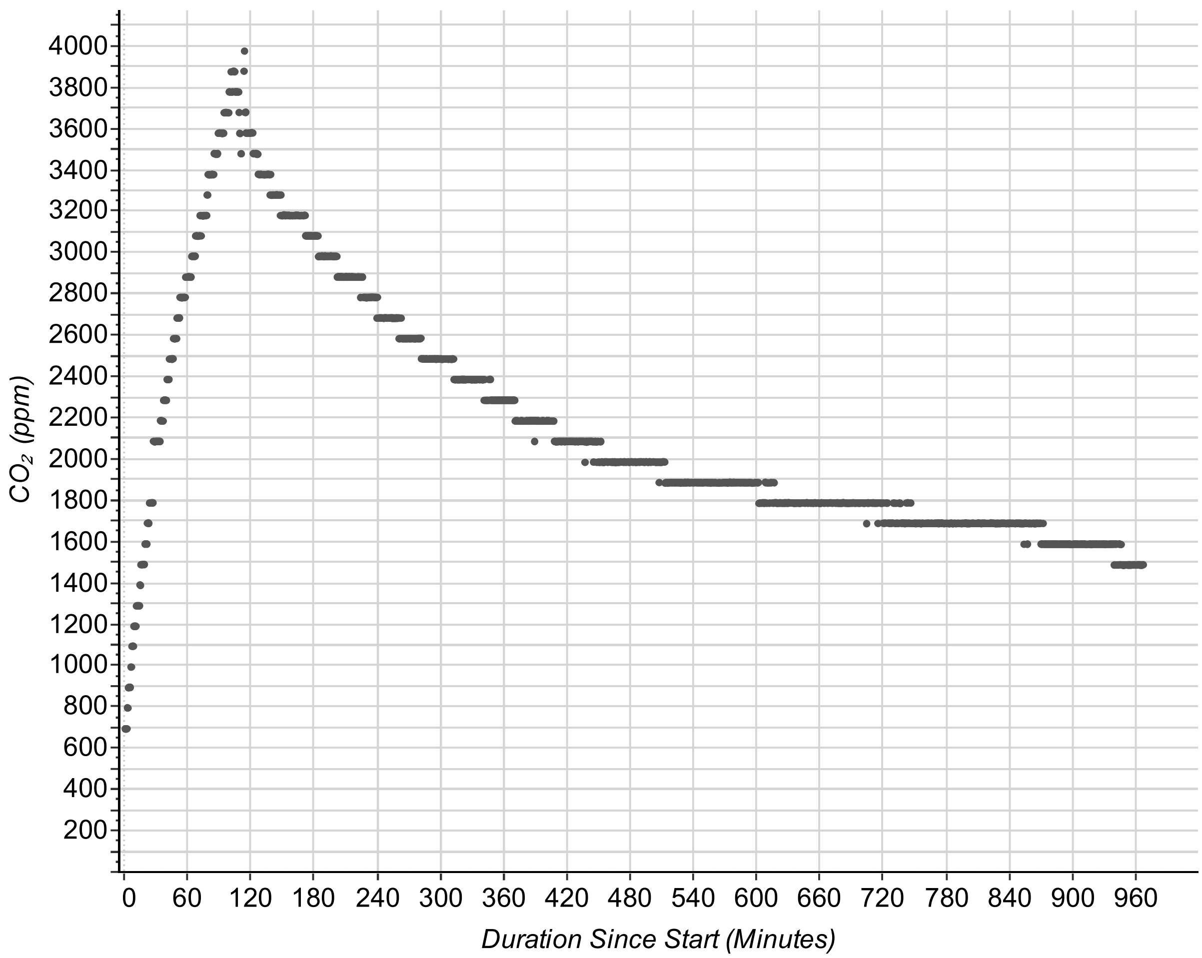
Active ventilation was used between each study event to purge CO_2 concentrations to ≤ 400 ppm CO_2 by exhausting trailer and tent interior to the tent exterior. Windows/doors were opened. Fans were located at the doorway of each trailer to facilitate return of trailer interior CO_2 andO_2 concentrations back to pre-test ambient conditions.

3.0 Results

3.1 Occupant CO_2 Loading and Trailer Air Change Rate Estimation

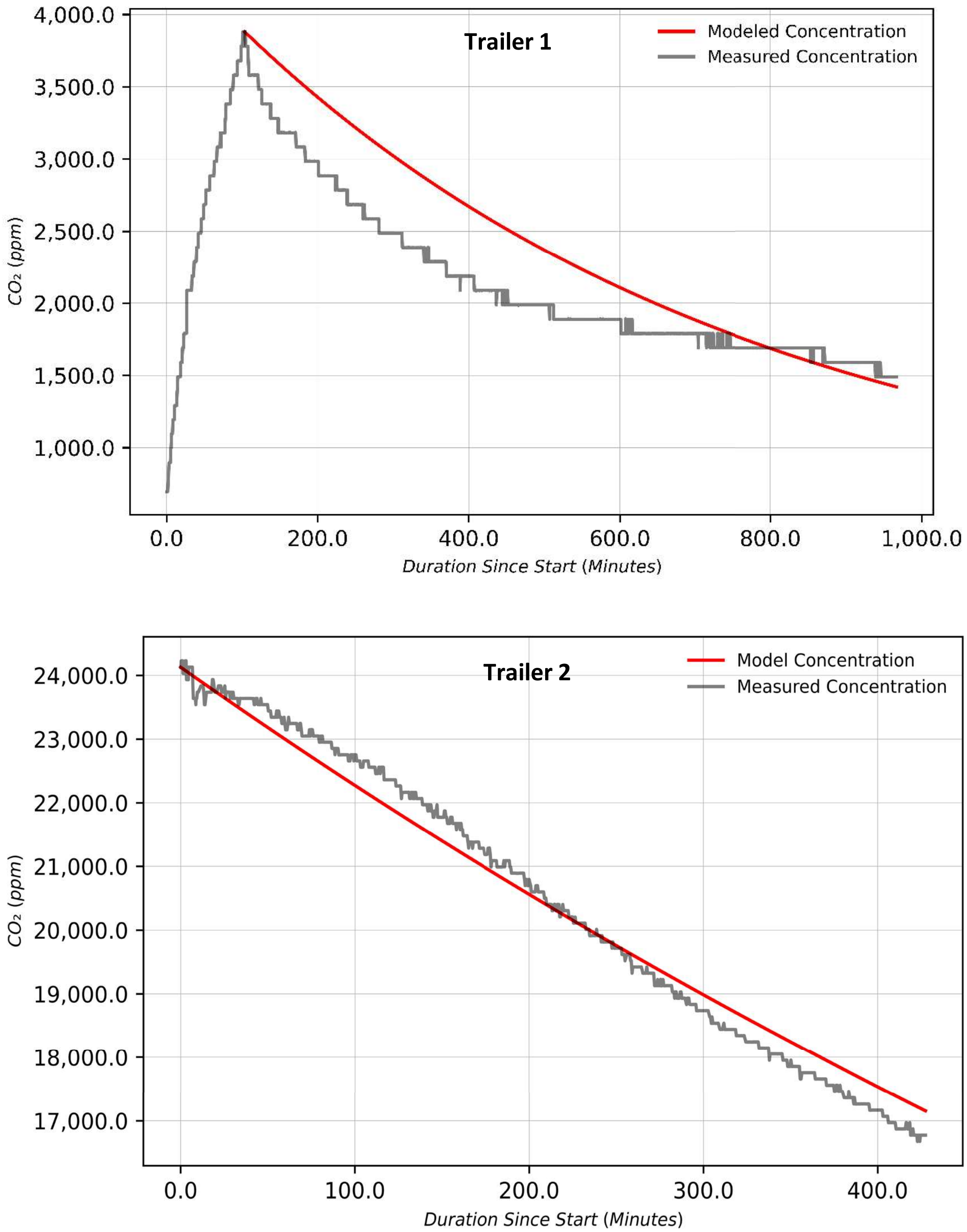
CO_2 concentrations reached 3,878 ppm during this time (Figure 3.1). Assuming the CO_2 exhalation of each study participant represented that of an average adult, this CO_2 loading level of approximately 4,000 ppm would be generally representative of the loading level produced by four adults over 90 minutes for a closed structure of approximately 1,700 ft^3 (approximately 48 m^3). A correction for the volume occupied by furniture inside each trailer was estimated to be 353 ft^3 (approximately 10 m^3).

Figure 3.1 CO_2 Loading and Clearance Profile Following Trailer 1 Occupancy



The data for CO_2 loss from Trailer 1 occupant CO_2 loading test, as well as data for CO_2 loss following the 40,000 ppm test in Trailer 2, were used to calculate air change rates. The measured and modeled CO_2 are shown in Figure 3.2. The modeled profile was created using the mean air exchange flow rates determined from **Error! Reference source not found.** to identify a predicted concentration in each trailer using the standard form for concentration decay in a well-mixed space model (Equation 2.1). The estimated air exchange flow rates from **Error! Reference source not found.** were then used to calculate ACH rates of approximately 0.2 ACH in Trailer 1 and 0.048 ACH in Trailer 2. Thus, Trailer 1 was about 4-times leakier than Trailer 2. For comparison, a typical unventilated home is estimated to have an ACH of 1 to 2 (Reichman et al., 2017).

Figure 3.2 Trailer 1 (Top) Trailer 2 (Bottom) Model-Predicted Air Change Rates



3.2 Tent and Trailer CO_2 and O_2 Time Profiles

Each of four study tests of 4-hour durations were performed, with increasing tent interior concentrations of CO_2 ranging from 10,000 to 40,000 ppm. A study test of concentration > 50,000 ppm was also attempted but aborted prior to reaching 50,000 ppm interior tent concentration due tent leakage exceeding the safety abort trigger condition.

During the 10,000, 20,000, 30,000, and 40,000 ppm tests, overall average CO_2 concentrations were maintained inside the tent within approximately 500 ppm of the target concentrations (Table 2, Figure 3.3 and Figure 3.4).

Table 2. Target and Actual Measured CO_2 Level in Tent Breathing Zone

Target CO2 Concentrations (ppm)	Measured Average Ground CO_2 Concentrations (ppm)	Measured Average Breathing Zone CO_2 Concentrations (ppm)	Measured Average Rooftop CO_2 Concentrations (ppm)	Measured Overall Average CO_2 Concentrations (ppm)
10,000	10,891	10,613	10,576	10,664
20,000	20,861	20,724	19,531	20,168
30,000	29,991	30,484	28,272	29,266
40,000	41,250	40,426	38,242	39,543

As tent breathing zone CO_2 levels fell to about 500 ppm below target concentration, study participants added a 2- to 8-second "puff" of CO_2 from the supply manifold, resulting in a transient CO_2 level that was slightly higher than the target level. This behavior is evident in Figure 3.3 and Figure 3.4 from the multiple peaks and troughs in the CO_2 graphs, with each peak representing a "puff". Ground level and rooftop CO_2 levels were similar to breathing zone levels, indicating rapid and uniform mixing of CO_2 in the tent enclosure. Oxygen levels in the tent decreased with increasing CO_2 levels, with the tent rooftop monitors measuring the lowest O_2 levels. The lowest O_2 levels observed remained above 19.5% in ground and breathing zone measurements (CO2 and O_2 concentrations were measured at the interior trailer floor and at breathing zone levels throughout the tests (**Error! Not a valid bookmark self-reference.** and Figure 3.6). The CO_2 concentrations on the trailer floor and in the breathing zone increased with similar patterns and concentrations over time during the 10,000 and 20,000 ppm study tests. In contrast, the 30,000 and 40,000 ppm test trailer floor CO_2 concentrations rose more rapidly than that of the breathing zone, indicating an initial stratification of CO_2 by height. In both tests, floor level CO_2 increased rapidly, then began to decrease, at which time the rate of increase at the breathing zone level began to rise. The reason is not clear for this rapid increase in breathing zone concentration followed by a decrease in floor level CO_2 in these higher tent concentration tests. Some interior trailer atmospheric property or some feature of changing CO_2 ingress becomes apparent in the 30,000 and 40,000 ppm trailers, resulting in height-specific differences in CO2 loading followed by a marked reduction in floor level CO_2. The lowering of CO_2 levels at the floor height of both trailers in the high ppm tests indicated an upset of low-lying CO_2, forcing it toward the breathing zone height after which it reached a new floor-level equilibration. It is not known whether this phenomenon is specific to the test trailers, or would be observed in other residential homes. The O_2 concentration never fell below 19.5% throughout all study tests from 10,000 to 40,000 ppm.

Figure 3.5). The reason for rooftop deficits of O_2 concentrations is uncertain.

Figure 3.3 Tent CO_2 and O_2 Concentration Time Course During 10,000 and 20,000 ppm Tests

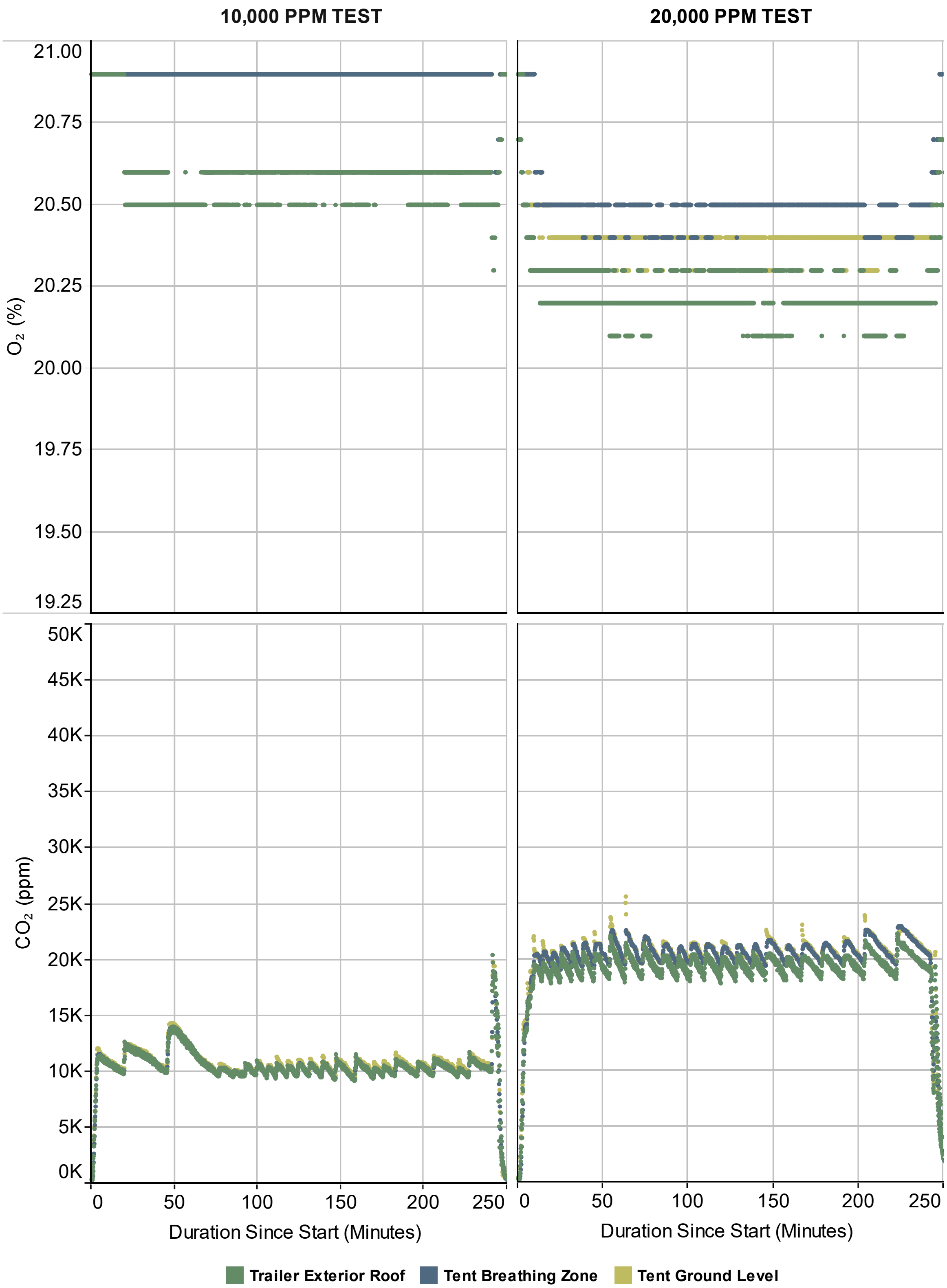
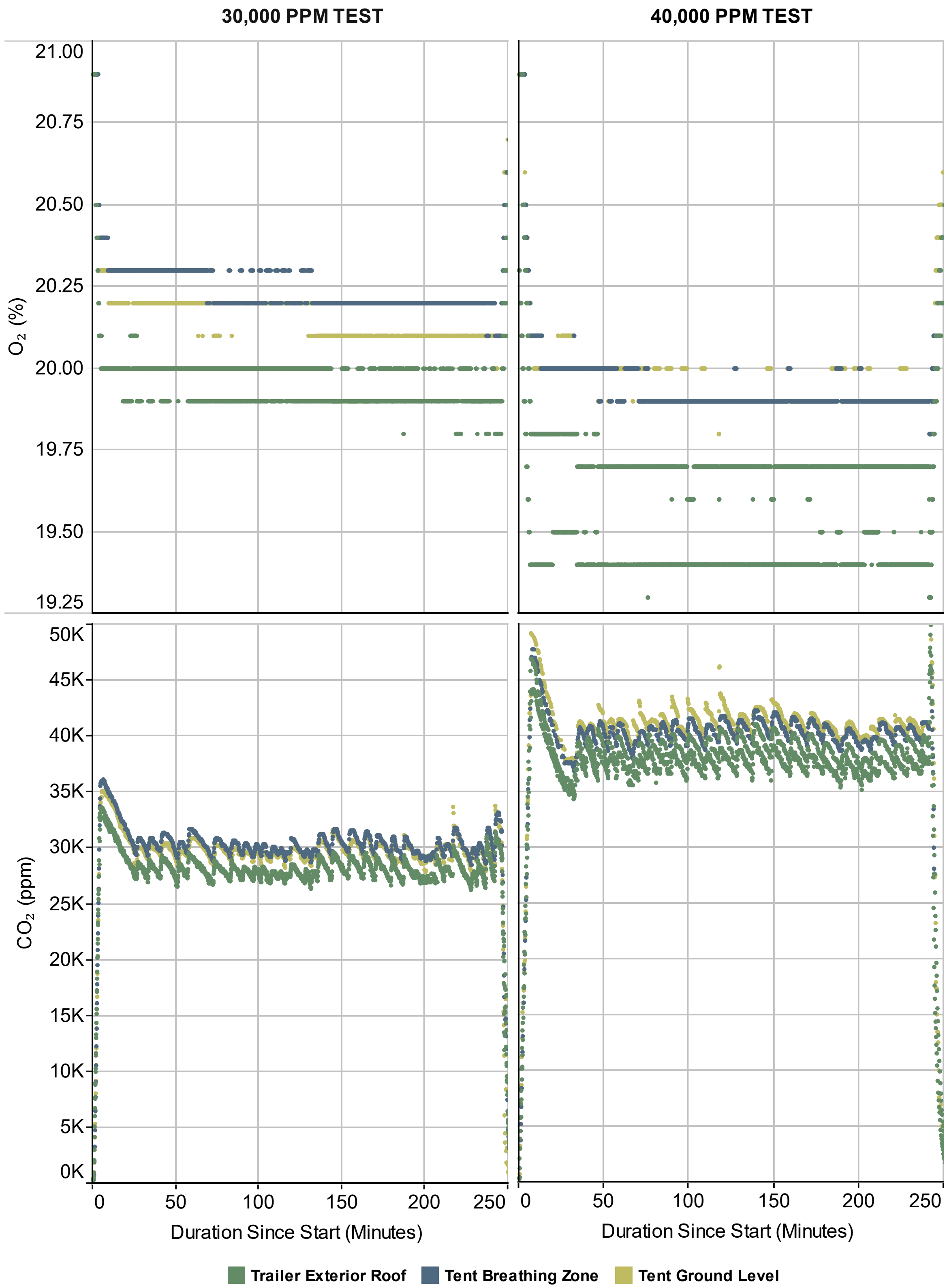


Figure 3.4 Tent CO_2 and O_2 Concentration Time Course During 30,000 and 40,000 ppm Tests



CO_2 and O_2 concentrations were measured at the interior trailer floor and at breathing zone levels throughout the tests (**Error! Not a valid bookmark self-reference.** and Figure 3.6). The CO_2 concentrations on the trailer floor and in the breathing zone increased with similar patterns and concentrations over time during the 10,000 and 20,000 ppm study tests. In contrast, the 30,000 and 40,000 ppm test trailer floor CO_2 concentrations rose more rapidly than that of the breathing zone, indicating an initial stratification of CO_2 by height. In both tests, floor level CO_2 increased rapidly, then began to decrease, at which time the rate of increase at the breathing zone level began to rise. The reason is not clear for this rapid increase in breathing zone concentration followed by a decrease in floor level CO_2 in these higher tent concentration tests. Some interior trailer atmospheric property or some feature of changing CO_2 ingress becomes apparent in the 30,000 and 40,000 ppm trailers, resulting in height-specific differences in CO2 loading followed by a marked reduction in floor level CO_2. The lowering of CO_2 levels at the floor height of both trailers in the high ppm tests indicated an upset of low-lying CO_2, forcing it toward the breathing zone height after which it reached a new floor-level equilibration. It is not known whether this phenomenon is specific to the test trailers, or would be observed in other residential homes. The O_2 concentration never fell below 19.5% throughout all study tests from 10,000 to 40,000 ppm.

Figure 3.5 Trailer Floor and Breathing Zone CO_2 and O_2 Concentration for 10,000 and 20,000 ppm Tests

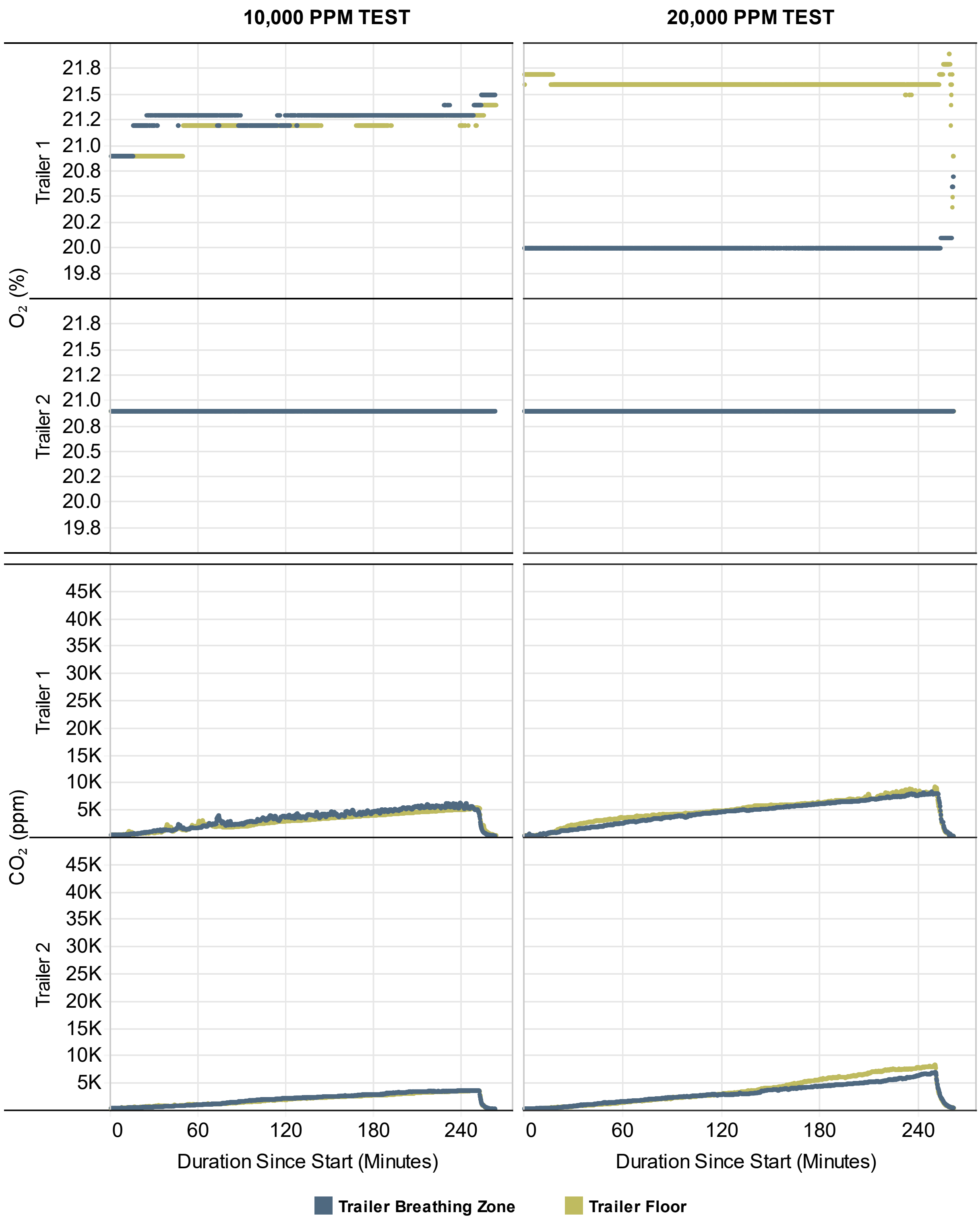
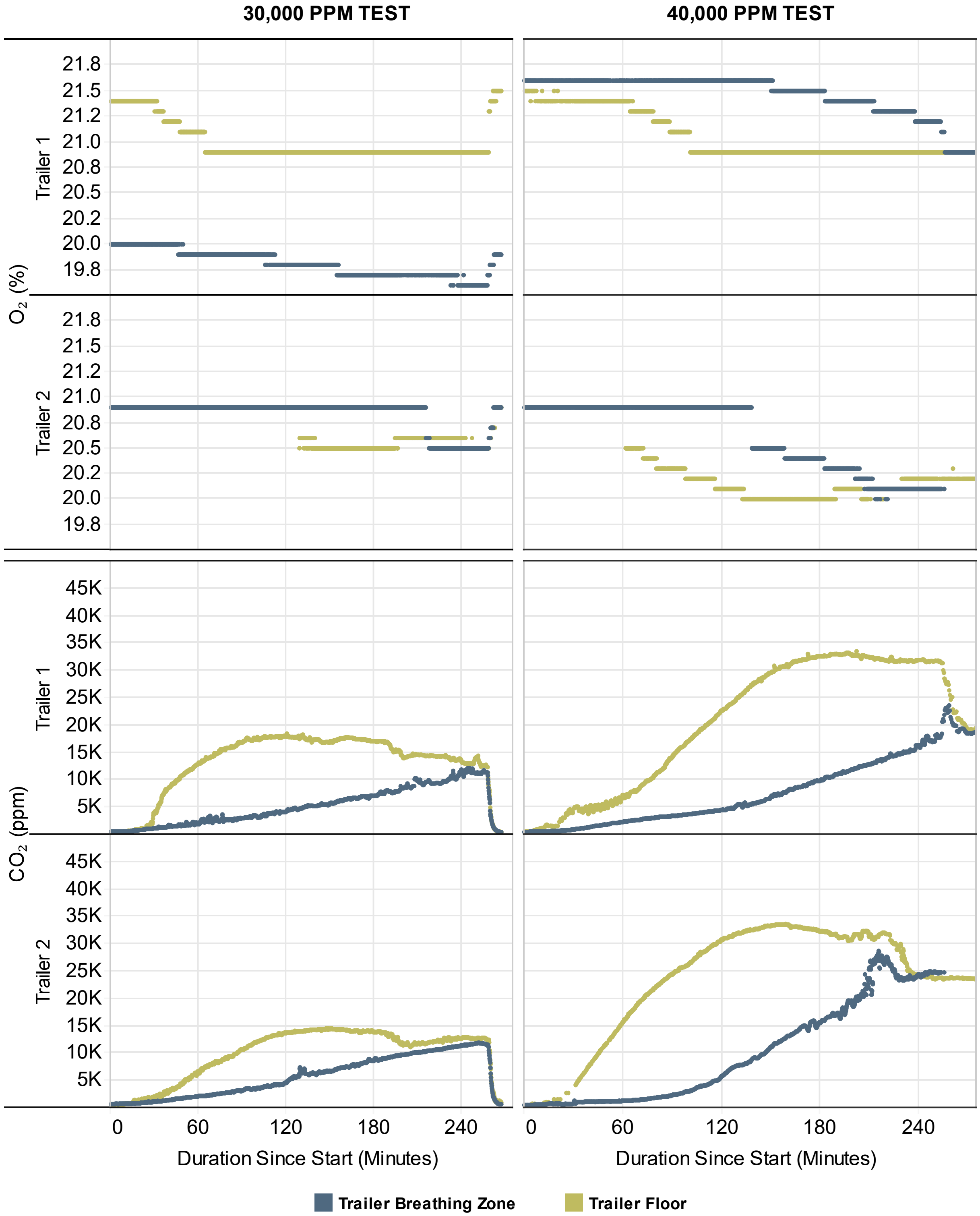


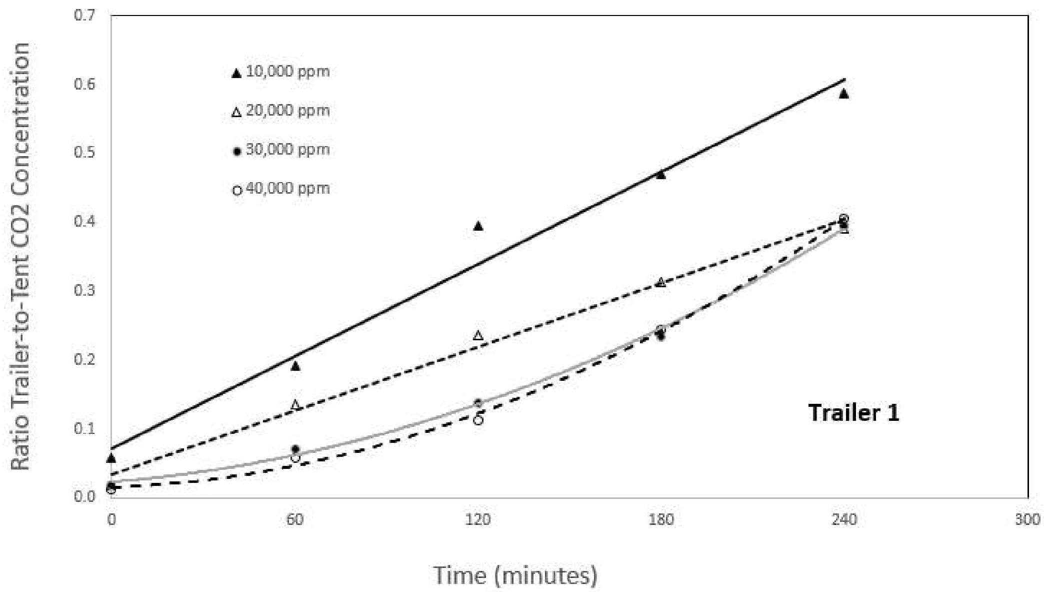
Figure 3.6 Trailer Floor and Breathing Zone O2 Concentration for 30,000 and 40,000 ppm Tests

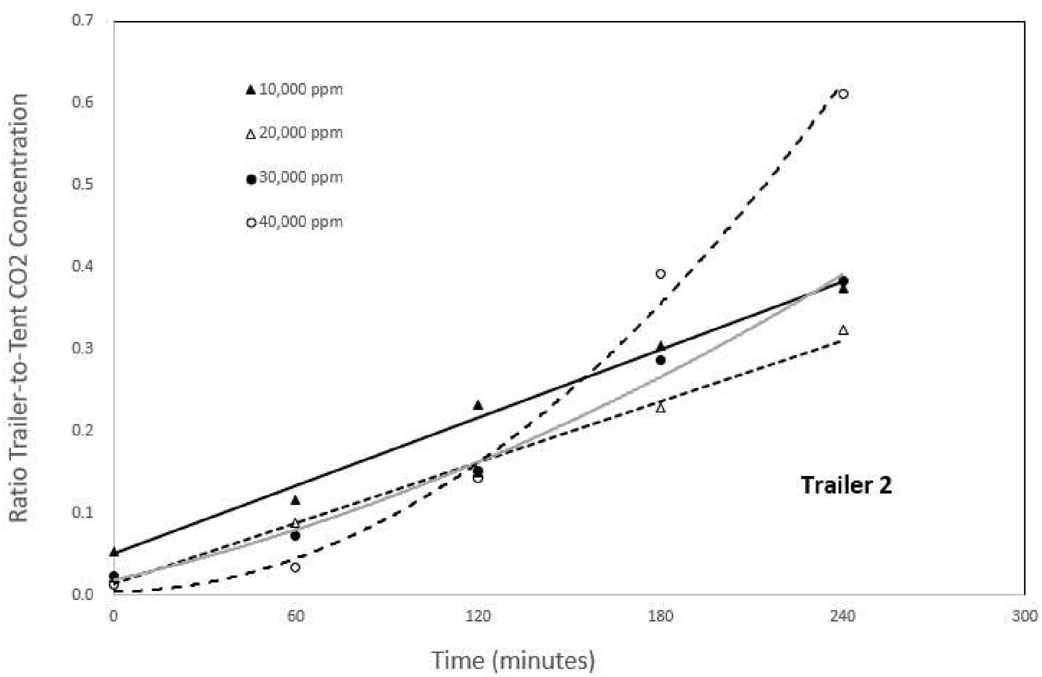


3.3 Trailer CO_2 Loading Relative to Tent Levels Over Time

Figure 3.7 shows the indoor-to-outdoor CO_2 ratios for both trailers across the 10,000 to 40,000 ppm tests. Both trailers exhibited linear increases in ratios across time for the 10,000 and 20,000 ppm tests. Trailer 2 ratios across tests were generally lower than those of Trailer 1, ostensibly due to its less leaky construction. It is uncertain whether the higher rate of ratio increase seen in the 40,000 ppm test data from Trailer 2 is due to an actual shift to different ingress behavior at this CO_2 test level or was an artifact of an unidentified structural change in the Trailer 2 points of entry.

Figure 3.7 Ratios of Trailer to Tent Breathing Zone CO_2 Over Time





3.4 CO_2 Maximum Loading Tests

In order to model worst case scenario, and catastrophic displacement of O_2 with CO_2, a maximum loading test was also conducted, where CO_2 concentration was ≥ 50,000 ppm (Figure 3.8 and Figure 3.9). The maximum loading test was aborted after approximately six minutes due to an identified enclosure leak; measured CO_2 concentrations were 90,000 ppm at the abort time. The trailer with open windows (Trailer 2) rapidly exhibited CO_2 levels that exceeded the indoor instrument's detection limit with a concomitant reduction in indoor 02. Even with this level of CO_2, O_2 decreased to only 18.2% within the tent, and the minimum oxygen inside the trailer with opened windows was 19.5%. O_2 concentration was not affected in the trailer with closed windows.

Figure 3.8 CO_2 and O_2 in the Enclosure Tent During CO_2 Maximum Loading Test

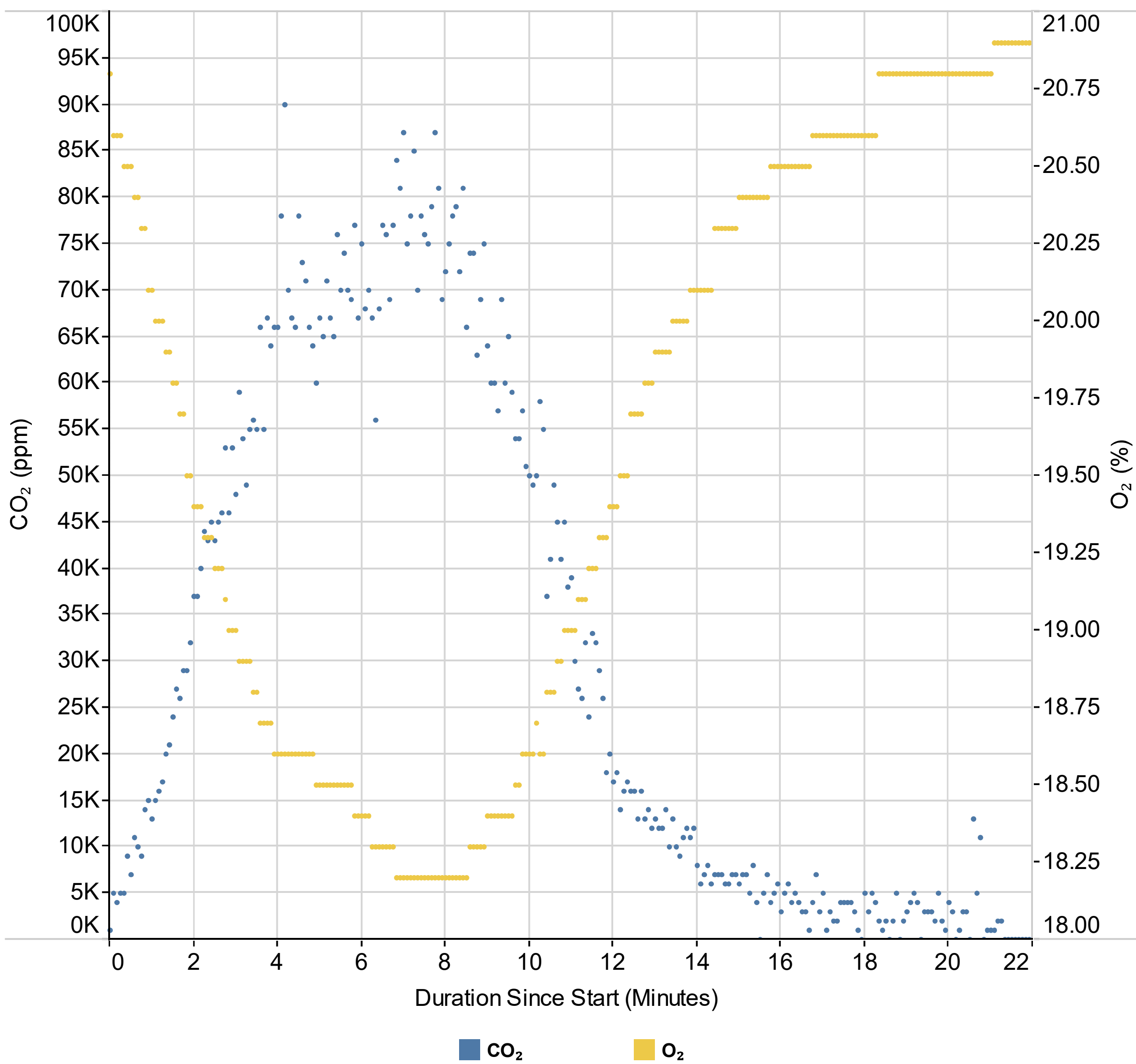
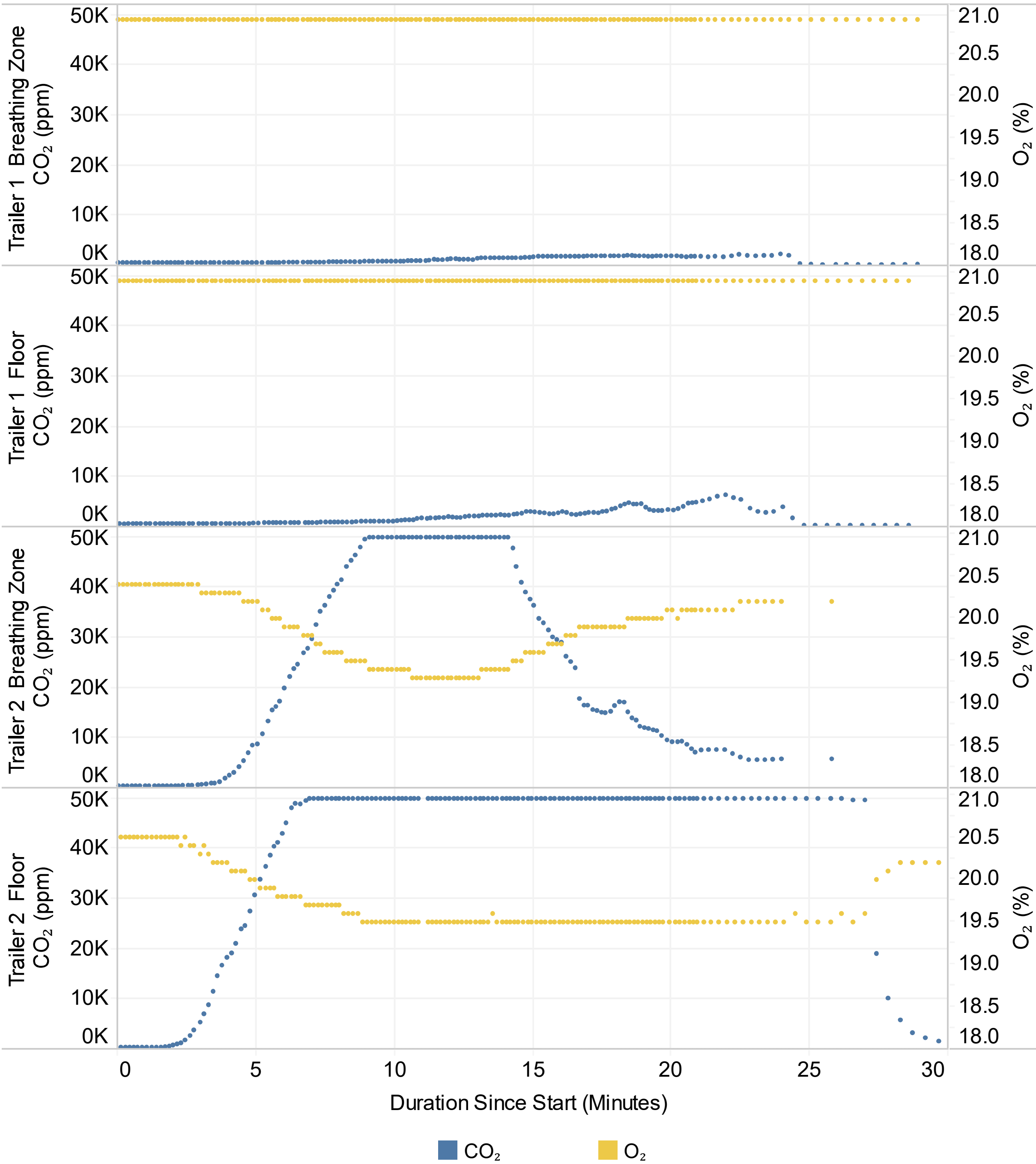


Figure 3.9 CO_2 and O2 Inside the Trailer 1 (windows closed) and Trailer 2 (windows open) During CO_2 Maximum Loading Test



4.0 Discussion

4.1 Potential for O_2 Deprivation in High CO_2 Atmospheres

One of the hazards of high ambient CO_2 levels is the displacement of O_2. However, understanding the conditions for CO_2-induced O_2 displacement is important in emergency response. The tent O_2 levels decreased with increasing levels of CO_2. However, 40,000 ppm CO_2 levels (the NIOSH IDLH level) resulted in relatively small decreases in tent O_2 of just under 20% in the breathing zone during the 40,000 ppm test. Interior trailer O_2 levels were observed to decrease at test concentrations of 30,000 ppm or greater. However, O_2 within the trailers remained greater than 19.5% at all CO_2 concentrations up to and including 40,000 ppm. Even during the maximum CO_2 test, O_2 decreased to 18.2% within the breathing zone of the tent when CO_2 concentrations reached approximately 90,000 ppm.

The observed relationship between test CO_2 and O_2 levels is not unexpected. A formula relating CO_2 levels to O_2 displacement follows:

Equation 4.1 CO_2 levels to O_2 displacement

$$\%\ O_2 = 0.209 \times (1 - fractional\ percent\ CO_2) \times 100$$

Thus, a 40,000 ppm CO_2 atmosphere would be expected to result in an O2 atmosphere of 20%, similar to the levels we observed of 19.5% to 20%. Similarly, a 90,000 ppm CO_2 atmosphere would be expected to result in an O_2 atmosphere of 19%, similar to the levels we observed of 18.2%.

4.1.1 Shelter in Place Implications

All of the exposure simulation tests reported herein whether representing a lingering 4-hour 40,000 ppm exposure or a short (8 minute) "blast" of 90,000 ppm CO_2 did not result in indoor CO_2 levels of more than 30,000 ppm. Further, indoor O_2 levels in closed trailers did not drop below 19.5%.

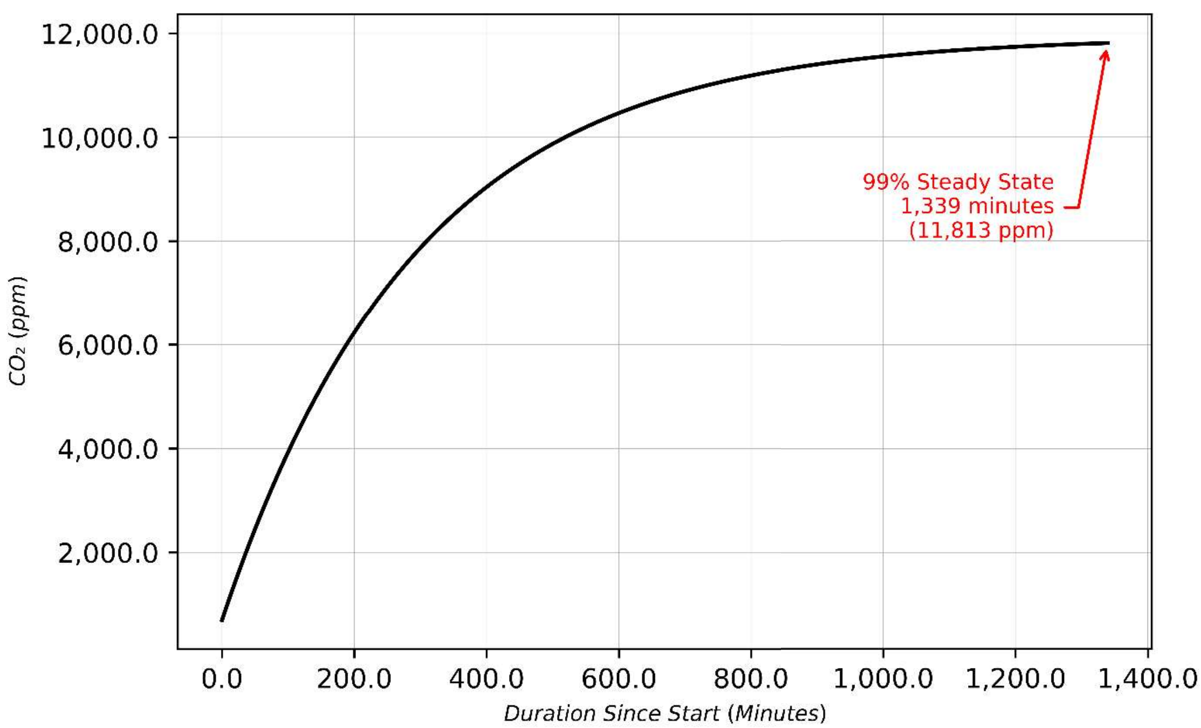
Studies of submariners exposed to 30,000 ppm CO_2 for extended periods of time resulted in only mild changes in pulse and blood pressure, a physiological response of the body to eliminate CO_2 from the circulatory system (Schaefer, 1951 as cited by NIOSH, 1994a). A recent study reported high tolerability of up to 90,000 ppm for 60 minutes in healthy volunteers (van der Schrier et al., 2022). While there is uncertainty in the ability of persons with compromised respiratory systems (i.e., COPD or asthma patients) to tolerate CO_2 levels as healthy volunteers and submariners, SIP during an elevated CO_2 release is likely to provide superior risk reduction than egress from an effected area via vehicle or on foot.

Jetter and Whitfield (2005) and USEPA (2009) asserted that SIP is a viable option in the event of a release of a potentially hazardous agent, with considerations as to the maximums for the number of people sheltering together, and for the period of time. For instance, in their 2009 report, USEPA reported that in a high-density occupied space (i.e., one person per 2 m^2 floorspace), and with an ACH of 0.27, the shelter CO_2 concentrations were estimated to be 13,732 mg/m^3 (7,629 ppm) after three hours. However, the

USEPA (2009) and Jetter and Whitfield (2005) did not adjust for the eventual achievement of steady state CO_2 levels inside the shelter, accounting for the ACH.

According to the U.S. Census Bureau, the average occupancy in US homes is three people. Thus, in the current analysis, four individuals inside a trailer with 177 ft^2 (16.4 m^2) of occupiable floor space is a realistic overestimation of person density and is approximately equal to 4 m^2 per person. Using the same CO_2 accumulation rate calculations from USEPA for the current scenario of SIP in a residential setting with reduced occupancy, wherein four people occupy 4 m^2 each of space, the resulting theoretical CO_2 concentrations were 6,866 mg/m^3 (3,814 ppm) after three hours. To validate this theoretical CO^2 build-up, measured CO_2 loading rates from the occupant loading test in the current study were used. The modeled occupant loading time to reach steady state CO_2 concentration is shown in Figure 4.1 Modeled Occupant Loading Time to Reach Steady Stateand is based on measured data for 90 minutes inside of Trailer 1.

Figure 4.1 Modeled Occupant Loading Time to Reach Steady State



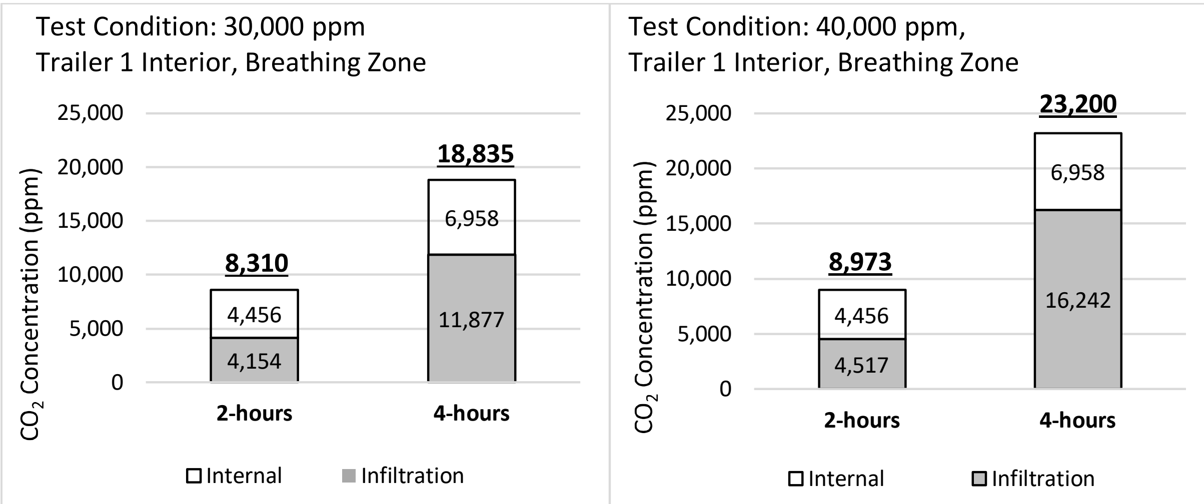
After three hours inside Trailer 1 with four occupants, the CO_2 concentration is estimated to be 8,021 mg/m^3 (4,456 ppm) and is estimated to be 17,514 mg/m^3 (9,730 ppm) after eight hours. The modeled steady state CO_2 concentration does not exceed 21,263 mg/m^3 (11,813 ppm) after 24 hours. For perspective, the CO_2 concentrations for an 8-h time-weighted average CO_2 concentration of 6,393 ppm is slightly above 5,000 ppm limit as set by the Occupational Safety and Health Administration (OSHA), but is well below the American Conference of Governmental Industrial Hygienists (ACGIH) Short-Term Exposure

Limit (STEL) ppm and the National Institute of Occupational Safety and Health (NIOSH) STEL of 30,000 ppm.

In 2006, experts from Argonne National Laboratory published SIP guidance on behalf of the U.S. Army and Department of Homeland Security's Chemical Stockpile Emergency Preparedness Program (CSEPP). The *Shelter in Place Protective Action Guidebook* (CSEPP, 2006) discussed the risks and benefits of evacuation versus SIP before and during arrival of a plume of a gaseous chemical warfare agent. The authors noted that shelters with lower ACH rates (e.g., tighter structures) would result in lower exposure ratios with respect to the outdoor plume concentration. The authors went on to say that SIP strategies should consider the time at which outdoor plume levels become lower than indoor levels, so that sheltering persons leave their shelter and enter an outdoor environment that has a lower plume concentration. In our experiments, the highest recorded indoor breathing zone concentration during the 40,000 ppm test was about 5,000 ppm at two hours and less than 30,000 ppm at four hours of the event. The highest 2-hour value of about 5,000 ppm was similar to the expected occupant load of four adults exhaling CO_2 in a trailer (about 4,000 ppm observed after 90 minutes). The maximum indoor CO_2 level we recorded after an 8-minute plume that rose to about 90,000 ppm was slightly higher than ambient levels. We note that the experimental conditions did not include indoor air movement due to occupants that would be present in a real-world event. Thus, breathing zone-to-floor CO_2 levels over time may be different than seen experimentally. These CO_2 results using low-ACH camper trailers comport with CSEPP guidance for SIP until plume egress, after which structure ventilation should be performed.

The addition of internally generated CO_2 concentrations from residents and the infiltration of CO_2 from outdoors must be considered when evaluating SIP safety. Based on the circa-linear increase in CO_2 concentration in the breathing zone during infiltration (as shown in Figure 3.6) and the similar increase observed during the first four hours of the occupant loading test (Figure 4.1), the infiltrated and internally generated CO_2 concentrations during the 30,000 ppm test can be summed. As shown in Figure 4.2 in the test condition of 30,000 ppm, the maximum CO2 concentration inside the trailer in the breathing zone is estimated to be 18,835 ppm. While not directly applicable, this concentration is well below the ACGIH and NIOSH STELs. The positive rate of increase in CO_2 concentration in the 40,000 ppm test was consistent up to approximately 120 minutes, after which time the rate almost doubled (80% increase in slope after 120 minutes compared with 0 to 120 minutes). However, the CO_2 concentrations in the breathing zone remain well below the STEL of 30,000 ppm and the IDLH of 40,000 ppm, which is based on submariners continuously exposed to 30,000 ppm CO_2 and who exhibited slightly increased respiration (Schaefer, 1951 as cited by NIOSH, 1994a). Of note, the submariner tests were conducted under conditions where O_2 concentrations were maintained, and the authors postulated that an emergency release might result in decreased O_2 concentrations. However, in contrast to the hypothesis by Schaefer (1951), measured O_2 concentrations in the breathing zone of both trailers for the duration of the test period for all 10,000 ppm to 40,000 ppm tests were well above 19.5%, below which is considered an O_2-deficient environment by OSHA. The results of the current study suggest that, even at 40,000 ppm exposures, O_2 concentrations remain at a safe and normal atmospheric concentration while CO_2 concentrations do not exceed highly conservative STEL or IDLH values.

Figure 4.2. Estimated Cumulative Infiltrated and Internally Generated CO_2 Concentrations in Trailer 1.



SIP is a viable, health protective option for at least four hours following a release of at least 40,000 ppm CO_2. The effectiveness of SIP to reduce exposure to plume-level concentrations is less certain for residences that are significantly leakier than the trailers used in this experiment.

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van der Schrier, R., van Velzen, M., Roozekrans, M., Sarton, E., Olofsen, E., Niesters, M., Smulders, C., & Dahan, A. (2022). Carbon dioxide tolerability and toxicity in rat and man: A translational study. *Frontiers in Toxicology*, *4*, 1001709. https://doi.org/10.3389/ftox.2022.1001709

Appendix A: Health and Safety Measures and the Health and Safety Plan (HASP)

CTEH®

Safety Measures

Chemical Hazards

Carbon dioxide (CO_2), CAS# 124-38-9, is a colorless, odorless gas comprised of one carbon atom and two oxygen atoms. Select physical and chemical properties of CO_2 include molecular weight of 44 g/mol, vapor pressure 56.5 atm at 22 °C, vapor density 1.53 (unitless), ionization potential 13.77 eV, and specific gravity of 1.56 at -110.2 °F (NIOSH, 2019). In the event of a release, the public may be exposed to CO_2 via inhalation or skin or eye contact. Symptoms of sufficiently high CO_2 exposure include dizziness, headache, restlessness, tingling 'pins and needles' sensation, difficulty breathing, increased heart rate, cardiac output, and blood pressure, coma, asphyxia, and death.

Hydrogen Sulfide (H_2S) is a colorless gas having a strong odor of rotten eggs and poses a respiratory hazard. The odor threshold, or the concentration of H_2S when the human nose is first able to detect the odor of rotten eggs, is approximately 0.00005-1.4 ppm.(Murnane et al., 2013) H_2S concentrations greater than 100 ppm causes human smell sensory fatigue which means that rotten egg odors cannot be counted on to warn of the continued presence of the gas. The National Institute for Occupational Safety and Health (NIOSH) set and Immediately Dangerous for Life and Health (IDLH) value for H_2S of 100 ppm based on acute inhalation toxicity data in humans and animals; concentrations above 200 ppm for prolonged periods may cause edema or death (NIOSH, 1994b; OSHA, 2022) .

Methane is a colorless odorless gas, also known as marsh gas or methyl hydride. Methane is easily ignited. The vapors are lighter than air. The lower explosive limit of methane is approximately 5% by volume in air. Sufficiently high concentrations may cause asphyxiation through the displacement of oxygen (USCG, 1999), which has a normal ambient range of 19.5-23.5% per Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.134.

Total VOCs as a group do not have any established standards or guidelines. However, VOC monitoring was conducted to determine if more specific sampling or investigation is needed.

Chemical Hazard Action Levels

There is no consensus on what concentration of CO_2 is appropriate for a community emergency response guidance value. Health effects reported in older studies include lightheadedness, but details on the extent or transient nature of the effect are scant. NIOSH designated a CO_2 concentration that is 'Immediately Dangerous to Life and Health' (IDLH) of 40,000 parts per million (ppm). For comparison, the current OSHA permissible exposure limit for an eight-hour work period is 5,000 ppm (9,000 mg/m^3) (OSHA, 2018). While permissible short-term (15-minute) exposure limits (STEL) for CO2 are not provided by OSHA, both NIOSH and the American Conference for Governmental Industrial Hygienists (ACGIH) provide a STEL of 30,000 ppm (54,000 mg/m3) (DFG, 2012).

Studies of non-occupational exposures to CO2 inform the tolerance of the human body to a wide range of CO2 exposure concentrations. In a recent review article by Permentier et al. (2017), the physiological effects of CO2 exposure were described in human and animal models, based on decades of research. In general, CO2 concentrations that resulted in human fatalities ranged between 14% and 26%, while CO2 concentrations less than 5% (50,000 ppm) had "little, if any, toxicological effects" (Permentier et al., 2017, p. 2). A recent study by van der Schrier et al., (2022) of CO2 exposure to groups of adult volunteers and rats provides a basis to propose raising the IDLH to as high as 75,000 ppm.

Considering the existing PEL, STEL, IDLH, and the range of responses from human exposures to CO2 summarized by Permentier et al., (2017) and reported recently by van der Schrier et al., we determined that a reasonable and scientifically justifiable acute emergency guidance level for a 60-minute exposure would range somewhere between 20,000 and 75,000 ppm (2% to 7.5%) CO2. The study action levels to protect on-site study participants for CO2, H2S, %LEL, and O2, and their respective actions to be taken if exceeded, are shown in Table 2.1. For the purposes of this study, a detailed Health and Safety Plan (HASP) was developed and is included in Appendix A.

Table A.4.1 Study Action Levels for Study Participant (Worker) Protection

Chemical	Action Level	Action	Basis
Carbon Dioxide	5,000 ppm (15-min)	Notify SSO*	OSHA PEL & ACGIH TLV (8-hr)
	30,000 ppm (5-min)	Egress upwind and notify SSO	ACGIH STEL (15-min)
LEL (as methane)**	0.5%	Notify SSO	1/10th LEL
Hydrogen Sulfide	1 ppm	Notify SSO	ACGIH TLV-TWA (8-hr)
	5 ppm	Egress upwind and notify SSO	ACGIH STEL (15-min)
Oxygen	< 19.5 %	Notify SSO	Oxygen deficient atmosphere

**SSO: Study Safety Officer*

***Based on LEL of methane (100% LEL = 5% methane, or 50,000 ppm)*

Action levels used during the study for CO2 and H2S to protect nearby off-site receptors (community), and their respective actions to be taken if exceeded, are shown in **Error! Reference source not found.**. The United States Environmental Protection Agency's (EPA) Acute Exposure Guideline Level 1 (AEGL-1) is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure (NRC, 2010).

Table A.4.2 Study Action Levels for Community Protection

Chemical	Action Level	Basis	Action
Carbon Dioxide	20,000 ppm	Study specific	Report reading to SSO; reevaluate enclosure leakiness or ventilation rate and wind direction
Hydrogen Sulfide	0.51 ppm	AEGL-1 (60 minutes)	

**SSO: Study Safety Officer*

Physical Hazards

A number of physical hazards potentially existed onsite and were controlled administratively during the assessment to include the following: thermal stressors; weather; traffic; equipment; electrical; fire and explosion; slip, trip, and falls; noise; flying debris; and dermal hazard. The full mitigation and hazard list is included in Appendix A.

Administrative Controls

Prior to work commencing each day, a Job Safety Analysis was conducted and documented to outline the tasks for the day as well as the potential hazards and mitigation strategies. Personnel participated in daily safety briefings each day before work started as well as if operations changed during each day. Contingency plans were developed as part of the HASP in the event of an emergency to include evacuation, notification, and containment if a release occurred.

Select workers were also trained in hydrogen sulfide awareness, site hazards, emergency actions, communication, PPE, first aid, CPR, and AED, Denbury HSE Orientation, and Safety Awareness Training.

Indoor Carbon Dioxide Loading Following a Simulated Carbon Dioxide Pipeline Release

CTEH® Site-Specific Health and Safety Plan (HASP)

Version 1.0

Prepared By:

CTEH, LLC

5120 Northshore Drive

North Little Rock, Arkansas 72118

501-801-8500

December 05, 2022

CTEH Project Number PROJ-021914

	Name	Signature	Date Signed
Prepared By:	Micah Kendrick	Micah Kendrick	November 30, 2022
Reviewed By:	Angie Perez, PhD, CIH	Angela L Perez	November 30, 2022

Study Information

Effective Date	December 05, 2022
Study Name	Indoor Carbon Dioxide Loading Following a Simulated Carbon Dioxide Pipeline Release
Location	Brookhaven, MS

5.0 DESCRIPTION OF PROJECT:

Denbury, Inc. (Denbury) and American Petroleum Institute (API) asked CTEH, LLC (CTEH) to design and conduct a carbon dioxide (CO2) exposure simulation study to inform potential revisions to response actions currently described in the Emergency Response Guidebook (ERG) pertaining to protection of public safety in the event of a catastrophic CO2 release from a pipeline or associated infrastructure. Specifically, CTEH was asked to develop data to help first responders better determine whether evacuation or SIP orders represent the safer of two actions for the public in the event of a major CO2 release. This Health and Safety Plan was developed for use during the CO2 release simulation study to be conducted the week of December 5 to December 9, 2022 at the Denbury Pump Station located at 332 Rogers Lane Northeast, Brookhaven, Mississippi.

6.0 PURPOSE:

This plan addresses air monitoring tasks to be performed by CTEH®, LLC (CTEH) during the study. The air monitoring locations include inside towable residential structures (camper trailers), air monitoring outside of camper trailers but inside a large enclosure that houses the camper trailers, and air monitoring outside of the enclosure. Additional air monitoring will be conducted outside of the enclosure to determine the magnitude of fugitive emissions and along the property fence line.

This site-specific information has been developed from the latest available information. Revisions and alterations to this plan may become necessary as further information becomes available (i.e., unexpected sampling results, changes in site conditions, changes in scope of work, etc.). All alterations to this plan will be recorded in the Health & Safety Plan Management of Change section.

All on-site personnel are required to review and comply with this Health and Safety Plan. It is the responsibility of the project manager to ensure this plan is implemented.

7.0 SITE & EMERGENCY CONTACTS

7.1 Emergency Services Contact Information

Fire/Police/Ambulance – 911

Lincoln County Local Dispatch – 601-833-5231

King's Daughters Medical Center: ER - 601-833-6011

7.2 Project Contact Information

Title	Name	Company	Phone
Project Technical Director	Michael Lumpkin, PhD, DABT	CTEH	501-366-8304
Project Safety Officer	Cole Ledbetter, CIH, CSP	CTEH	501-337-2900
Denbury HSE Manager	Ryan Jacob, REM, CES	Denbury Inc.	985-855-4627
Denbury Safety Officer	Kevin Posey	Denbury Inc.	601-757-4143
Denbury Pipeline Manager	Jason Davis	Denbury Inc.	601-540-4808

8.0 SITE CONTROL

See Addendum for a Location map and hospital route.

Site Control	Location
Staging Area:	Brookhaven Pump Station, 332 Rogers Lane NE, Brookhaven, MS 39601
Site Security and Access Points:	The access point for the site will be the gate located off of Rogers Lane. All participants will need to check in and out at the office located on the west side of the facility.
Permit to Work	Denbury will issue a permit for the activities being conducted on location.
Job Safety Analysis	During the safety briefing a JSA will be completed and all safety related issues will be discussed.

9.0 HAZARD ASSESSMENT

9.1 Chemical Hazards

9.1.1 Carbon Dioxide

Carbon dioxide (CO_2), CAS# 124-38-9, is a colorless, odorless gas comprised of one carbon atom and two oxygen atoms. Select physical and chemical properties of CO_2 include molecular weight of 44 g/mol, vapor pressure 56.5 atm at 22 °C, vapor density 1.53 (unitless), ionization potential 13.77 eV, and specific gravity of 1.56 at -110.2 °F (NIOSH 2019). In the event of a release, the public may be exposed to CO_2 via inhalation or skin or eye contact. Symptoms of sufficiently high CO_2 exposure include dizziness, headache, restlessness, tingling 'pins and needles' sensation, difficulty breathing, increased heart rate, cardiac output, and blood pressure, coma, asphyxia, and death.

9.1.2 Hydrogen Sulfide

Hydrogen Sulfide (H_2S) is a colorless gas having a strong odor of rotten eggs and poses a respiratory hazard. According to OSHA, the odor threshold, or the concentration of H2S when the human nose is first able to detect the odor of rotton eggs, is approximately 0.01 ppm (OSHA, 2022). H2S concentrations greater than 100 ppm causes human smell sensory fatigue which means that rotton egg odors cannot be counted on to warn of the continued presence of the gas. NIOSH set the IDLH for H2S at 100 ppm based on acute inhalation toxicity data in humans and animals and concentrations above 200 ppm for prolonged periods may cause edema or death (NIOSH, 1994b; OSHA, 2022). Death or permanent injury may also occur after very short exposure to high concentrations of H2S as it acts directly upon the nervous system resulting in paralysis of respiratory centers (USEPA, 1998).

9.1.3 Methane

Methane is a colorless odorless gas, also known as marsh gas or methyl hydride. Methane is easily ignited and the vapors are lighter than air. The lower explosive limit of methane is approximately 5% by volume in air. It is used in chemical producation and is a constituent of natural gas. High concentrations may cause asphyxiation through the displacement of oxygen (USCG, 1999).

See attached Safety Data Sheet (SDS) in Addendum B for more details on chemical hazards.

9.2 Chemical Hazard Action Levels

There is no consensus on what concentration of CO2 is appropriate for a community emergency response guidance value. As noted above, any spill over 208 liters initiates evacuation orders within 100 m in all directions, irrespective of CO2 concentration in the air in proximity to the release. One approach to determine what is a scientifically justifiable community-based emergency response guideline concentration is to, first, understand the existing occupational exposure guidelines and on what health endpoints these occupational guidelines were derived. Health effects reported in older studies include lightheadedness, but details on the extent or transient nature of the effect are scant. The National Institute for Occupational Safety and Health (NIOSH) designated a CO_2 concentration that is 'Immediately Dangerous to Life and Health' (IDLH) of 40,000 parts per million (ppm), based on acute inhalation toxicity data in humans (Aero Medical Association, 1954; Flury and Zernik, 1931; Schaefer, 1951 as cited by NIOSH, 1994a). However, a recent study by van der Schrier et al., (2022) of CO_2 exposure to adult volunteers and rats provides a basis to propose raising the IDLH to as high as 75,000 ppm. For comparison, the current Occupational Safety and Health Administration (OSHA) permissible exposure limit for an eight-hour work period is 5,000 ppm (9,000 mg/m^3) (OSHA, 2018). While permissible short-term (15-minute) exposure limits (STEL) for CO_2 are not provided by OSHA, both NIOSH and the American Conference for Governmental Industrial Hygienists (ACGIH) provide a STEL of 30,000 ppm (54,000 mg/m^3), shown in **Table 5.1**, below.

Non-occupational exposures to CO2 are especially informative about the tolerance of the human body to a wide range of CO2 exposure concentrations. In a recent review article by Permentier et al., (2017), the physiological effects of CO2 exposure were described in human and animal models, based on decades of research. In general, CO2 concentrations that resulted in human fatalities ranged between 14% and 26%, while CO2 concentrations less than 5% (50,000 ppm) had "*little, if any, toxicological effects*" (Permentier et al., 2017, p. 2). Considering the existing PEL, STEL, IDLH, and range of responses from human exposures to CO2 as summarized by Permentier et al., (2017) and the new data provided by van der Schrier et al., we anticipate that a reasonable and scientifically justifiable acute emergency guidance Level for a 60-minute exposure would range somewhere between 20,000 and 75,000 ppm (2% to 7.5%) CO2.

The community emergency response guideline levels for a CO2 release are shown in **Table 5.2** below. The United States Environmental Protection Agency's Acute Exposure Guideline Level 1 (AEGL-1) is the air-borne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

Table 5.1 Study Action Levels for Study Participant (Worker) Protection

Chemical	Action Level	Action	Basis
Carbon Dioxide	5,000 ppm (15-min)	Notify SSO*	OSHA PEL & ACGIH TLV (8-hr)
	30,000 ppm (15-min)	Egress upwind and notify SSO	ACGIH STEL (15-min)
LEL**	0.5%	Notify SSO	1/10th LEL
Hydrogen Sulfide	1 ppm	Notify SSO	ACGIH TLV-TWA (8-hr)
	5 ppm	Egress upwind and notify SSO	ACGIH STEL (15-min)
Oxygen	< 19.5 %	Notify SSO	Oxygen deficient atmosphere

*SSO: Study Safety Officer, Cole Ledbetter (501) 337-2900
**Based on LEL of methane (100% LEL = 5% methane, or 50,000 ppm)

Table 5.2 Study Action Levels for Community Protection

Chemical	Action Level	Action	Basis
Carbon Dioxide	20,000 ppm	Report reading to SSO; reevaluate enclosure leakiness or ventilation rate and directionality	Internal Proposed AEGL-1 (60 minutes)
Hydrogen Sulfide	0.51 ppm		AEGL-1 (60 minutes)

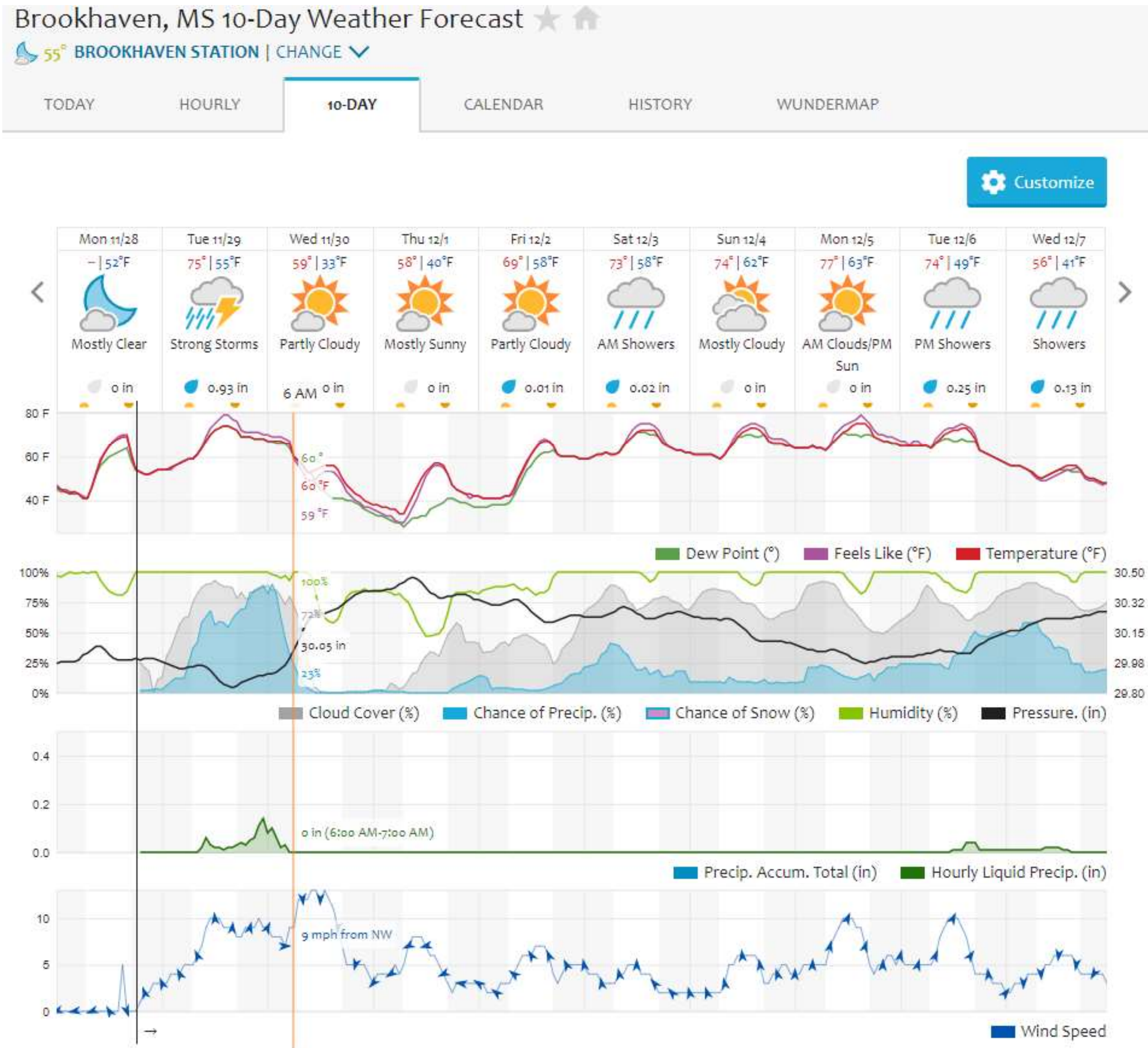
*SSO: Study Safety Officer, Cole Ledbetter (501) 337-2900

9.3 Physical Hazards

9.3.1 Weather Information

Responders should always maintain situational awareness of changing weather conditions through their CTEH® provided handheld device, the National Weather Service, local news networks, and on-site observations. Additionally, a safety briefing will occur prior to the beginning of each shift and weather information will be presented at that time. The current weather for the study site can be accessed via the QR code below:

Link to current weather



9.3.2 Thermal Stress

Thermal stress (heat stress or cold stress) hazards and strategies for mitigating impact on worker safety and health can be addressed based on information obtained in the OSHA-NIOSH Heat App downloadable from Google Play or the Apple Store. An addendum to this document may be added if deemed necessary by the project manager and corporate safety officer.

9.3.3 Severe Weather Hazard

In the event that a severe weather event disrupts work activity, seek shelter immediately. Egress work areas to the nearest enclosed shelter and stay away from windows if possible. Alert the CTEH® division supervisor or project manager as soon as possible and provide a situational update.

If a lightning strike is observed within 6 (six) miles of the work site, a mandatory 30-minute stand down will be in effect. Seek shelter indoors or in a vehicle. The stand down will continue until 30 minutes after the last lightning strike within 6 miles is observed. Stay indoors or in a vehicle until the entire 30-minute stand down period expires.

9.3.4 Moving Vehicles

Be cautious of all motor vehicles on site as well as in the community. As a pedestrian, look 360° before walking to any moving vehicles in your nearby vicinity. Personnel should wear reflective safety gear as the outermost layer of clothing on site, day or night.

9.3.5 Distracted Driving and Driving Safety

CTEH® personnel must abide by CTEH®, client, state, and local regulations and guidelines regarding driving while using cell phones. Under no circumstances are CTEH® personnel permitted to text or email while driving any vehicle on or off road. CTEH® personnel must pull over safely, away from traffic, to conduct cell phone or radio communications except when local regulations allow hands-free operation of communication devices. Use of these devices not in hands-free mode is prohibited at all times while driving any vehicle type on or off road.

CTEH® personnel are not permitted to operate a motor vehicle without seatbelts being properly worn. Once you have secured your seatbelt, please adjust your window and driver mirrors. Do not block windows with contents such that your view is obstructed while driving.

9.3.6 Motor Vehicle Hazards

When operating a motor vehicle, look both ways before entering a roadway or crossing intersections. Look for pedestrians on or near roadways. Driving at dusk and dawn or low light conditions decrease driver visibility and be aware that animals are much more active during these times. Driving on wet, snowy, gravel, or dirt roads warrant operation of the vehicle at a conservative speed. Not all gravel road crossings are controlled crossings; some do not have stop signs. In addition to lack of signage, high grasses may obstruct a driver's view at crossings.

9.3.7 Heavy Equipment

Track hoes, bulldozers, dump trucks, vacuum trucks, commercial pickup trucks, and other heavy machinery may be present at the site. Stay outside of the boom radius of any lever-based heavy machinery. Be aware of high-pressure gas lines when positioning equipment.

9.3.8 Electrical

Underground power lines, generators, light plants, and plug-in power sources may create the potential for electrical shock or electrocution. Assess all CTEH® power equipment and power cords for defects. If any electrical equipment is defective, remove from service, and clearly indicate that the equipment is not safe for use until repaired. For your own safety, maintain awareness of other site personnel and equipment that may cause electrical issues.

9.3.9 Fire & Explosion

Fire and explosion hazard is highly unlikely at this site. The potential existence of trace concentrations of methane, H2S, and an ignition source, may create fire and explosion hazards either indoors or outdoors.

In general, vapors and gases may travel to sources of ignition and flash back. Many vapors and gases are heavier than air, spreading along ground and collecting in low or confined areas (basin, sewers, basements, tanks) resulting in areas of increased concentration. Accumulation in these low-lying areas may create fire or explosion hazard.

Specifically, H_2S is heavier than air and may travel a considerable distance to sources of ignition causing flash back or an explosion.

Methane burns readily at atmospheric pressure and amgient temperature. Methane is a reducing agent and reacts explosively when combined with especially powerful oxidizers such as bromine pentafluoride, chlorine trifluoride, chlorine, iodine, heptafluoride, dioxygenyl tetrafluoroborate, dioxygen difluoride, trioxygen difluoride and liquid oxygen (Handling Chemicals Safely 1980)[5].

9.3.10 Hot Work

Response operations may include hot work (i.e., cutting or grinding). Due to the potential fire and explosion hazards of hydrogen sulfide and methane , **WELDING OR USE OF TORCHES IS NOT PERMITTED UNLESS A HOT WORK PERMIT OR OTHER WRITTEN PERMISSION IS OBTAINED FROM THE SITE HEALTH AND SAFETY OFFICER - NO EXCEPTIONS**. CTEH® employees will not participate or assist in the performance of hot work if this condition is not met. If hot work occurs and CTEH® is tasked with providing air monitoring

[5] Nederlandse Vereniging van Veiligheidstechnici Veiligheidsinstituut (Amsterdam Netherlands) & Vereniging van de Nederlandse Chemische Industrie. (1980). *Handling chemicals safely 1980* (2d ed.). Dutch Association of Safety Experts : Dutch Chemical Industry Association : Dutch Safety Institute.

for the hot work permit, LEL monitoring (confirmed by VOC readings) will be performed to determine whether combustible vapors are detected at or near the relevant Action Levels. CTEH personnel will not sign hot-work permits. See the CTEH® hot work policy or speak with the Corporate Safety Officer for clarification.

9.3.11 Trip Hazards

Uneven or slick terrain provides an environment in which slips, trips, and falls should be considered. Be aware of your travel path prior to walking or changing directions. Search for any obstructions that may present a trip hazard.

9.3.12 Noise

Emergency Response work sites are considered non-traditional and often difficult to characterize noise exposures. Please keep hearing protection readily accessible. For work areas experiencing high noise levels (greater than 90 dB) and/or impact noise (greater than 140 dB), please utilize hearing protection.

9.3.13 Eye Protection

The site may include dusty conditions or particulate hazards from other sources. If dusty conditions are present, helmet-mounted goggles should replace safety glasses to further protect your eyes from particulate-induced eye injury. Safety glasses must be worn whenever there is a potential for flying object or debris from any source (e.g., grinding, cutting, construction activities, etc.). All eye protection including glasses, face shields, and goggles, must meet minimum requirements contained in ANSI standard Z87.1.

9.3.14 Dermal Contact Hazards

Compressed gases may create low temperatures when they expand rapidly. Leaks and uses that allow expansion may cause a frostbite hazard. Wear appropriate protective clothing to prevent the skin from becoming frozen.

Poison Oak and Poison Ivy may be present in areas encountered by field personnel. Use caution to avoid contact with these plants, this includes equipment as well.

10.0 EXPOSURE CONTROL

10.1 Personal Protection Requirements

The following is the default level of PPE required. This level may be modified depending on specific site conditions or job tasks as determined by the Project Manager. Prior to beginning any work task determine the appropriate level of PPE through consultation with the PM or Site Safety Officer.

- Level D - Hardhat, eye protection, foot protection, hearing protection.

- Level D PPE may also include helmet-mounted eye protection goggles.

10.2 Respiratory Protection Guidelines

If CTEH® elects or is requested to engage in operations necessitating respiratory protection, an addendum to this document may be produced. If CTEH® employees are required to work in Immediately Dangerous to Life or Health (IDLH) atmospheres then the CTEH® Respiratory Protection Program will consulted for procedures and controls that shall be in place, including requirements for use of self-contained breathing apparatus (SCBA) equipment.

11.0 JOB SAFETY ANALYSIS

A daily Job Safety Analysis will be discussed prior to the start of work. The names and duties of non-CTEH onsite personnel will be presented at that time. CTEH personnel who will be onsite for the study and associated job tasks are provided in Table 7-1 below.

Table 7-1. CTEH Employees onsite for the Denbury CO2 simulation study and their associated job descriptions for the study duration.

Name	Title	Job Description	Phone/Email
Cole Ledbetter, CIH, CSP	Study Safety Officer	Conducts equipment calibration, pre-study validation testing, air monitoring external to the containment structure during study, clearance air monitoring during study, and air monitoring along the fence line in the event of an emergency release; ensures compliance with the HASP; assumes leadership role for CTEH personnel in the event of an emergency.	501-337-2900 Cledbetter@cteh.com
Michael Lumpkin, PhD, DABT	Study Technical Director	Conducts equipment calibration, pre-study validation testing, air monitoring external to the containment structure during study, clearance air monitoring during study, and air monitoring along the fence line in the event of an emergency release.	501-366-8304 mlumpkin@cteh.com
Angie Perez, PhD, CIH	Study Project Manager		541-901-9000 aperez@cteh.com
Jason Callahan, MS, CIH, CSP	Study Participant – Ventilation Lead		501-366-8044 jcallahan@cteh.com
Ernie Shirley	Study Participant		601-946-9474 eshirley@cteh.com
Taylor Simoneau	Study Participant		501-271-8189 tsimoneau@cteh.com

12.0 EDUCATION & TRAINING

Training documentation will be verified using the ISN Quick Check process.

- General Safety Awareness Training – Examples include OSHA 10-hour, PEC SafeLand, IADC Rigpass, etc.
- First Aid, CPR, and AED – Minimum of one crew member per work location
- Denbury HSE Orientation

12.1 Site specific training required:

Hydrogen sulfide awareness training will be required by all onsite personnel. Additionally, the following site-specific training topics may be reviewed prior to work on the site:

☒ Site Hazards (chemical hazards, physical hazards, etc.)

☒ Work areas / activities identified

☒ Site Emergency Alerting / Contingency Plan

☒ Evacuation Route / Assembly Areas

☒ Required PPE

☒ Obtaining Medical Treatment / First Aid

☒ Buddy System

☐ Confined Space

Other: Low Oxygen Environments

☐ Other: ____

12.2 Safety Briefing/Hazard Communication

A safety briefing will occur prior to the beginning of each shift and anytime that work conditions change. Site safety briefings will be completed each day and kept on file.

13.0 SAFETY EQUIPMENT, LOCATION, RESPONSIBILITY

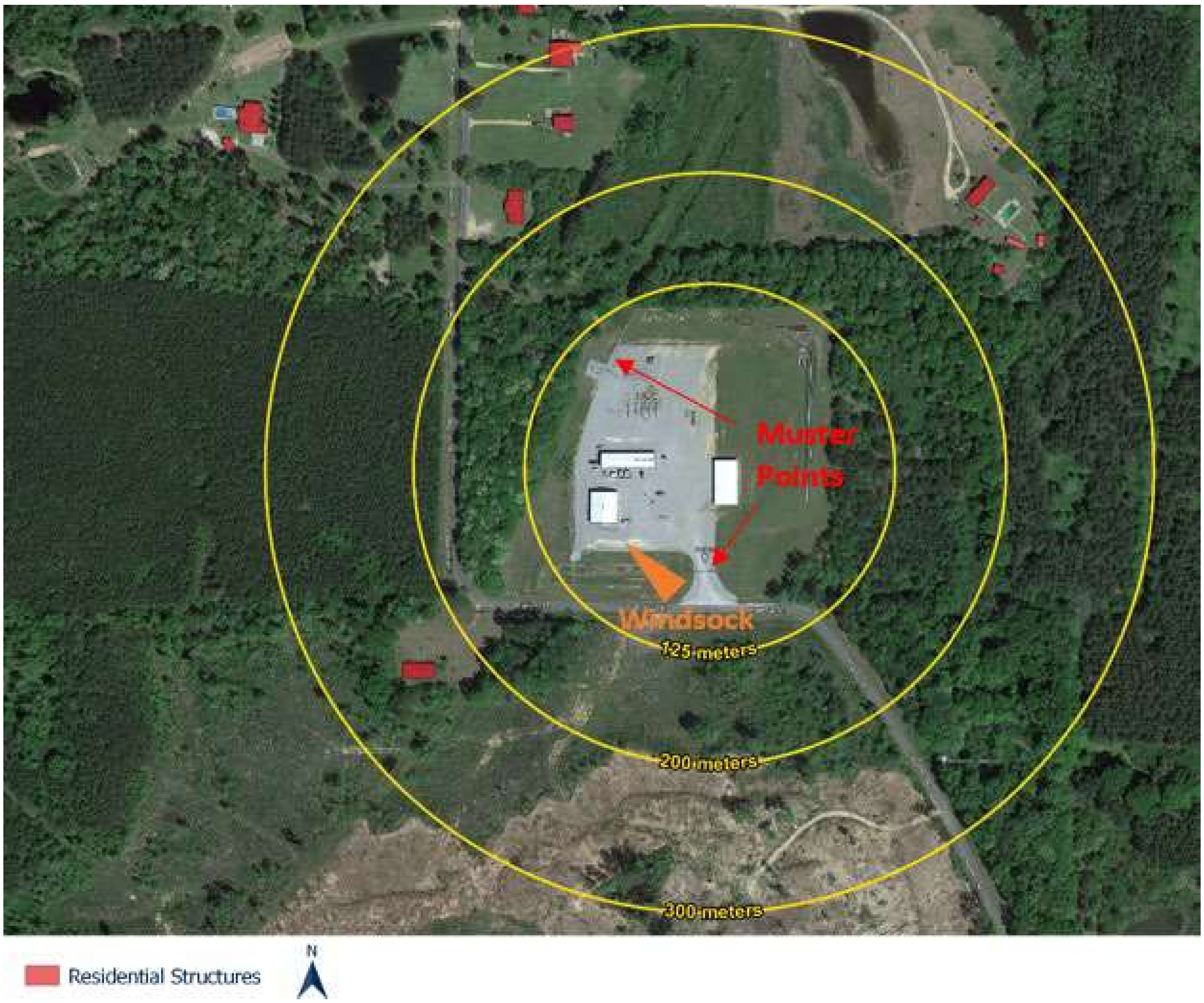
First Aid Kit	All Sites	First Aid/CPR trained personnel may use this kit to administer first aid as necessary.
Fire Extinguisher	Ask Site Safety Officer	Fire Extinguisher trained personnel may use this to extinguish small, manageable fire. Do not attempt to extinguish chemical fires based on compatibility, nor large fires for which the extinguisher is incapable of mitigating. For chemical fires or large fires, contact the fire dept.
Communication	Throughout site	Cell phones shall be used to maintain communication for all personnel.
Sanitation	Throughout site	Portable latrines or designated restroom facilities must be present in compliance with 29 CFR 1910.141 - Sanitation.
Lighting	Throughout site and on personnel	Permanent or temporary lighting must be used to illuminate the work area during dark or night operations. Personnel must be equipped with flashlights or headlamps during dark or night operations where other forms of lighting are not practicable.

14.0 CONTINGENCY PLANS

In the event of an emergency at the worksite, the person first noticing the emergency should notify other workers in the immediate area. Evacuation should commence at once if the emergency poses any threat to the safety of the workers. Upon receiving notification of an emergency, the individual in charge of the work area should take appropriate measures to protect human life, the environment (including wildlife), and property.

14.1 Escape Routes:

Specific to an accidental release of CO2, on-site personnel will evacuate to the muster location that is uphill and upwind of the release location.



14.2 Emergency Source Control:

In the event of a release that results in CO2 concentrations exceeding the community air monitoring action level (20,000 ppm), the CO2 source will immediately be shut off and the enclosure will be evaluated for leaks.

In the event of a catastrophic release, as soon as it is safe to do so, Denbury personnel will don relevant PPE to shut off flow to the leaking source, if applicable.

14.3 Alerting Method:

Be aware of alerting methods, such as air horns, whistles, etc., that may indicate site conditions are no longer safe and workers should egress as directed in the onsite safety briefing or JSA. Communication will be through two-way radios and/or cell phones.

14.4 Community Notification:

In the event of a release that results in CO_2 concentrations exceeding the community air monitoring action level (20,000 ppm for one hour or more), the neighboring residents will be notified of the exceedance.

15.0 AMENDMENTS TO SITE SPECIFIC HEALTH & SAFETY PLAN

This Site-Specific Health and Safety Plan is based on information available at the time of preparation. Unexpected conditions may arise which necessitate changes to this plan. Unplanned activities and/or changes in the hazard status should initiate a review of major changes in this plan.

Changes in the hazard status or unplanned activities are to be submitted on "Amendments to Site-Specific Health and Safety Plan" which is included on the following page. Amendments must be approved by the Project Manager prior to implementation.

All notes, documentation, and records must NOT be discarded after their use. Documents are to be submitted to the CTEH Project Manager and departmental policies on document retention shall be followed.

Health & Safety Plan Management of Change

Change 001			
Description of Change (include sections & page numbers):			
	Name/Position	Signature	Date Signed
Prepared By:			
Approved By:			

Change 002			
Description of Change (include sections & page numbers):			
	Name/Position	Signature	Date Signed
Prepared By:			
Approved By:			

Change 003			
Description of Change (include sections & page numbers):			
	Name/Position	Signature	Date Signed
Prepared By:			
Approved By:			

Sign-In

Name	Signature	Date Signed

Addendum A

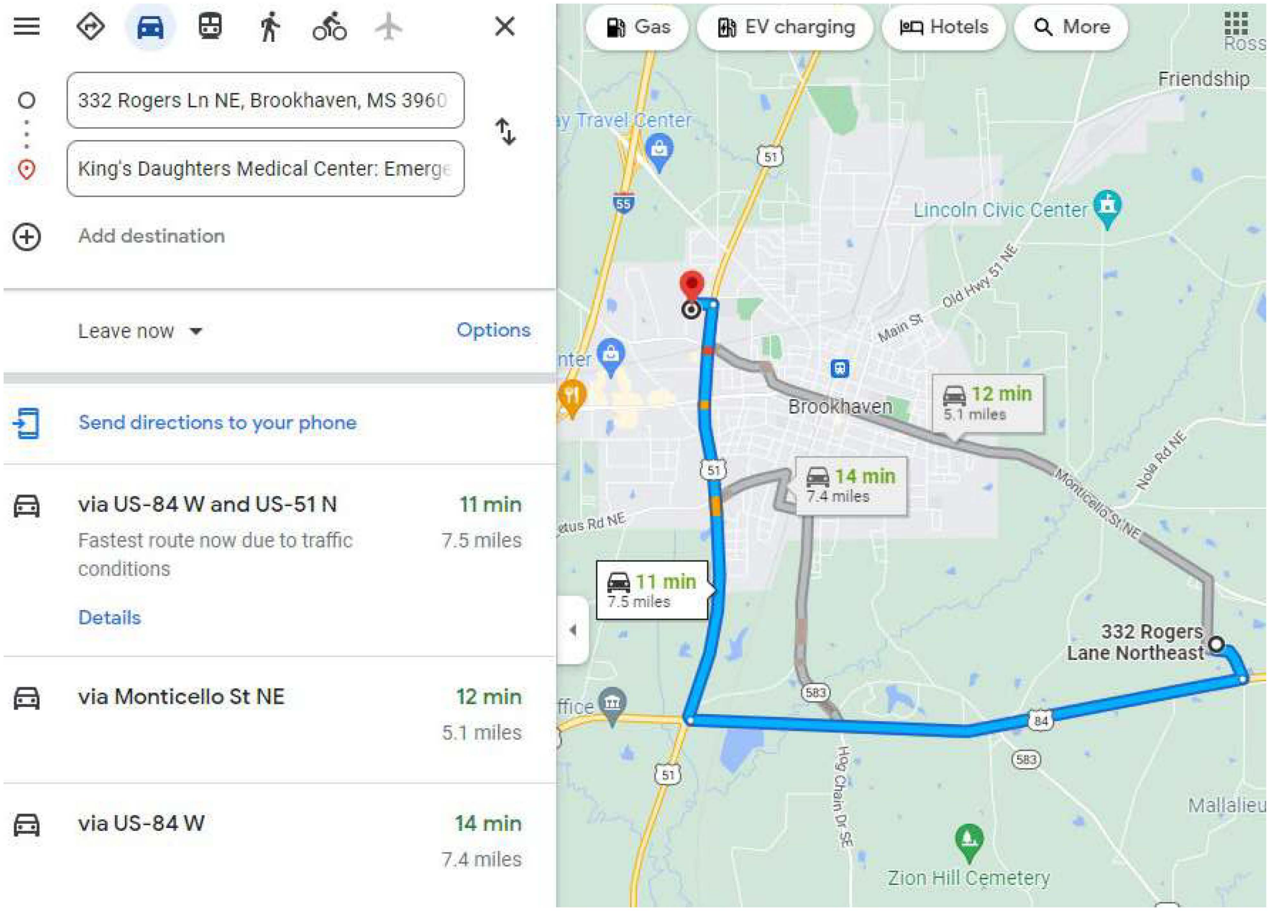
Hospital Map

King's Daughters Medical Center: ER

427 US-51

Brookhaven, MS

601-833-6011



Appendix B: Calibration Logs and Field Forms

Appendix C: Study Gas Certificate of Analysis

Airborne Labs International
22C World's Fair Drive Somerset, NJ 08873 T: 732-302-1950 F: 732-302-3035
E-mail: LabServices@airbornelabs.com Website: www.airbornelabs.com

Carbon Dioxide (CO_2) Analysis
Advanced Feed Gas Characterization Program©

Denbury Onshore LLC	ALI Track No.: 22-1372
332 Rogers Lane	Received On: 12/09/22
Brookhaven, MS 39601	Report Date: 12/16/22
Phone: 601-248-3295, 601-248-1520	Invoice No.: 2022-1619
Attn.: Mr. John Ard and Mr. Jamie Price	
E-Mail: john.ard@denbury.com; jamie.price@denbury.com	Sample Date: 12/05/22
Sample ID.: Vaporized Liquid CO_2 / Gaseous CO_2: "Brookhaven Pump Station"	Process Stage: Feed
Sample ID.: Received in 2L True Blue MLB Polybag 1.2 + MiniCyl 1.0 No-Haz Feed Gas Kit	

Test Description/Units:	**Result**	**LOQ**	**Spec**
CO_2 Identification (Positive / Negative by [DT]):	positive	5	report
Comments: Positive ID = Positive Detector Tube Response.			
CO_2 Purity (% v/v, [GC]):	99.6+	5	report
Comments: Obtained by NCG + target list impurity subtraction method			
Hydrogen (H_2, ppm v/v, [GC]):	nd	10	report
Helium (He, ppm v/v, [GC]):	--*	50	report
Comments: *Not a std feed gas test = special add-on test requiring 2nd minicyl.			
Oxygen + Argon (O_2 + Ar, ppm v/v, [GC]):	nd	10	report
Comments: Result represents Total O_2 + Ar ppm v/v.			
Nitrogen (N_2, ppm v/v, [GC]):	450	10	report
Carbon Monoxide (CO, ppm v/v, [DT]):	nd	2	report
Ammonia (NH_3, ppm v/v, [DT]):	nd	0.5	report
Oxides of Nitrogen (NO_x, ppm v/v,[DT]):	nd	0.5	report
Comments: Speciation performed if NO_x is above 2.5 ppm v/v			
Nitric Oxide (NO, ppm v/v, [DT]):	nd	0.5	report
Nitrogen Dioxide (NO_2, ppm v/v, [DT]):	nd	0.5	report
Phosphine (PH_3, ppm v/v, [DT]):	INT*	0.25	report
Comments: *Interference from sulfides present.			
Total Hydrocarbons (THC, ppm v/v as CH_4, [THA]):	3,400	0.1	report
Comments:			
Total Non-Methane Hydrocarbons (TNMHC, ppm v/v as CH_4, [GC]):	79	0.1	report
Methane (CH_4, ppm v/v, [GC]):	3,300	0.1	report
Acetaldehyde (AA, ppm v/v, [GC]):	0.14	0.05	report
Aromatic Hydrocarbon Content (ppb v/v as Benzene, [GC]):	580	2	report
Benzene (ppb v/v [GC]):	580	2	report
Toluene (ppb v/v, [GC]):	280	2	report
Ethyl Benzene (ppb v/v, [GC]):	nd	2	report
m,p Xylenes (ppb v/v [GC]):	120	2	report
o Xylene (ppb v/v [GC]):	38	2	report
Comments:			
Total Sulfur Content* (TSC* ppm v/v as S, [GC]):	9.6	0.01	report
Comments: *Obtained by summation of all speciated VSC target impurities less SO_2			
Sulfur Dioxide (SO_2, ppm v/v, [GC]):	nd	0.05	report
Hydrogen Cyanide (HCN, ppm v/v, [GC]):	nd	0.2	report
Vinyl Chloride (VCl, ppm v/v, [GC]):	nd	0.1	report
Radon (Rn^{222}, pCi/L, [Lucas Cell]):	--*	0.1	report
Comments: *Not a std feed gas pgm test = specialized add-on test requiring an Rn222 sampling kit.			
Ethylene Glycol (ppm v/v, [GC]):	--*	2	report
Comments: *Not a std feed gas pgm test = specialized add-on test requiring a Sorbent tube sampling kit.			

Sample ID: Denbury Onshore LLC **ALI Track No.:** 22-1372

Speciated Volatile Hydrocarbons (VHC, ppm v/v)	Result	LOQ	Spec.
Ethane:	21	0.1	report
Ethylene:	nd	0.1	report
Propane:	4.2	0.1	report
Propylene:	nd	0.1	report
Isobutane:	0.8	0.1	report
n-Butane:	1.1	0.1	report
Butene:	nd	0.1	report
Isopentane:	0.6	0.1	report
n-Pentane:	0.5	0.1	report
Hexanes+:	4.3	0.1	report

Comments: C_6+ results include VOX compounds and C_6+ alkanes/alkene hcs. Pk ID based upon t_r match vs target analyte std. CH_4 result on pg 1.

Speciated Volatile Sulfur Compounds (VSC, ppm v/v)	Result	LOQ	Spec.
Hydrogen Sulfide (H_2S):	9.5	0.01	report
Carbonyl Sulfide (COS):	0.016	0.01	report
Methyl Mercaptan:	nd	0.01	report
Ethyl Mercaptan:	nd	0.01	report
Dimethyl Sulfide:	nd	0.01	report
Carbon Disulfide:	nd	0.01	report
t-Butyl Mercaptan:	nd	0.01	report
Isopropyl Mercaptan:	nd	0.01	report
n-Propyl Mercaptan:	nd	0.01	report
Methyl Ethyl Sulfide:	nd	0.01	report
2-Butyl Mercaptan:	nd	0.01	report
i-Butyl Mercaptan:	nd	0.01	report
Diethyl Sulfide:	nd	0.01	report
n-Butyl Mercaptan:	nd	0.01	report
Dimethyl Disulfide:	nd	0.01	report
Unknown VSC:	nd	0.01	report

Comments: Peak ID based upon t_r match against target analyte standards. Note: SO_2 + TSC* results reported on pg. 1.

Speciated Volatile Oxygenates (VOX, ppm v/v)	Result	LOQ	Spec.
Dimethyl Ether:	nd	0.1	report
Ethylene Oxide:	nd	0.1	report
Diethyl Ether:	nd	0.1	report
Propionaldehyde:	nd	0.1	report
Acetone:	0.3	0.1	report
Methanol:	0.2	0.1	report
t-Butanol:	nd	0.1	report
Ethanol:	0.8	0.1	report
Isopropanol:	nd	0.1	report
Ethyl Acetate:	0.9	0.1	report
Methyl Ethyl Ketone:	nd	0.1	report
2-Butanol:	nd	0.1	report
n-Propanol:	nd	0.1	report
Isobutanol:	nd	0.1	report
n-Butanol:	trace	0.1	report
Isoamyl Alcohol:	nd	0.1	report
Isoamyl Acetate:	trace	0.1	report
Unknown VOX:	3.6	0.1	report

Comments: Peak ID based upon t_r match against target analyte standards. AA & Ethylene Glycol results reported on pg. 1.

LOQ = Limit of Quantitation (lowest amount of analyte quantitatively determined with suitable precision and accuracy) **MDL** = method detection limit (lowest amount of analyte detected). **trace =** unquantified amount observed between MDL and LOQ. **nd =** indicates the impurity was not detected (below MDL). **--** = test not performed. **na** = not available. **LT** = less than the amount specified. **GT** = greater than the amount specified. **%** = percent. **ppm** = parts per million. **ppb** = parts per billion. **v/v** = volume analyte/volume sample. **w/w** = weight analyte/weight sample. **[result]** indicates the result was obtained by the method listed within brackets. **TSC*** = ISBT Total Sulfur Content excluding SO_2. **Unit Conversions:** 1ppm v/v = 1µL/L = 1000 ppb = 0.0001% v/v. **Date format:** MM/DD/YY.

Report Summary:

Customer requested an advanced CO_2 feed gas test program.

Reviewed by / Date:

Jeff Wahome 12/16/22

Jeff Wahome - Analytical Operations Manager

Attachments: none

Addendum: Signatures, Instrument & Notebook data on-file

Accreditation # 68099

ISO Statement

Statements of conformity (pass or fail) resulting from the test/analysis performed on the above sample will not take into account the reported measurement uncertainty unless otherwise specified. This is a shared risk decision rule in which the customer also has responsibility for determining acceptance of the results. The methods Airborne Labs International uses are developed by Airborne Labs International and are based on the current revisions of international, national, or industry standards unless otherwise specified. Methods can be reviewed by the customer upon request. The acceptance criteria of the above item are based on ISBT specifications, NFPA, CGA, USP, or other industry specifications unless otherwise specified on the contract.

F-21.3.2v3 (04/21)

Appendix D: Monitoring Equipment Information Sheets

CTEH®

AreaRAE Pro

Easy to use transportable area monitor for multiple threat detection.

AreaRAE Pro

Remote visibility on more threats than ever for a new level of real-time situational awareness

AreaRAE Pro is a wireless, transportable area monitor that can simultaneously detect toxic and combustible gases, volatile organic compounds, radiation and meteorological factors. Whether you're carrying it into a hazmat response, setting up perimeter at a fire or protecting a public venue, the AreaRAE Pro works with Honeywell's remote monitoring software to give you a real-time view of threat readings so you can make real time decisions to ensure the safety of your teams and the general public.

AreaRAE Pro delivers maximum flexibility and versatility in one device:

- **Up to six 4R+ sensors for toxic and combustible gas.**

AreaRAE Pro offers more than 20 interchangeable sensors that can be swapped at a moments notice to meet the changing needs of first responders.

- **7R+ photoionization detector.**

Monitor VOCs in parts per billion, with built-in compensation for temperature and humidity.

- **Meteorological station for tracking toxic plumes.**

Honeywell's compact RAEMet sensor sits at the top of the AreaRAE Pro and measures wind speed, wind direction, temperature and humidity. This information is then modeled in Honeywell's real time monitoring software which integrates the ALOHA hazard monitoring program.

- **Optional gamma sensor for radiation detection.**

Detect and measure gamma radiation with increased sensitivity and faster response without using an additional sensor slot.

Applications

- First responders
- Hazmat
- Civil Defense & Military
- Public Venue Protection

Ease and Fexibility

- Available in Rapid Deployment Kit for quick threat assessment
- User-friendly interface; turn it on and go
- Supports long-distance remote monitoring
- Built-in mesh modem for short-range monitoring — no external router required
- Flexible power options for short- and long-term deployments
- Easy to hear and see, with 108-decibel alarm
- Easy USB connection to configuration software
- Device Management with Honeywell Sotera™

Remote Visibility on Threats

- Delivers real-time readings to Honeywell's remote monitoring software, so you can instantly determine the location and severity of a threat
- Map-based display is accessible from any computer with an internet connection — or from our laptop as a turnkey host
- Enables coordination and data sharing in joint operations

Specifications

DIMENSIONS	314 x 306 x 166 mm (with rubber boot) 12.36" x 12.04" x 6.53" (with rubber boot)
WEIGHT	6.3 kg (13.88 lb) full option configuration 6.5 kg (14.33 lb) full option configuration (+RAEMet)
GAS SENSORS SLOTS	up to 7; see Sensor list
ADDITIONAL SENSORS	Gamma; RAEMet (Wind Speed, Wind Direction, Temperature & Humidity)
GPS	Standard equipment in every unit
BATTERY	Rechargeable 7.2 V / 10 Ah Li-ion battery pack with built-in charger Alkaline Battery Adapter
OPERATING HOURS	~20 hours with wireless connectivity on Li-ion battery pack ~12 hours with wireless connectivity on Alkaline battery adapter
	Specification at room temperature (20ºC)
DISPLAY	Large 240 x 320 pixel LCD backlit display
	64 x 85 mm / 2.5" x 3.33"
KEYPADS	3 operation and programming keys
ALARMS	Multi-tone 108 dB buzzer @ 3.3 ft / 1 m, Bright LED 360 degree view and on-screen indication of alarm conditions
	Additional diagnostic alarm and display message for low battery
	Wireless connectivity alarm
DATA LOGGING	Continuous data logging (90 days for 7 gas sensors, 1 Gamma sensor, 1 RAEMet (wind speed & direction, temp and RH), and GPS at 1 min intervals, 24/7)
DATA STORAGE	24M bytes (memory full action: stop when full or Wrap around)
DATA INTERVAL	User-configurable from 1 to 3,600 sec
WIRELESS[1]	Bluetooth Low Energy module (BT4.0) and GPS
	Primary radio module: - Long range ISM License Free 900 MHz or 2.4 GHz radio - IEEE 802.11 b/g Wi-Fi
	Secondary radio module: Short Range IEEE 802.15.4 900 MHz or 868 MHz Mesh Radio
	Wireless range[3]: Up to 2 miles (3 km) for ISM 900 MHz; Up to 1.2 miles (2 km) for ISM 2.4 GHz; Up to 330 ft (100m) for Wi-Fi; Up to 660 ft (200m) for Mesh secondary radio; Up to 15 ft (5m) for BLE.
	Wireless Approval: FCC Part 15, CE R&TTE, Others[4]
COMMUNICATION	Communicates to ProRAE Studio II via USB cable to PC;
	Wireless data and alarm status transmission via Wi-Fi or ISM modem;
	Act as gateway to connect up to 8 remote instruments (using secondary radio module)
SAFETY CERTIFICATION	US / Canada: Class 1, Division 2 Groups A, B, C, D
SAMPLING PUMP	Built-in pump, typical flow rate 450 cc/min
TEMPERATURE	-20 ºC to +50 ºC / (- 4 ºF to +122 ºF)
HUMIDITY	0% to 95% relative humidity (non-condensing)
INGRESS PROTECTION (IP)	IP 65
PERFORMANCE TESTS	MIL-STD-810G and 461F
	LEL CSA C22.2No. 152, ISA-12.13.01
WARRANTY[2]	Four years for O_2 Liquid Oxygen sensors Three years for CO, and H_2S sensors Two years for non-consumable components, catalytic LEL sensor and 10.6eV 7R+ PID lamp One year on all other sensors, battery, and other consumable parts Six months for 9.8eV lamp PID sensor

RAEMet SPECIFICATIONS	
WIND SPEED	Range: 0 to 20 m/s (0 to 44 mph) Start Speed: 0.1 m/s (0.22 mph)
WIND DIRECTION	Range: 360º (No dead band)
TEMPERATURE	- 20 ºC to 60 ºC (-4 ºF to 140 ºF) Resolution 0.1 ºC (1.8 ºF)
HUMIDITY	10 to 95% RH Resolution 1% RH
COMPASS	Resolution 1°
POWER	Power supplied by the AreaRAE Pro

[1]Additional equipment and/or software licenses may be required to enable remote wireless monitoring and alarm transmission
[2]Against factory defects
[3]Receiving > 80%
[4]Contact RAE Systems for country specific wireless approvals and certificates
Specifications are subject to change

Supported Sensors

SENSOR	RANGE	RESOLUTION
PID SENSORS		
4R+; 10.6eV ppb	0 to 2,000 ppm	10 ppb
7R+; 10.6 eV ppb	0 to 2,000 ppm	10 ppb
4R+; 9.8 eV*	0 to 2,000 ppm	0.1 ppm
COMBUSTIBLE SENSOR		
CATALYTIC BEAD SENSOR	0 to 100% LEL	1% LEL
NDIR SENSOR		
CARBONE DIOXIDE (CO_2)	0 to 50,000 ppm	100 ppm
ELECTROCHEMICAL SENSORS		
AMMONIA (NH_3)	0 to 100 ppm	1 ppm
CARBON MONOXIDE (CO)	0 to 500 ppm	1 ppm
CARBON MONOXIDE EXT. (CO HR)	0 to 2,000 ppm	10 ppm
CARBON MONOXIDE H_2 Comp (CO H_2 Comp)	0 to 2,000 ppm	10 ppm
CHLORINE (Cl_2)	0 to 50 ppm	0.1 ppm
CHLORINE DIOXIDE (ClO_2)	0 to 1 ppm	0.03 ppm
ETHYLENE OXIDE (ETO-A)	0 to 100 ppm	0.5 ppm
ETHYLENE OXIDE (ETO-B)	0 to 10 ppm	0.1 ppm
ETHYLENE OXIDE (ETO-C)	0 to 500 ppm	10 ppm
HYDROGEN (H_2)	0 to 2,000 ppm	10 ppm
HYDROGEN CHLORIDE (HCl)	0 to 15 ppm	1 ppm
HYDROGEN CYANIDE (HCN)	0 to 50 ppm	0.5 ppm
HYDROGEN FLUORIDE (HF)	0.5 to 10 ppm	0.1 ppm
HYDROGEN SULFIDE (H_2S)	0 to 100 ppm	0.1 ppm
HYDROGEN SULFIDE EXT. (H_2S HR)	0 to 1,000 ppm	1 ppm
OXYGEN (O_2)	0 to 30 %	0.10 %
SULFUR DIOXIDE (SO_2)	0 to 20 ppm	0.1 ppm
NITRIC OXIDE (NO)	0 to 250 ppm	0.5 ppm
NITROGEN DIOXIDE (NO_2)	0 to 20 ppm	0.1 ppm
PHOSPHINE (PH_3)	0 to 20 ppm	0.1 ppm
GAMMA RADIATION SENSOR		
GAMMA I-SENSOR	0.01 μSv/h to 0.2 mSv/h (1 μrem/h to 0.02 rem/h)	50 keV to 3 MeV

Honeywell Gas Detection

Honeywell is able to provide gas detection solutions to meet the requirements of all applications and industries.
Contact us in the following ways:

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www.raesystems.com

Please Note:
While every effort has been made to ensure accuracy in this publication, no responsibility can be accepted for errors or omissions. Data may change, as well as legislation, and you are strongly advised to obtain copies of the most recently issued regulations, standards, and guidelines. This publication is not intended to form the basis of a contract.

AreaRAE Pro_DS01162_V3_EN
01-17

Device Management with
Honeywell Sotera™

honeywellanalytics.com/products/
Honeywell-Sotera

Honeywell

RAE SYSTEMS by Honeywell

MultiRAE Pro

Wireless Portable Multi-Threat Radiation and Chemical Detector

The MultiRAE Pro is the industry's only portable wireless multi-threat monitor. The MultiRAE Pro's ability to simultaneously detect gamma radiation and toxic industrial chemicals (TICs/TIMs) enables responders to reduce the equipment footprint and achieve greater agility when operating downrange.

The MultiRAE Pro's optional wireless capability improves safety by providing commanders and safety officers real-time access to instrument readings and alarm status from any location[1] for better situational awareness and faster incident response.

- **Detector of choice for government agencies and top HazMat teams worldwide**
- **Highly versatile and customizable**
- **Man Down Alarm with real-time remote wireless notification**
- **Compliant with MIL-STD-810G and 461F performance standards**
- **Fully automatic bump testing and calibration with AutoRAE 2**

KEY FEATURES

Wireless. Versatile. Proven.

- All-in-one monitoring capabilities for radiation, VOCs, oxygen, toxic and combustible gases, up to 6 threat types at a time[2]
- Over 25 interchangeable sensor options, including parts-per-billion PID and gamma radiation
- Wireless access to real-time instrument readings and alarm status from any location
- Unmistakable five-way local and remote wireless notification of alarm conditions
- Intelligent sensors store calibration data, so they can be swapped in the field[3]
- Large graphical display with easy-to-use, icon-driven user interface

APPLICATIONS

- Civil defense (search and rescue)
- Homeland security
- HazMat response
- Military
- Semiconductor manufacturing
- Environmental

CBRN detection with the MultiRAE Pro

MIL-STD-461F | MIL-STD-810G | Wireless | AutoRAE 2 Compatible | ISO 9001 CERTIFIED | CSA | ATEX | IECEx | CE | Ex | FCC

MultiRAE Pro

Wireless Portable Multi-Threat Radiation and Chemical Detector

RAE SYSTEMS by Honeywell

SPECIFICATIONS

Instrument Specifications[4]

Size	7.6" H x 3.8" W x 2.6" D (193 x 96.5 x 66 mm)
Weight	31 oz (880 g)
Sensors	Over 25 intelligent interchangeable field-replaceable sensors including gamma radiation, ppb and ppm PID sensors for VOCs, electrochemical sensors for toxic gases and oxygen, combustible LEL and NDIR sensors, and CO_2 NDIR sensor
Battery Options, Runtime[5] and Recharge Time	- Rechargeable Li-ion (~12-hr. runtime, < 6-hr. recharge time) - Extended duration Li-ion (~18-hr. runtime, < 9-hr. recharge time) - Alkaline adapter with 4 x AA batteries (~6-hr. runtime)
Display	Monochrome graphical LCD display (128 x 160) with backlighting Automatic screen "flip" feature
Display Readout	- Real-time reading of gas concentrations; PID measurement gas and correction factor; Man Down Alarm on/off; visual compliance indicator; battery status; datalogging on/off; wireless on/off and reception quality. - STEL, TWA, peak, and minimum values
Keypad Buttons	3 operation and programming keys (Mode, Y/+, and N/-)
Sampling	Built-in pump. Average flow rate: 250 cc/min. Auto shutoff in low-flow conditions
Calibration	Automatic with AutoRAE 2 Test and Calibration System or manual
Alarms	Wireless remote alarm notification; multi-tone audible (95 dB @ 30 cm), vibration, visible (flashing bright red LEDs), and on-screen indication of alarm conditions - Man Down Alarm with pre-alarm and real-time remote wireless notification
Datalogging	Continuous datalogging (6 months for 5 sensors at 1-minute intervals, 24/7) - User-configurable datalogging intervals (from 1 to 3,600 seconds)
Communication and Data Download	- Data download and instrument set-up and upgrades on PC via desktop charging and PC comm. cradle, travel charger, or AutoRAE 2 Automatic Test and Calibration System - Wireless data and alarm status transmission via built-in RF modem (optional)
Wireless Network	ProRAE Guardian Real-Time Wireless Safety System or EchoView Host-based Closed-Loop System
Wireless Range (Typical)	MultiRAE Pro to RAELink3 [Z1] Mesh modem ~330 feet (100 meters) MultiRAE Pro to EchoView Host, RAEMesh Reader or RAEPoint ~660 feet (200 meters)
Operating Temperature	-4° to 122°F (-20° to 50°C)
Humidity	0% to 95% relative humidity (non-condensing)
Dust and Water Resistance	IP-65 ingress protection rating
Safety Certifications	CSA: Class I, Division 1, Groups A, B, C and D, T4 Class II, Division 1, Groups E, F, G T85°C ATEX: 0575 II 1G Ex ia IIC T4 Ga 2G Ex ia d IIC T4 Gb with IR Sensor installed I M1 Ex ia I Ma IECEx: Ex ia IIC T4 Ga Ex ia d IIC T4 Gb with IR Sensor installed I M1 Ex ia I Ma IECEx/ANZEx: Ex ia IIC T4 Ga Ex ia d IIC T4 Gb with IR Sensor installed Ex ia I Ma
EMI/RFI[5]	EMC directive: 2004/108/EC
Performance Tests	MIL-STD-810G and 461F compliant. LEL CSA C22.2 No. 152; ISA-12.13.01
Languages	Arabic, Chinese, Czech, Danish, Dutch, English, French, German, Indonesian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Spanish, Swedish, and Turkish
Warranty	- Two years on non-consumable components and catalytic LEL, CO, H_2S, and O_2 sensors - One year on all other sensors, pump, battery, and other consumable parts
Wireless Frequency	ISM license free band. IEEE 802.15.4 Sub 1GHz
Wireless Approvals	FCC Part 15, CE R&TTE, Others[4]
Radio Module	Supports RM900A

Sensor Specifications[4]

Radiation Sensor	Range	Sensor Type
Gamma	0 to 20,000 μRem/h (dose rate)	1cc CsI (Tl) scintillator with photodiode
PID Sensors	**Range**	**Resolution**
VOC 10.6 eV (Ext. Range) VOC 10.6 eV (ppb)	0 to 5,000 ppm 0 to 2,000 ppm	0.1 ppm 10 ppb
Combustible Sensors	**Range**	**Resolution**
Catalytic LEL NDIR (0-100% LEL Methane) NDIR (0-100% Vol. Methane)	0 to 100% LEL 0 to 100% LEL 0 to 100% Vol.	1% LEL 1% LEL 0.1% Vol.
Carbon Dioxide Sensor	**Range**	**Resolution**
Carbon Dioxide (CO_2) NDIR	0 to 50,000 ppm	100 ppm
Electrochemical Sensors	**Range**	**Resolution**
Ammonia (NH_3)	0 to 100 ppm	1 ppm
Carbon Monoxide (CO) Carbon Monoxide (CO), Ext. Range Carbon Monoxide (CO), H_2-comp. Carbon Monoxide (CO) + Hydrogen Sulfide (H_2S) Combo	0 to 500 ppm 0 to 2,000 ppm 0 to 2,000 ppm 0 to 500 ppm 0 to 200 ppm	1 ppm 10 ppm 10 ppm 1 ppm 0.1 ppm
Chlorine (Cl_2)	0 to 50 ppm	0.1 ppm
Chlorine Dioxide (ClO_2)	0 to 1 ppm	0.03 ppm
Ethylene Oxide (EtO-A) Ethylene Oxide (EtO-B)	0 to 100 ppm 0 to 10 ppm	0.5 ppm 0.1 ppm
Formaldehyde (HCHO)	0 to 10 ppm	0.05 ppm
Hydrogen Cyanide (HCN)	0 to 50 ppm	0.5 ppm
Hydrogen Sulfide (H_2S)	0 to 100 ppm	0.1 ppm
Methyl Mercaptan (CH_3-SH)	0 to 10 ppm	0.1 ppm
Nitric Oxide (NO)	0 to 250 ppm	0.5 ppm
Nitrogen Dioxide (NO_2)	0 to 20 ppm	0.1 ppm
Oxygen (O_2)	0 to 30% Vol.	0.1% Vol.
Phosphine (PH_3)	0 to 20 ppm	0.1 ppm
Sulfur Dioxide (SO_2)	0 to 20 ppm	0.1 ppm

1 Additional equipment and/or software licenses may be required to enable remote wireless monitoring and alarm transmission.
2 A two-gas combination sensor is required for a 6-gas configuration.
3 RAE Systems recommends calibrating sensors on installation.
4 Specifications are subject to change.
5 Specification for non-wireless monitors.
6 Please contact RAE Systems for specific wireless approvals

ORDERING INFORMATION (MODEL: PGM-6248)

- Wireless[1] and non-wireless configurations are available
- Refer to the Portables Pricing Guide for part numbers for monitors, accessories, sampling and calibration kits, gas, sensors, and replacement parts

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ONE TO SIX GAS PORTABLE MONITOR

Gas Detection For Life

EAGLE 2 Model

Features

- **Monitor up to 6 different gases**
- **PPM, % LEL, or % Vol. auto-ranging combustible detection**
- **Specialty Sensors**
  - **PID (Photoionization Detector)**
    - Low or high range for VOC detection
    - Fence Electrode Technology for humidity and contamination resistance
  - **Infrared (IR)**
    CO2, % LEL CH4, % Vol. CH4, % LEL HC, % Vol. HC
  - **Thermal Conductivity (TC)**
    % Vol. H2, % Vol. CH4
  - **Smart toxic, plug and play sensors**
    NH3, AsH3, Cl2, HCN, PH3, & SO2
  - **Hydrogen specific LEL / ppm sensor**
- **Powerful long-life pump up to 125' range**
- **Low flow pump shut off and alarm**
- **Methane elimination for environmental use**
- **Alkaline 18 hours or NiMH 20 hours capability**
- **EPA Method 21 VOC Monitoring**
- **Internal hydrophobic dust filter**
- **External probe with hydrophobic filter**
- **Multilingual (5 languages)**
- **Ergonomic RFI / EMI / chemical / weather resistant enclosure**
- **Intrinsically safe design, CSA approval**
- **Datalogging standard**

The EAGLE 2 is the solution for just about any portable gas monitoring situation. Equipped with features that are not available on competitive units, the EAGLE 2 is a powerful instrument that does more than just offer the standard confined space protection for LEL, O2, H2S and CO. The EAGLE 2 offers easy access to controls such as autocalibration, alarm silence, demand zero, peak hold, and methane elimination. Each channel has two alarm levels plus TWA and STEL alarms for toxic channels. The two alarm levels are user adjustable and can be latching or self resetting.

The EAGLE 2 available features include a PID sensor for detecting high or low ppm levels (0-50 & 0-2,000) of VOC gases; % volume capability for CH4 and H2 using a TC (thermal conductivity) sensor; PPM or LEL hydrocarbon detection at the push of a button; infrared sensors for CO2 (ppm or % volume), methane or hydrocarbons in LEL and % volume ranges; methane elimination feature for environmental applications; and a variety of super toxic gases. The EAGLE 2 has a strong internal pump with a low flow auto pump shut off and alarm, which can draw samples from up to 125 feet. This allows for quick response and recovery from distant sampling locations. The EAGLE 2 will continuously operate for over 18 hours on alkaline batteries or 20 hours on NiMH. A variety of accessories are also available to help satisfy almost any application such as long sample hoses, special float probes for tank testing, and dilution fittings, just to name a few. Datalogging is a standard feature for all sensors on all versions.

The Eagle 2 is ideal for performing EPA Method 21 fugitive emission monitoring of VOC leaks from process equipment.. EPA Method 21- Determination of Volatile Organic Compound Leaks, is a test method used for the determination of leaks of VOCs from process equipment. The Eagle 2 meets the equirements for portable instruments used for this purpose as outlined in Sections 6 and 8 of Method 21.

EAGLE 2 Model

Enclosure	Weatherproof, chemical resistant, RFI / EMI coated high impact polycarbonate-PBT blend. Can operate in 2.0” of water without leakage. Ergonomically balanced with rugged top mounted handle. Water & dust resistant equivalent to IP64.
Dimensions	9.5” L x 5.25” W x 5.875” H
Weight	3.8 Lbs (standard 4 gas with batteries).
Detection Principle	Catalytic combustion, electrochemical cell, galvanic cell, infrared, Photoionization detector, and thermal conductivity.
Sampling Method	Powerful, long-life internal pump (over 6,000 hours) can draw samples over 125 feet. Flow rate approximately 2.0 SCFH.
Display	3 display modes: display all gases, large font-autoscroll, or large font-manual scroll. Polyurethane protected overlay. Backlight, illuminates for alarms and by demand, with adjustable time.
Language	Readout can display in 5 languages (English, French, German, Italian, or Spanish).
Alarms	2 Alarms per channel plus TWA and STEL alarms for toxics. The two alarms are fully adjustable for levels, latching or self reset, and silenceable.
Alarm Method	Buzzer 95 dB at 30 cm, four high intensity LED’s.
Controls	4 External glove friendly push buttons for operation, demand zero, and autocalibration. Buttons also access LEL/ppm, alarm silence, peak hold, TWA/STEL values, battery status, conversion factors, and many other features.
Continuous Operation	At 70°F, 18 hours using alkaline batteries, or 20 hours using NiMH.
Power Source	4 alkaline or NiMH, size C batteries (Charger has alkaline recognition to prevent battery damage if charging is attempted with alkalines).
Operating Temp. & Humidity	-20°C to 50°C (-4°F to 122°F), 0 to 95% RH, non-condensing.
Environmental	IP-64
Response Time	30 Seconds to 90% (for most gases) using standard 5 ft hose.
Safety Rating	Intrinsically Safe, Class I, Groups A, B, C, D. Approval: CSA
Standard Accessories	Shoulder strap, alkaline batteries, hydrophobic probe, and 5 foot hose, internal hydrophobic filter.
Optional Accessories	• Dilution fitting (50/50) • NiMH batteries • Battery charger, 115 VAC, 220 VAC, or 12 VDC (charge time 4 hours) • Continuous operation adapter, 115 VAC or 12 VDC • Extension hoses • IRDA cable for datalogging download
Warranty	Two year material and workmanship, one year for PID sensor.

Gas	Measuring Range	Accuracy * Which ever is greater
Gases & Detectable Ranges		
Standard Confined Space Gases		
Hydrocarbons (CH_4, std)	0 - 100% LEL	± 5% of reading or ± 2% LEL (*)
	0 - 5% Vol. (CH_4)	
	0 - 50,000 ppm	± 50 ppm or ± 5% of reading (*)
Oxygen (O_2)	0 - 40% Vol.	± 0.5% O2
Carbon Monoxide (CO)	0 - 500 ppm	± 5% of reading or ± 5 ppm CO (*)
Hydrogen Sulfide (H_2S)	0 - 100 ppm	± 5% of reading or ± 2 ppm H2S (*)
Toxics		
Ammonia (NH_3)	0 - 75 ppm	± 10% of reading or ± 5% of full scale (*)
Arsine (AsH_3)	0 - 1.5 ppm	
Chlorine (Cl_2)	0 - 3 ppm	
Hydrogen Cyanide (HCN)	0 - 15 ppm	
Phosphine (PH_3)	0 - 1 ppm	
Sulfur Dioxide (SO_2)	0 - 6 ppm	
IR Sensors		
Carbon Dioxide (CO_2)	0 - 10,000 ppm 0 - 5% Vol. 0 - 60% Vol.	± 5% of reading or ± 2% of full scale (*)
Methane (CH_4)	0 - 100% LEL/ 0 - 100% Vol.	
Hydrocarbons	0 - 100% LEL/ 0 - 30% Vol.	
PID Sensors		
VOC	0 - 2,000 ppm 0 - 50 ppm	–
TC Sensors		
Methane (CH_4)	0 - 100% Vol.	± 5% of reading or ± 2% of full scale (*)
Hydrogen (H_2)	0 - 10% Vol. 0 - 100% Vol.	
Hydrogen Specific		
Hydrogen (H_2)	0-100% LEL 0-40,000 ppm	± 5% of reading or ± 2% of full scale (*)

The EAGLE 2 can be configured with up to 6 gas sensors from the above list.

Specifications subject to change without notice.

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Carbon Dioxide (CO_2) Emergency Response Tactical Guidance Document

Guidelines for Preparedness and Initial Response to a Pipeline Release of Carbon Dioxide (CO_2)

August 2023

American Petroleum Institute

LIQUID ENERGY PIPELINE ASSOCIATION

NATIONAL ASSOCIATION OF STATE FIRE MARSHALS NASFM

This guide was developed by the American Petroleum Institute and the Liquid Energy Pipeline Association with input from the National Association of State Fire Marshals.

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Introduction

This field operations guide is not an educational or decision-making tool. This guide contains a set of operational tools and references to assist in the response to a pipeline release of carbon dioxide (CO_2).

The priorities for CO_2 response are:

People: safety of response personnel and the public;

Environment: prevention of environmental, human health, and welfare effects;

Assets: minimizing damage to structures and equipment; and

Relations: keep customers, community, and federal, state, and local government agencies informed.

Responder safety and health should never be compromised for tactical considerations. Likewise, CO_2 release response should be conducted to maximize safety around health impacts to responders, the public, and the surrounding areas of a release. For the purpose of this report, we are limiting the response effort to supercritical transmission pipelines.

Intended Audience

This guide is intended for pipeline operators and response operations personnel having basic knowledge in emergency response.

Current Applicable Federal Regulations

49 CFR 195, *Transportation of Hazardous Liquids by Pipeline*

Additional Resources

— API Recommended Practice 1109, Line Markers and Signage for Hazardous Liquid Pipelines and Facilities

— API Recommended Practice 1162, *Public Awareness Programs for Pipeline Operators*

— API Recommended Practice 1174, *Recommended Practice for Onshore Hazardous Liquid Pipeline Emergency Preparedness and Response*

— DOT/PHMSA *Emergency Response Guidebook (ERG)*

— CDC/NIOSH *Pocket Guide to Chemicals*

NOTE Additional state or local regulations may apply.

Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Level
CASRN	CAS Registry Number
CCS	carbon, capture, and storage
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
CO2	carbon dioxide
CPM	computational pipeline monitoring
EOR	enhanced oil recovery
ERPG	emergency response planning guidelines
HAZCOM	hazardous communication
HAZWOPER	OSHA's Hazardous Waste Operations and Emergency Response Standard
HCA	high consequence areas
HSE	health, safety, and environment
HVL	highly volatile liquid
ICS	Incident Command System
IDLH	immediately dangerous to life or health
LEPC	local emergency planning committee
NCEI	National Centers for Environmental Information
NIMS	National Incident Management System
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRC	National Response Center
O_2	oxygen
OSHA	Occupational Safety and Health Administration
OSRO	oil spill removal organization
PAC	protective action criteria per SCAPA (see below)
PEL	permissible exposure limit
PHMSA	United States Pipeline and Hazardous Materials Safety Administration
PPE	personal protective equipment
PPM	part per million
PREP	Preparedness for Response Exercise Program
PSI	per square inch
REL	recommended exposure limits
ROW	right of way
SAR	supplied air respirator
SCADA	Supervisory Control and Data Acquisition
SCAPA	U.S. Department of Energy's Subcommittee on Consequence Assessment and Protective Actions
SCBA	self-contained breathing apparatus
STEL	short-term exposure limit
TEEL	temporary emergency exposure limit
TLV	threshold limit values per ACGIH (see above)
TWA	time-weighted average

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1 Transportation of Carbon Dioxide (CO_2) in Pipelines

CO_2 transportation pipelines have been operating safely in the United States for decades. CO_2 is typically transported in the dense phase as a supercritical fluid, typically at pressures higher than 1,000 psi. It may also be transported in the gaseous phase in a pipeline. There are thousands of miles of CO_2 pipelines, ranging from 8 in. to 36 in. in diameter. This CO_2 is used for enhanced oil recovery (EOR); carbon, capture, and storage (CCS); and other commercial and industrial purposes.

Various Uses of CO_2	
Dry ice	Used as a refrigerant during shipping of perishable products such as meats or ice cream
Fire extinguisher	Used to displace oxygen to extinguish a fire
Life jackets	An inflatable life jacket contains a small cylinder of compressed CO_2 used for rapid inflation
Carbonated beverages	Used in soda products as a protective measure that keeps the soft drink fresh and prevents the growth of bacteria in the liquid while stored
Enhanced oil recovery	The injection of CO_2 into existing oil fields increases the overall pressure of the oil reservoir, forcing the oil toward production wells
Carbon capture and storage	CO_2 emissions are captured from industrial processes, then transported to and stored in deep, underground geological formations

Figure 1—Examples of Uses of CO_2

2 Characteristics of CO_2

In its purest form, CO_2 is a nonflammable, colorless, and odorless gas. Depending on temperature and pressure conditions, CO_2 can exist in a gas, liquid, or solid state. When pressures and temperature exceed the critical point, such as in supercritical pipelines, the gas phase and liquid phase become indistinguishable.

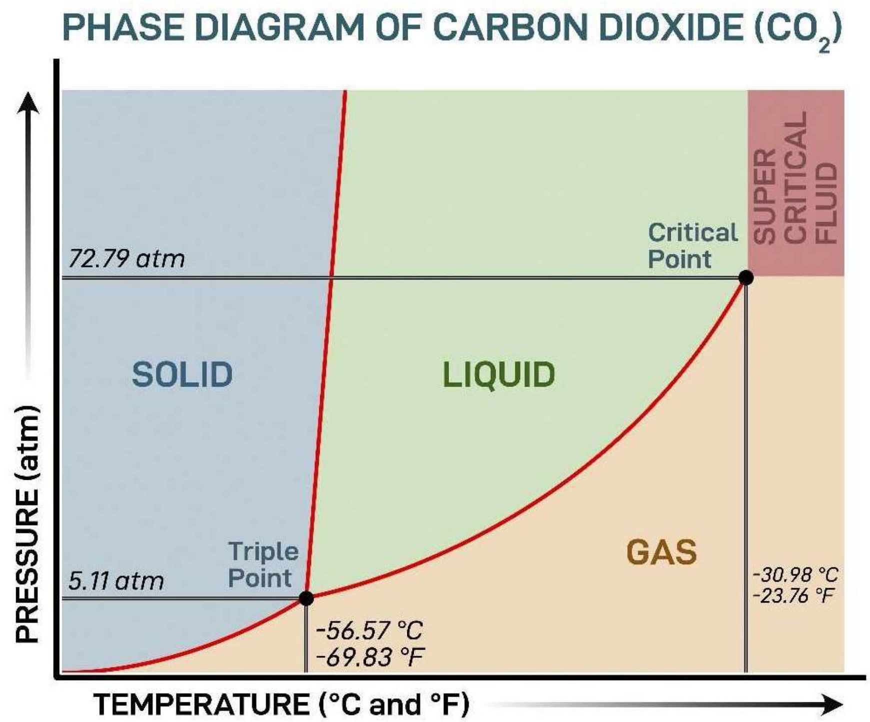

Figure 2—Phase Diagram of Carbon Dioxide

Atmospheric CO_2 is derived from many natural sources, including volcanoes, forest fires, respiration, and the decomposition of organic material by bacteria. Cars, trucks, industrial equipment, and burning fuel for power plants are some of the major man-made contributors to carbon dioxide in the air.

Airborne CO_2 concentrations are easy and inexpensive to measure. Carbon dioxide is not generally found at hazardous levels in outdoor environments, yet it is often measured when trying to determine indoor air quality because it is a good surrogate measure of how well natural and mechanical ventilation systems are working. If the levels of carbon dioxide are elevated, it is assumed that there may not be adequate ventilation to that area, which in turn may allow for buildup of other environmental pollutants.

Human exposure to CO_2 occurs constantly. It is a regular by-product of cellular respiration, and the CO_2 content of normal fresh air varies between approximately 0.03 % (300 ppm) and 0.06 % (600 ppm).

2.1 Physical Hazards

During a release of CO_2 from a pressurized pipeline to the atmosphere, the dramatic change of pressure at the release point will cause rapid large-scale expansion of the CO_2, which generates a refrigeration effect. This can produce an opaque water vapor cloud, which may be dispersed by the wind. However, due to the density of CO_2, during cool and humid conditions with little to no wind, the CO_2 could accumulate in low-lying areas, such as valleys and ditches. This water vapor cloud can significantly reduce visibility, especially during nighttime hours, making driving or walking through the CO_2 release hazardous.

At the release point, CO_2 can present a dermal hazard to those coming into contact with the extremely cold released product or adjacent piping and equipment. After exiting the release point and warming up to ambient temperatures, the opaque water vapor cloud will dissipate. Since CO_2 is colorless, it may still be present. In dry, arid climates, an opaque water vapor cloud may not develop at the release point due to the lack of humidity in the atmosphere.

In general, day conditions allow for greater turbulent mixing and dispersion caused by solar intensity, winds, and lower relative humidity. Calm night conditions lead to far less dispersion and are considered to yield the worst-case air concentrations of CO_2.

Meteorological Effects on Physical Hazards			
Scenario	**Potential Hazards**		
	Reduced Visibility	**Dermal Hazards**	**Accumulation of CO_2 in Low Areas**
Daytime, sunny, with winds greater than 10 mph		X	
Daytime, cloudy, humid, with winds less than 3 mph		X	X
Nighttime, with winds greater than 10 mph		X	X
Nighttime, humid, with winds less than 3 mph	X	X	X

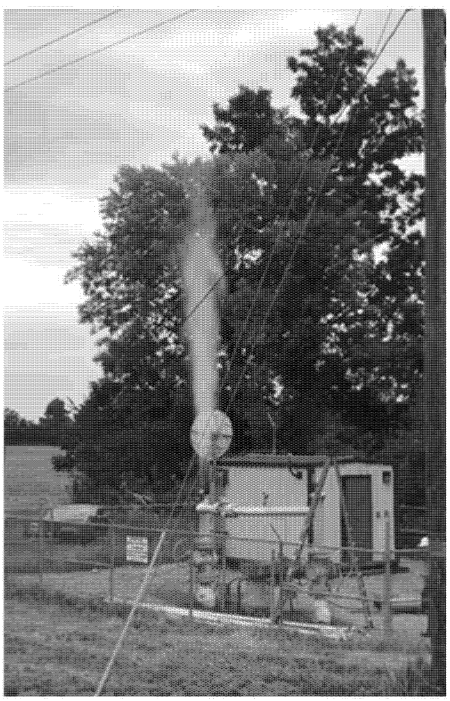

Figure 3—Day Dispersion during Blowdown Operations

Figure 4—Night Dispersion during Blowdown Operations

2.2 Oxygen Displacement

When released in large quantities, such as in the case of a pipeline rupture, CO_2 can physically displace the other components of ambient air and reduce the amount of available oxygen. Normal oxygen concentration is 20.9 % of ambient air, with the balance consisting primarily of nitrogen, water vapor, trace gases, and other gases and particulates present due to local geography and ambient air quality. Oxygen concentration needed for normal body function is at least 19.5 % of inhaled air. As oxygen levels fall below 19.5 %, physiological compensation results in higher breathing rates and higher cardiac output through increased heart rate. However, as oxygen levels drop further, decreased physical coordination and impaired mental acuity increase. At oxygen levels of 6 % to 10 %, nausea, vomiting, and lethargy increase markedly to the point of unconsciousness. Oxygen levels of less than 6 % will result in cessation of breathing, convulsions, cardiac arrest, and death.

Atmospheric Hazard Action Levels		
Analyte	**Acceptable Levels**	**Action Required by Responders if Outside Acceptable Levels**
Oxygen (O_2)	19.5 %-23.5 %	Evacuate to fresh air or supplied air respirator (SAR) or SCBA

2.3 Exposure Limits

The U.S. Department of Energy's Subcommittee on Consequence Assessment and Protective Actions (SCAPA) has established protective action criteria (PACs) for over 3,300 chemicals for planning and response to uncontrolled releases of hazardous chemicals (DOE/SCAPA2018). These criteria, based on concentration levels, combined with estimates of actual exposure, provide information necessary to evaluate chemical release events for the purpose of taking appropriate protective actions. During an emergency response, these criteria may be used to evaluate the severity of the event and to inform decisions regarding what protective actions may be taken. The PAC values for CO_2 are provided in the table below. The PAC-1, PAC-2, and PAC-3 for CO_2 are 30,000, 40,000, and 50,000 ppm, respectively.

No.	**Product Name**	**CASRN**	**PACs Based on AEGLs, ERPGs, or TEELs**			**Units**
			PAC-1[a]	**PAC-2[b]**	**PAC-3[c]**	
570	Carbon Dioxide	124-38-9	30,000	40,000	50,000	ppm
Action Required for Responders			**Evacuation to Fresh Air or SAR or SCBA**			

a) PAC-1: The maximum concentration in air [measured as the peak 15-minute time weighted average (TWA)] below which it is believed nearly all individuals could be exposed without experiencing other than mild transient health effects (DOE/SCAPA, 2018).

b) PAC-2: The maximum concentration in air (measured as the peak 15-minute TWA) below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action (DOE/SCAPA, 2018).

c) PAC-3: The maximum concentration in air (measured as the peak 15-minute TWA) below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects (DOE/SCAPA, 2018)

For comparison, the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) are shown in the table below. Although the TLVs are intended for occupational daily work shift exposures over an entire working lifetime, the current ACGIH TLV-time-weighted average (TLV-TWA) for CO_2 (5,000 ppm) is based on the lack of inhalation toxicity data in humans at this level and the ACGIH TLV-short-term exposure limit (STEL) for CO_2 is 30,000 ppm.

Product Name	CASRN	ACGIH TLVs		Units
		TWA (8 hr)[a]	STEL (15 min)[b]	
Carbon dioxide	124-38-9	5,000	30,000	ppm
Action Required for Responders		SAR or SCBA (if longer than eight hours of exposure)	Evacuation to fresh air or SAR or SCBA	

a) ACGIH TLV-TWA: Threshold limit value-time-weighted average (TLV-TWA). The TWA concentration for a conventional eight-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect (ACGIH, 2023).

b) ACGIH TLV-STEL Threshold limit value-short-term exposure limit (TLV-STEL). A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the eight-hour TWA is within the TLV-TWA. The TLV-STEL is the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, 3) dose-rate-dependent toxic effects, or 4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency. Exposures above the TLV-TWA up to the TLV-STEL should be less than 15 minutes, should occur not more than four times per day, and there should be at least 60 minutes between successive exposures in this range (ACGIH, 2023).

The National Institute for Occupational Safety and Health (NIOSH) has recommended exposure limits (RELs) for CO_2 that mirror the TWA and STEL of ACGIH, although NIOSH also has a listed IDLH (immediately dangerous to life or health) of 40,000 ppm. OSHA's permissible exposure limit (PEL) for CO_2 is 5,000 ppm.

Product Name	CASRN	NIOSH REL			Units
		TWA (10 hr)	STEL (15 min)	IDLH	
Carbon dioxide	124-38-9	5,000	30,000	40,000	ppm
Action Required for Responders		SAR or SCBA (if longer than 10 hours of exposure)	Evacuation to fresh air or SAR or SCBA		

3 Emergency Preparedness and Planning

3.1 Community/Stakeholder Outreach and Liaison

Operators transporting CO_2 through pipelines are required to conduct outreach and awareness efforts for specific areas along the pipeline's route. A CO_2 release and the subsequent response will present unique circumstances that will likely differ from responses to more common products, such as natural gas, crude oil, gasoline, etc. It is important to educate the stakeholders on these unique circumstances so that they will be more likely to identify a release of CO_2 and assist in enacting the proper response procedures. Stakeholders may include, but are not limited to:

— affected public;

— local emergency managers;

— fire department, law enforcement, local emergency planning committees (LEPCs);

— hazardous materials response teams (HAZMAT);

— excavators/contractors;

— public officials.

Operators should also become familiar with potential public gathering centers such as schools, hospitals, etc., along their pipeline rights-of-way (ROWs) and proactively develop a plan of action for a large-scale pipeline release with local emergency response officials. When developing a course of action with local emergency response officials, the following should be considered:

— ability to safely evacuate people from the school, hospital, or other place of gathering;

— visibility limitations caused by the dense vapor cloud and risk of driving or walking into the vapor cloud;

— potential of vehicles stalling in the dense vapor cloud and increasing exposure to the released CO_2;

— effectiveness of sheltering in place, making sure people stay off the ground or move to an upper floor of a building and not into a basement or low area where CO_2 may enter a building and collect;

— communicating with and educating emergency response personnel that may be stationed outside of your area for public awareness but could ultimately respond to a release from your pipeline.

It is common for members of the public to be the first to discover surface releases in or around ROWs or facilities. Federal regulation requires pipeline operators to develop and implement a written continuing public education program[1]. One of the traditional methods of achieving this is through the mailing of flyers/postcards with educational information about the location, product, and ownership of pipelines in a given geographic area.

Each pipeline operator is required to place and maintain line markers over each buried pipeline in a sufficient number along the line so that its location is accurately known, and also at each public road and railroad crossing[2]. Additionally, each operator shall provide line marking at locations where the line is above ground in areas that are accessible to the public. The marker must contain the word "Warning," "Caution,"

[1] 49 CFR § 195.440.
[2] 49 CFR § 195.410.

or “Danger” followed by the words “Carbon Dioxide Pipeline,” and include the name of the operator and a telephone number where the operator can be reached at all times.

For more information on signage and public awareness, refer to API Recommended Practice 1109, *Line Markers and Signage for Hazardous Liquid Pipelines and Facilities*, and Recommended Practice 1162, *Public Awareness Programs for Pipeline Operators*.

3.2 Response Drills and Exercises

One of the means of ensuring the proper communication of emergency response procedures is to drill them with pipeline operators and the applicable emergency responders for a given scenario, as required for high consequence areas (HCAs)[3]. Drills and exercises are great ways of ensuring pipeline operators are prepared and rehearsing needed response actions with emergency responders that would likely be responding to a pipeline release.

Although only applicable for oil pipelines (49 CFR 194), the National Preparedness for Response Exercise Program (PREP) Guidelines outline a PHMSA-endorsed drill and exercise program that can prove effective if adopted by CO_2 pipeline operators, especially if it is used beyond the HCAs of the pipeline system.

The PREP Guidelines identify a format for qualified individual drills (per requirements of OPA 90 that are not applicable to CO_2 pipelines) that can be used to achieve the exercise requirements of control room operator emergency procedures[4]. Exercises can be conducted that test collaboration between pipeline and control room operators as it relates to emergency response procedures. These exercises should be documented per the PREP Guidelines.

Similarly, such collaboration can be exercised by the PREP Guidelines’ format for a tabletop exercise, where designated emergency response team members should demonstrate adequate knowledge and understanding of their response procedures and the ability to organize, communicate, coordinate, and respond in accordance with those procedures. When coupled with applicable emergency response officials, they facilitate the initiation and demonstration of the use of a unified command, consistent with the Incident Command System. These exercises can help identify opportunities for improvement of the emergency procedures, understand the response capabilities of the applicable emergency response agencies, allow for cross-education between your organization and the applicable emergency response agencies, and allow for proper coordination of response efforts as required for HCAs.

Type of Drill	Frequency	Attendees
Internal notifications/tests	Quarterly	Controllers, emergency response team members
Tabletop exercise	Annually	Controllers, emergency response team members, third-party response organizations, local, state, and federal emergency response officials*
* Full-scale exercises with federal, state, and local emergency response officials are recommended at least once every three years.		

Adoption of a formal drill and exercise program can help to achieve the training requirements of 49 CFR 195.403 highlighted in the following section.

[3] 49 CFR 195.452.
[4] 49 CFR 195.446(h)(6).

3.3 Training

Pipeline operators must have a training program that covers the roles and responsibilities outlined in the emergency response plan designated for their pipeline operations. As per 49 CFR 195.403, each operator shall establish and conduct an annual training program to instruct emergency response personnel to:

1) carry out the emergency procedures established under 195.402 that relate to their assignments;
2) know the characteristics and hazards of CO_2;
3) recognize conditions that are likely to cause emergencies, predict the consequences of facility malfunctions or failures and CO_2 releases, and take appropriate corrective action;
4) take steps necessary to control any accidental release of CO_2 and to minimize the potential impacts to the public; and
5) learn the potential causes, types, sizes, and consequences of a leak, involving, where feasible, a simulated pipeline emergency condition.

In addition to the above listed items, pipeline operators should provide training on topics that will be leveraged during the response to a pipeline emergency. Those trainings should include, but are not limited to the following:

Training	Frequency
Hazardous waste operations and emergency response (HAZWOPER) technician level	One time, then annual refresher
Incident command system (ICS)	One time, then routine refresher
Use of portable air monitoring/gas detection equipment*	Annual
Proper use of personal protective equipment*	Annual
Hazard communication (HAZCOM)*	Annual
Respiratory protection	Annual
First aid/CPR	Biennial
* Can be included in or conjunction with HAZWOPER training.	

3.3.1 Hazardous Waste Operations and Emergency Response Standard (HAZWOPER)

OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) standard applies to five distinct groups of employers and their employees, one of which is emergency response operations for releases of, or substantial threats of releases of, hazardous substances regardless of the location of the hazard. Personnel who are engaged in emergency response to hazardous substance releases should be trained on a pre-written emergency response plan that addresses pre-emergency planning and coordination with outside parties, personnel roles, lines of authority, training, communication, emergency recognition and prevention, safe distances and places of refuge, site security and control, evacuation routes and procedures, decontamination, emergency medical treatment and first aid, emergency alerting and response procedures, personal protective equipment (PPE), and emergency equipment along with critique of responses and necessary follow-up should the plan be enacted[5]. The HAZWOPER standard notes that four people are required for an emergency response in an unknown or potentially IDLH atmosphere. This regulation also calls out the use of the Incident Command System in its procedures for handling an

[5] 29 CFR 1910.120(q).

emergency response. Specific training requirements for personnel within an organization are also defined[6]. While HAZWOPER identifies different training levels and requirements, it is recommended that operators expected to respond to a pipeline-related incident involving CO_2 be trained to at least the Hazardous Materials Technician level.

The table below describes the best means to achieve HAZWOPER Hazardous Materials Technician training in preparation for a CO_2 pipeline release.

HAZWOPER Training Level	**Applicable Training Requirements**	**Best Ways to Achieve or Verify**
Hazardous Materials Technician	Know how to implement employer's emergency response plan.	Training and review of applicable response plans or procedures with all response personnel through classroom training and/or drill participation.
	Know the classification, identification, and verification of CO_2 by using gas detection equipment; understand basic chemical and toxicological terminology and behavior of CO_2; understand hazard and risk assessment techniques.	Detailed overview of CO_2 hazards; review of past incidents, discuss identifiers of a CO_2 release, and the fate of released products in the atmosphere; training on the use of air monitoring equipment.
	Be able to function within an assigned role in the Incident Command System.	Incident command system training for all response and management personnel that could respond to a pipeline-related incident; ICS-100 (*Introduction to the Incident Command System*); ICS-200 (*Basic ICS for Initial Response*); and ICS-300 (*Intermediate ICS for Expanding Incidents*).
	Be able to perform advanced control, containment, and/or confinement operations within the capabilities of the available resources and personal protective equipment.	Training on applicable response procedures associated with isolation; simulated drills involving testing response times and techniques for isolation; respiratory protection training and the testing of equipment.

3.3.2 Incident Command System (ICS) Training

The Incident Command System (ICS) is used by public agencies to manage emergencies per the requirements of the National Incident Management System (NIMS). ICS can be used by private-sector businesses to work together with public agencies during emergencies such as CO_2 pipeline releases. As a result, operators and their personnel should be familiar with the fundamental concepts of the Incident Command System to help coordinate planning and incident management with public emergency services and agencies.

The ICS structure is meant to expand and contract as the scope of an incident requires. For small-scale incidents, only the incident commander may be assigned. Per ICS, the first on-scene representative of the responsible party would be considered the incident commander and would coordinate with the jurisdictional local, state, or federal emergency response agencies within Unified Command. Command of an incident

[6] 29 CFR 1910.120(q)(6)(I).

would likely transfer to the senior on-scene officer of the responding public agency when emergency services arrive on the scene, which may also happen for the responsible party incident commander. This is done by performing a proper Transfer of Command.

It is important to train responding personnel in the implementation and use of the Incident Command System, including relevant terminology, forms, and position roles and responsibilities. It is recommended to train personnel expected to respond to and manage a CO_2 pipeline-related incident to the ICS-200 level at a minimum.

4 Dispersion Modeling Best Practices

The potential for CO_2 pipeline systems to affect high consequence areas (HCAs) must be evaluated[7]. Modeling is conducted to estimate the potential worst-case consequences in the event of pipeline rupture in or near an HCA. The consequence analysis calculations should be performed for full bore pipeline rupture under worst-case operating and atmospheric conditions to obtain the worst potential dispersion distances or the impact area buffer.

Listed below are key inputs to most of the models and can impact the calculated potential impact area:

— pipeline parameters: name, length, internal diameter, operating pressure, fluid composition, product temperature and flow rate;

— meteorological conditions: data for wind speed, wind direction, air temperature, relative humidity and Pasquill-Gifford atmospheric stability class rating;

— isolation valves and isolation time;

— CO_2 concentrations of interest.

Similarly, due to the unique characteristics of CO_2 and the influence of the surrounding topography, conducting an atmospheric dispersion analysis could be challenging in terrain with significant topographic relief. Similar to wind, it is particularly problematic when the direction of the terrain relief is in the direction of a populated area or HCA. The use of atmospheric dispersion modeling, coupled with overland spread analysis using computational fluid dynamics (CFD) modeling, may be necessary in these areas where topography and elevation changes may cause the dispersion plume to travel further than what could be determined using only the traditional atmospheric dispersion analysis. In these areas, to truly understand whether a nearby HCA could be affected by a CO_2 release, CFD modeling can be added in order to determine the additional dispersion distance and ultimately determine whether the dispersion plume might impact a nearby HCA at any given point on the pipeline system.

An atmospheric dispersion analysis includes modeling pipeline releases utilizing software that uses a Gaussian plume model to evaluate the dispersion of the released CO_2 under site-specific seasonal weather conditions, to determine worst-case buffer distances for non-topographically impacted transport. Although oxygen displacement is the main safety concern for any CO_2 pipeline release, it is recommended that 30,000 PPM or 40,000 PPM of CO_2 be selected as the concentration endpoint for the exposure analysis, based on potential human health risks at that concentration.

[7] 49 CFR 195.450 (Definitions) and 195.452.

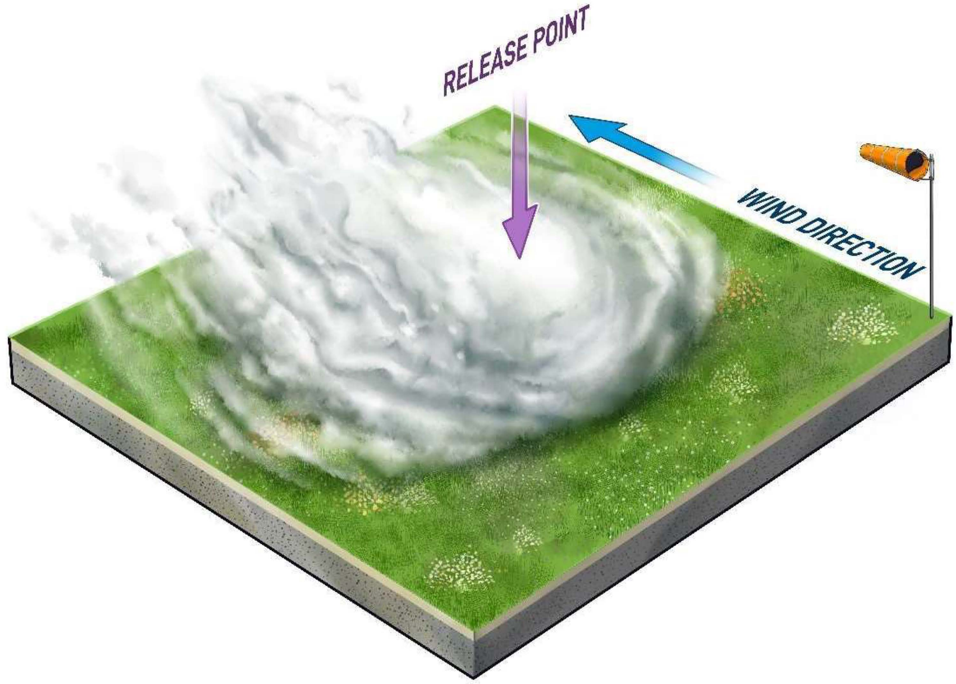

Figure 5—Transport and Dispersion of Released Carbon Dioxide on Flat Land

When the pipeline is in proximity to a nearby HCA, the effect of topography impacting transport must be considered. An overland spread analysis should be performed to determine whether the impact of topography and the dense vapor cloud could affect the nearby HCA. The overland spread analysis should consider worst-case operating conditions, ambient conditions, elevation changes, and topographic features, which would favor the channeling of CO_2 from a release location in the direction of the specific HCA. The Overland Spread Analysis uses site-specific, topographically based CFD modeling to further evaluate the potential hazard distances in these areas.

Simply stated, the atmospheric dispersion plume model will help predict the radius of impact following a pipeline rupture, while the CFD will evaluate the influence of the topographic features to provide the worst-case distance of impact caused by a release. Because CFD modeling requires high levels of computational power, modeling large distances of pipeline is, in most cases, not practical. A recommendation to achieve the highest level of effectiveness is to use the atmospheric dispersion model for the entire pipeline system and use CFD modeling in areas that exhibit significant elevation changes and significant channeling in the direction of an HCA that is within several miles of the pipeline system.

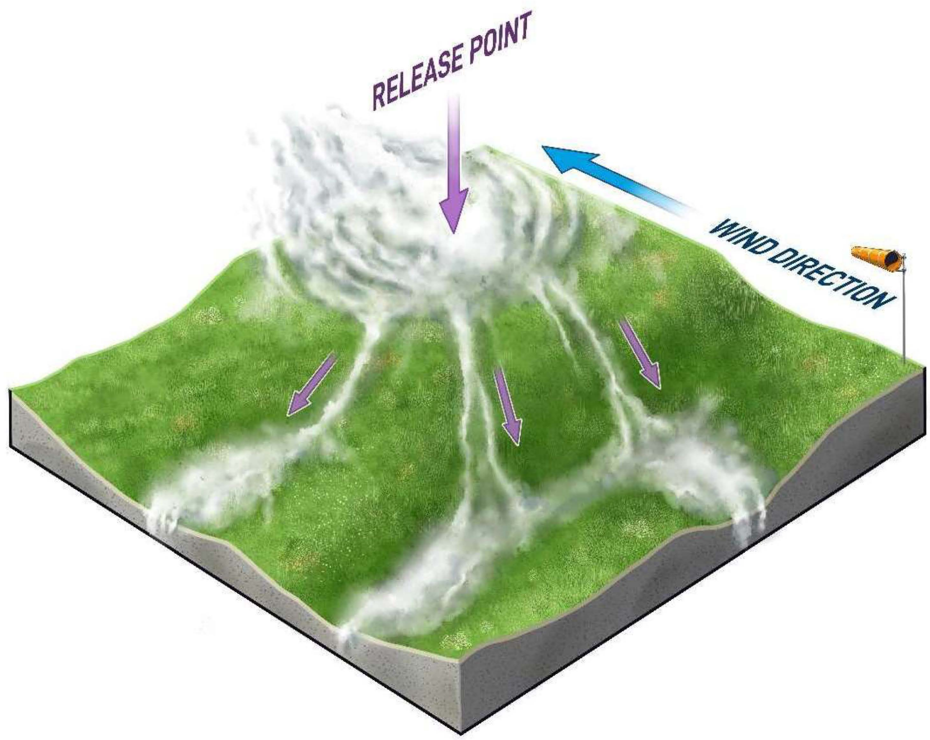

Figure 6—Transport and Dispersion of Released Carbon Dioxide with Topographical Features

In addition to the impact of topography, examples of meteorological data that can affect the transport of CO_2 during a pipeline release include air temperature, wind speed, and relative humidity. These factors can influence the rate of evaporation, the density, and the distance the products can travel in the air. Data for these factors can be obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Comparative Climatic Data for the United States through 2018[8]. When preparing models to determine potential impacts to an HCA, it is recommended that worst-case climate data inputs are used and compared to average most-probable climate data inputs. This will give the pipeline operator an understanding of how far the CO_2 can migrate under the worst possible atmospheric conditions.

5 CO_2 Pipeline Leak Detection and Identification

5.1 Physical Identification

When a leak occurs on a CO_2 pipeline, the rapid drop in pressure causes the supercritical fluid inside the pipeline to quickly change to a dense gaseous phase. In a smaller leak, this change will occur instantaneously at the point of the leak. In large, complete pipeline ruptures and during the worst-case ambient conditions, the dense gas may aggregate in low-lying topography and travel downhill before dispersing in the atmosphere. A leak of CO_2 from a pipeline may be recognized by using one or any combination of the following:

— sight: presence of a dense while cloud, fog, or ice developing near the pipeline release point, blowing dirt, dust, or soil in the air, or water bubbling in a puddle, pond, or creek;

[8] https://www.ncei.noaa.gov/products/land-based-station/comparative-climatic-data

— sound: a hissing, blowing, or roaring sound;

— smell: CO_2 is often odorless in a transmission line but may have a slightly musty odor.

5.2 Remote Identification

Like other pipeline systems, CO_2 pipelines are equipped with Supervisory Control and Data Acquisition (SCADA) systems, which transmit information and data that are critical to the operation of the pipelines back to a remote, centralized control center. Sensors and actuators installed on the pipeline system allow pipeline controllers to monitor the pressures and flow rates inside the pipeline from the control center and take action to remotely open or close valves when a pressure anomaly and flow rate change is observed.

Pipeline controllers play a significant role in the early detection of a leak by closely monitoring the SCADA systems. They are responsible for receiving initial notification of or recognition of a potential rupture of a pipeline based on information from the SCADA system as indicated by the following:

— an unanticipated or sudden pressure reduction outside of the pipeline's normal operating pressures, as defined in the operator's written procedures;

— an unanticipated or unexplained flow rate change, pressure change, equipment function, or other pipeline instrumentation indication at the upstream or downstream station.

In addition to the above, pipeline controllers should be able to identify a rupture through remote monitoring and fully close any remote rupture mitigation valves within 30 minutes of the initial rupture identification to minimize the volume of CO_2 released from a pipeline to mitigate the consequences of a rupture[9]. They must also be able to promptly respond to emergency and abnormality alarms and efficiently initiate proper response actions required to prevent or mitigate the condition.

Line break technology can also be used to remotely detect pipeline ruptures. When the pipeline pressure rapidly and significantly declines at a pipeline block valve (equipped with pressure telemetry and actuation), beyond a pre-established reference value, the control logic within the actuators of the upstream and downstream valves is designed to automatically close the valve, completely isolating and stopping flow to the segment in which the pressure decline occurred. This technology is designed to automatically isolate a pipeline rupture quickly and reliably, therefore reducing impacts to the areas surrounding the release.

Computational pipeline monitoring (CPM), typically used in crude oil pipeline operations, is difficult to achieve with CO_2 pipeline operations due to the compressibility of the CO_2 inside the pipeline.

5.3 Supplemental Identification Methods

In addition to the physical and remote identification methods mentioned above, patrol surveys on pipeline ROWs are performed as a way to detect a leak from the pipeline that may not be able to be detected through pressure monitoring or to identify activity that may be harmful to the integrity of the pipeline. Operators of regulated pipeline systems are required to develop procedures for conducting these patrol surveys. The procedures for conducting the patrol surveys will include methods for conducting the patrols by ground, air, or water, and provide guidance for identifying and reporting signs of:

— unusual conditions or activity;

— evidence of leaking or spilled products;

[9] 49CFR195.419(b).

— third-party excavation or construction activity;

— logging activity;

— vandalism;

— erosion, washouts, or subsidence;

— exposed portions of the pipeline;

— excessive vegetation or tree canopy that might impede inspection or maintenance of the pipeline;

— any other factors that could affect public safety and operations.

If any of the above signs or activities are reported during a ground or aerial survey of the pipeline, the pipeline company will investigate and take appropriate actions.

6 Internal Notification Protocols

Each operator should develop standardized reporting procedures for internally reporting pipeline-related incidents. These internal notification procedures ensure incidents are properly reported in an efficient, timely manner. The procedures should also be designed to enable the operator to provide the most consistent and accurate information when initially reporting incidents externally and when updating responding agencies. It is recommended that internal notification procedures include the following:

— a method for the pipeline controller to quickly provide information to the responding pipeline personnel, such as dedicated conference call lines, mass communication systems initiated from the control room, etc.;

— internal flowcharts that depict the flow of information, allow the operator to notify the appropriate level of management, and quickly involve all departments, such as legal, HSE, land, public relations, risk management, etc., needed to support the ramp-up of the Incident Command System and deployment of the incident command team.

7 Reportable Release Thresholds

At the earliest practicable moment following the discovery of a release of CO_2, but no later than one hour after confirmed discovery, the operator of the system must give notice to the National Response Center (NRC) of any failure that[10]:

— caused a death or personal injury requiring hospitalization;

— resulted in a fire or explosion not intentionally set by the operator;

— caused estimated property damage, including cost of cleanup and recovery, value of lost product, damage to the property of the operator or others, or both, exceeding $50,000;

— results in pollution of any stream, river, lake, reservoir, or other similar body of water that violated applicable water quality standards, caused a discoloration on the surface of the water or adjoining

[10] 49 CFR 195.52.

shoreline, or deposited a sludge or emulsion beneath the surface of the water or upon the adjoining shorelines; or

— in the judgment of the operator was significant even though it did not meet the criteria listed above.

Due to the ambiguity of the last bullet above, it is recommended that any release causing the following should result in notification to the NRC:

— highway or road closures;

— evacuations or sheltering in place;

— any public exposure to CO_2.

Any notification to the NRC or any state or local agency should occur verbally over the phone as soon as possible and never be delayed due to the lack of information about a release. The order in which verbal notifications occur should be prioritized with the focus on public safety.

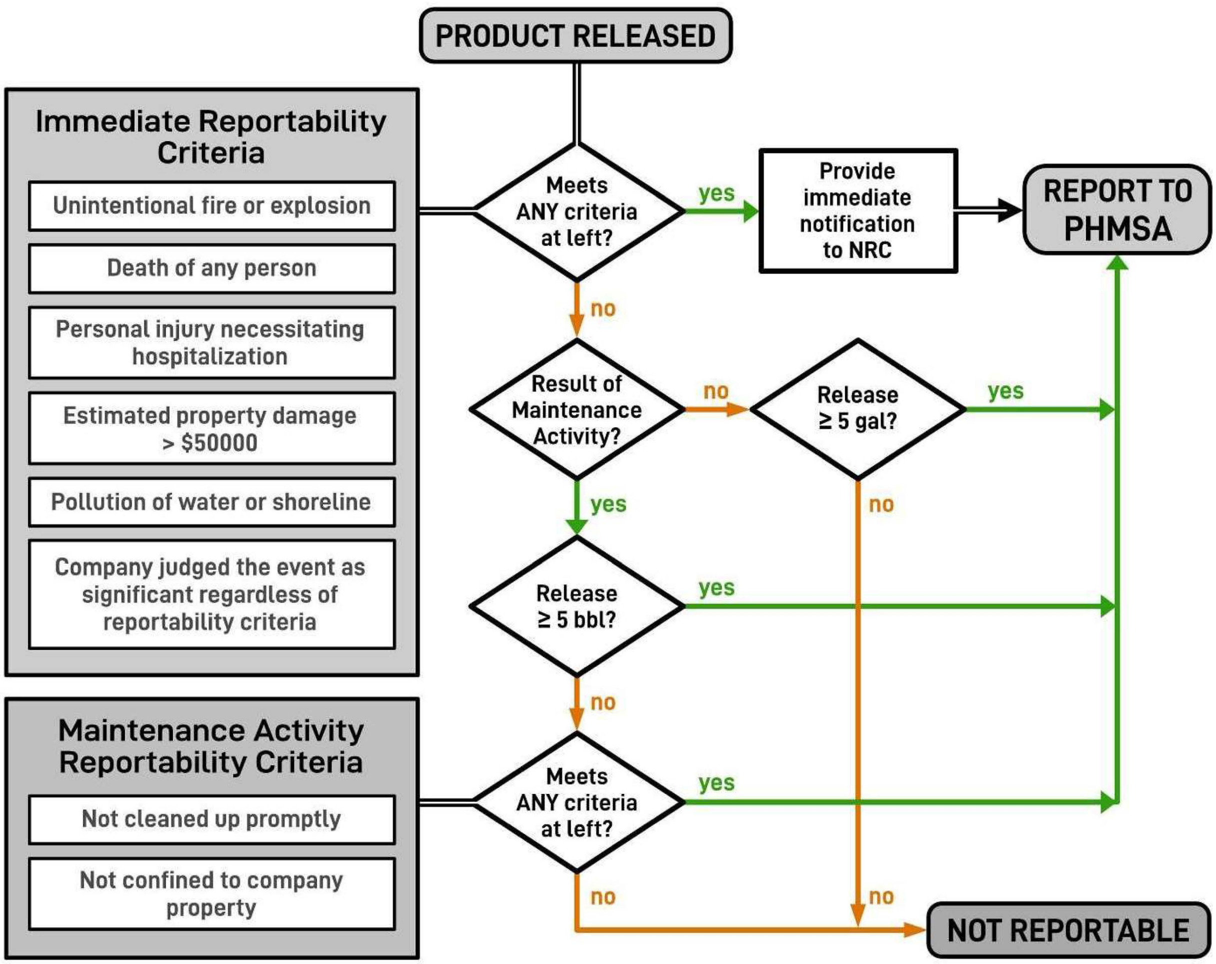

Figure 7—Incident Reporting Criteria

In addition to the federal reporting thresholds, some states have specific reportable quantities for CO_2. Operators should develop detailed reporting procedures for reporting CO_2 releases to all appropriate state agencies in the areas in which they operate. Where published reportable quantities for CO_2 do not exist, it is recommended that the operator notify the applicable state emergency hotline or state agency responsible for public safety for any release that results in the following:

— death or personal injury requiring hospitalization;

— road closures or evacuations; or

— any off-site or public exposure to CO_2.

When federal or state reportable thresholds are exceeded, operators should also consider notifications to owner/operator of nearby infrastructure that may be affected by the release, such as railroads, airports, businesses, hospitals, or places of gathering.

8 Public Safety Answering Point Notification of CO_2 Pipeline Release

Existing pipeline regulations also specify that operators must prepare a means for notifying the appropriate public safety answering point (i.e., 911 emergency call center) of carbon dioxide pipeline emergencies to coordinate and share information to determine the location of the release, including both planned responses and actual responses during an emergency, and any additional precautions necessary for an emergency. When a pipeline release occurs, the pipeline operator will immediately and directly notify the appropriate public safety answering point or other coordinating agencies for the communities and jurisdiction(s) in which the pipeline is located.

Because 911 dispatch centers are routed based on the area in which the call is originated, those outside of the geographic area of a potential rupture may not be able to reach the 911 dispatch center by simply dialing 911. As such, the pipeline operator should identify and document the “non-emergency” or “back-door” numbers for 911 dispatch centers so that, during an emergency, the appropriate 911 dispatch center can be reached, regardless of the caller’s origin location. These should be included within the applicable emergency response plans. It is recommended that the 911 dispatch center should be the first external notification made by the operator in the event of a pipeline rupture which has impacted, or has the potential to impact, the public.

In order to notify the affected public of a pipeline release, many local (county/parish) emergency services maintain reverse 911 services that allow for immediate notification to the affected public where a targeted alert can be broadcast to warn of potential danger, the need for evacuation or sheltering in place, or the like. Use your public awareness materials to make the public aware of such services.

8.1 Information to Provide to First Responders During Agency Notifications

Based on the identified hazards associated with a CO_2 pipeline-related incident, it is imperative to communicate accurate information in a timely manner to local first responders. All factual information known at the time of reporting should be conveyed, with the priority of protecting public health. Items that should be communicated include, but are not limited to:

— origin of release;

— nearest intersection/landmark;

— dispersion characteristics of vapor cloud (laying low to ground, overland travel, dispersion into atmosphere, etc.);

— suspected path and direction of travel;

— volume released (pre-calculating volumes between valve sets is recommended for this purpose);

— potential outcomes such as limited visibility due to the vapor cloud and potential oxygen displacement;

— Actions being taken by the pipeline operator;

— initial evacuation distances; and

— options to shelter in place.

If provided as soon as possible, the above information will enable local emergency managers and first responders to make critical decisions that will help ensure the safety of the public that is impacted, or has the potential to be impacted, by the release.

9 Third-party Notification of a CO_2 Pipeline Release

Existing pipeline regulations assist in ensuring the public is able to contact the appropriate operator following the discovery of a release. Each operator is required to maintain a process for receiving calls from the public and disseminating the information provided by the public to the appropriate internal responders. The process should include procedures for receiving calls from the public at the control center and gathering pertinent information regarding the report from the public. This information should include, but is not limited to:

— address of suspected release (including city/town and state);

— observations that have been made by the caller (vapor cloud, sounds, etc.);

— suspected path of travel of the vapor cloud (if observed);

— any roads, homes, schools, or other entities that are being impacted by the suspected release;

— injuries or fatalities caused by the suspected release;

— callback phone number for any follow-up questions.

The pipeline controller receiving the call should also help ensure the safety of the caller and instruct them on what personal protective measures to take, such as sheltering in place or evacuation upwind.

10 CO_2 Pipeline Release Response Actions

Each pipeline system is required[11] to have a manual of written procedures to cover not only conducting normal operations and maintenance activities, but also the handling of abnormal operations and emergencies, including the ability to respond to events and coordinate local, state, and federal response agencies to effectively minimize public exposure. The procedures (commonly compiled into an emergency response plan), should be written to allow the pipeline operator to achieve multiple objectives simultaneously in a timely manner. Since CO_2 is not likely to cause any short-term or long-term environmental impacts requiring extensive cleanup activities like an oil spill would, the objectives following a rupture should be focused on the following:

— protection of public;

— safety of the first responders and personnel;

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[11] 40 CFR 195.402.

— stabilizing the incident;

In the event of a CO_2 pipeline-related incident, ensuring the safety of the public and emergency responders and isolating the upstream and downstream control valves will be the most important objectives to mitigate the threats, including asphyxiation.

10.1 Emergency Responder Safety

The safety of emergency responders is a high priority. In addition to facilitating drills with local emergency responders, meetings should be routinely conducted with local emergency preparedness committee directors, fire chiefs, and law enforcement that are within the response radius of pipeline ROWs. During these meetings, the pipeline operator should ensure that local emergency responders understand the hazards associated with CO_2 and how they should protect themselves. In addition, the following should be discussed with local emergency responders:

— dermal hazards (frostbite to hands) and the use of leather or insulated rubber gloves while working in close proximity to a CO_2 release or while working at any of the facilities that were near the release point immediately after the release has been stopped;

— the risk of debris (soil, vegetation, rocks) being thrown from a buried pipeline release;

— exposure to excessively high noise caused by the CO_2 escaping the pipeline release or a controlled blowdown;

— respiratory protection capabilities and types of respirators (supplied air respirators or SCBA) that should be used when entering an area with elevated levels of CO_2.

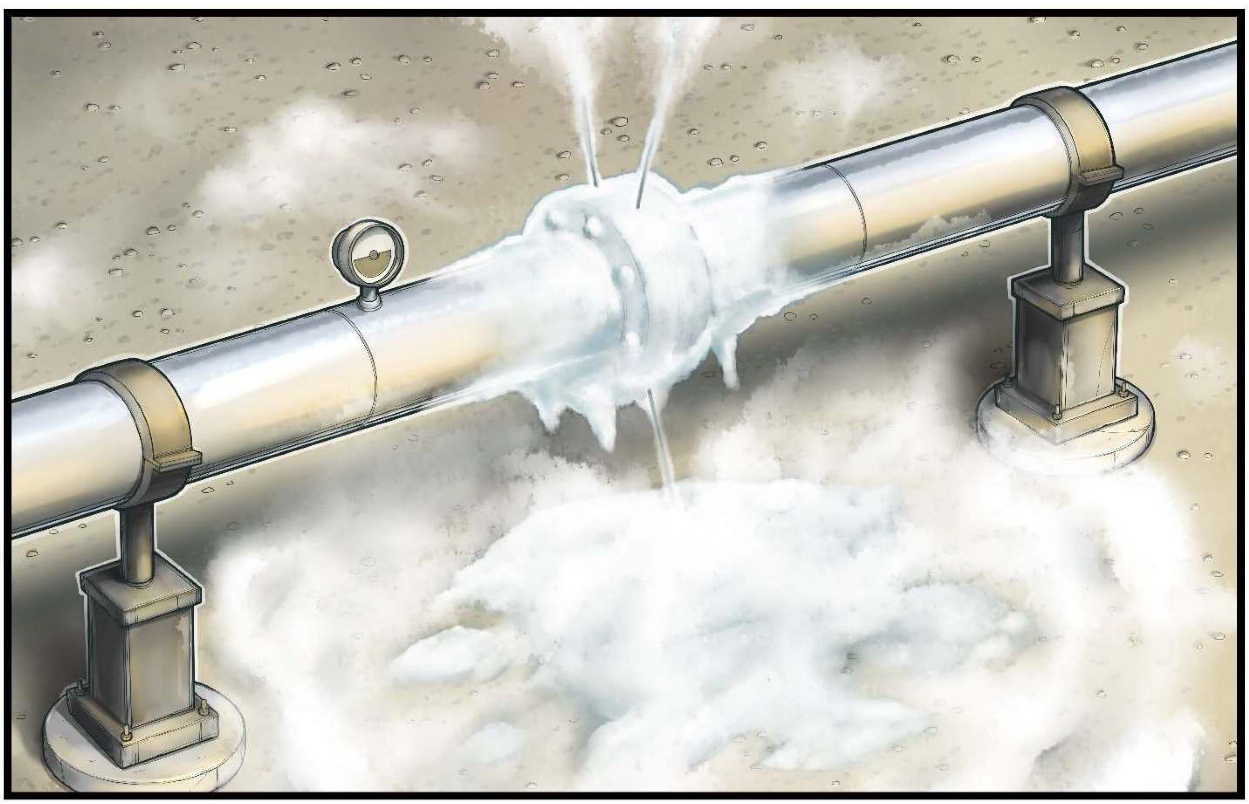

Figure 8—Icing of Flanges During a Release

Local emergency responders, especially in remote areas, may not have adequate equipment that would allow them to detect the concentrations of CO_2 or O_2 in the atmosphere. It is important for them to understand those limitations and not expose their responders to an atmosphere with elevated CO_2 concentrations or cause oxygen deprivation. If emergency responders have gas detectors, but they are not capable of reading CO_2, they should be educated to closely monitor O_2 levels when entering the hot zone. O_2 monitors will go into alarm mode at readings of 19.5%, but responders should be trained recognize decreasing O_2 levels and what actions are necessary (evacuation to fresh air or don SCBA) to protect themselves before exceeding the alarm threshold. Only properly trained and equipped responders should enter the hot zone.

Under certain conditions, pipeline CO_2 releases may create plumes extending thousands of feet that contain CO_2 concentrations greater than the STEL. It is important for emergency responders to understand the constraints of their respiratory protection equipment and how much time they have available to enter a hot zone while wearing a SCBA. Responders should allow enough time to enter and exit the hot zone without running out of supplied air.

The operator should also take steps to ensure the safety of their personnel responding to a CO_2 release. All personnel responding to a pipeline release should have the appropriate training to do so, as covered in 3.3. Operators should never allow personnel to enter an IDLH atmosphere alone. If personnel are to enter an IDLH atmosphere, they should have an adequate amount of supplied air, use the buddy system, and have rescue personnel on standby. All of the aforementioned safety precautions should also be taken.

The below table shows PPE that should be considered while responding to a pipeline release.

PPE	When Should It Be Used
Hard hat, safety glasses, and steel toe boots	While participating in any active response operations
Leather gloves	When contacting piping or valves in close proximity to the release*
Hearing protection (earmuffs or ear plugs)	When working near the pipeline release or controlled blowdown stack
Self-contained breathing apparatus (SCBA) or SAR	When entering an IDLH atmosphere or an atmosphere containing unknown levels of CO_2 or O_2
* Local emergency response officials (fire department, law enforcement, etc.) should never attempt to close a valve on a pipeline system, valve station, or facility.	

10.2 Isolation Strategies

The control and isolation of the pipeline is one of the highest priorities of any response to a pipeline failure. The longer the CO_2 is released, the more likely it is that high concentrations of CO_2, inside of the dense vapor plume, will migrate and impact the public. Dispersion modeling suggests that CO_2 will spread quickly following natural contours until it reaches an equilibrium and then will quickly disperse following the isolation of the pipeline. To prevent impact to the public, the means to limit the volume of the release should be established. These measures may include the following:

— installation of remote rupture mitigation valves near HCAs;

— improving response times to manually actuated isolation valves;

— providing power tools to pipeline operators that aid them to close manual valves quickly;

— installation of line break technology in areas that are more densely populated or susceptible to impact from a pipeline rupture.

Where remote isolation valves exist, establish protocols for verifying that remote valves have closed properly. These protocols provide field personnel with guidance on how and when to confirm closure of valves and provide pipeline controllers with methods of confirming that flow through the valve has ceased.

10.2.1 Controlled Venting or Blowdown

During a leak of the pipeline, it may be necessary to vent CO_2 from the pipeline in a controlled manner at a safe location. This can help bring the pipeline pressure down quicker and reduce the amount of CO_2 that may be releasing from the leak point, which could allow responders to access the release point to close a valve, assess damage, and/or minimize the duration of the release.

During controlled venting operations, the following procedure is recommended to safely vent the CO_2 from the pipeline system:

1) Select a location that will not impact the public (homes, roads, schools, etc.).

2) Avoid venting from locations near low areas such as creek crossings or heavily wooded areas, which prohibit the dispersion of CO_2 into the atmosphere.

3) As a courtesy, notify the local 911 dispatch center and emergency manager, and appropriate state agencies to make them aware of the venting operation and to discuss any questions they may have regarding the event.

4) During venting operations, minimize personnel on-site to only essential personnel.

5) Station air monitors capable of detecting oxygen and carbon dioxide levels in the atmosphere at the venting site. If oxygen levels below 19.5 % or CO_2 concentrations higher than 30,000 ppm are detected, personnel at the venting site must evacuate to fresh air immediately and the venting must cease.

6) When CO_2 is released from the pressurized pipeline into the atmosphere, the large associated pressure drop causes it to cool down dramatically (sub-freezing temperatures). Venting equipment should be designed to operate in extreme cold conditions.

7) Certain meteorological conditions (cool, humid, no wind) may limit the dispersion of CO_2 during venting. Every effort should be made to avoid controlled venting operations during these periods. In addition, understanding wind direction and how it may cause the plume to migrate is important so that it is not blown into a public area by the wind.

Controlled venting is typically not required on a pipeline rupture; however, it may be necessary for pipeline ruptures that have occurred on pipeline segments that have long distances between isolation valves or for releases that may have a smaller exit point.

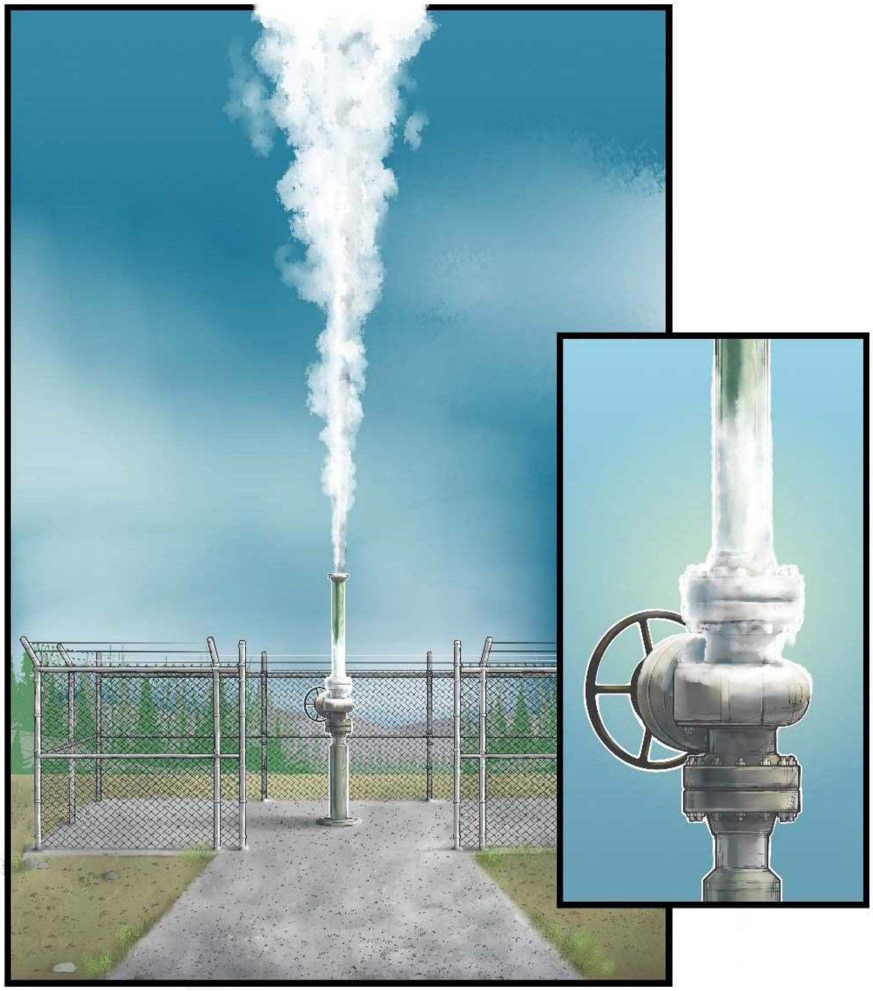

Figure 9—Controlled Venting Operations

10.2.2 Forced Air Displacement

When a pipeline release occurs, the dramatic change from pipeline pressure to atmospheric conditions will cause a white vapor cloud, which will reduce visibility at the leak point. When entering an atmosphere that exceeds an action level for respiratory protection, pipeline operators will have to don a SCBA; however, the reduction of visibility may prohibit responding pipeline operators from accessing an isolation valve or valve station. When this occurs, the use of forced air blowers, fans, etc., may be necessary to provide safe access to the site. This action is particularly effective for smaller releases such as flange or valve packing leaks that do not totally encompass the site with CO_2. Forced air displacement is not a viable option for most pipeline ruptures and large-scale releases of CO_2, particularly during nighttime hours, when dispersion is less likely to occur.

Figure 10—Forced Air Displacement Using a Trailer-mounted Fan

10.3 Real Time Plume Predictions and Surveillance

During a pipeline leak or rupture, the ability to predict the direction of the CO_2 plume will aid emergency responders in making key public safety decisions. Wind direction is the most common indicator of which direction the plume will travel. When winds are light, topography may influence the plume, carrying it down gradient or causing aggregation into low-lying channels.

During daylight hours, aerial surveys by plane or drones may also assist in predicting the travel of the CO_2 plume; pilots can provide real-time feedback and drones can capture pictures or video showing where the plume is going.

During nighttime hours, when aerial surveillance via plane or drones is not as feasible, real-time dispersion modeling may be useful in helping predict the plume direction and the possible concentrations of CO_2 inside the plume. However, real-time dispersion modeling may not be readily available during an event or take too long to process in order to provide emergency responders with timely data.

10.4 Air Monitoring Strategies

The operator should have and maintain contracts with third-party emergency response service providers such as oil spill removal organizations (OSROs), toxicologists, industrial hygienists, and environmental scientists that can provide assistance during a pipeline release. OSROs can help provide preliminary air monitoring results using handheld air monitoring devices that could aid in establishing hot and cold zones. They can also be used to assist in rescue efforts and provide supplied air bottles to fill the SCBAs of local emergency responders and/or the operator.

Due to the potential impact on the public, environmental health and toxicology service providers are extremely important in the response to the pipeline release. They can provide advanced remote air monitoring that will give the Unified Command information that could drive further response actions both at the incident site and in the impacted community. The third-party environmental health and toxicologist service providers can develop an air sampling and analysis plan to monitor hazards of a CO_2 pipeline release. In most cases, CO_2 and oxygen will be monitored during a pipeline release; however, some other analytes may also be included within the air sampling and analysis plan should the pipeline contain other potentially harmful contaminants. Monitoring will continue until results indicate that these analytes do not pose a health concern.

The air monitoring strategy typically consists of three broadly defined monitoring plans:

— work area monitoring;

— community monitoring; and

— site assessment.

Work area monitoring generally takes place in those areas where workers are actively performing/supporting remediation operations. The readings are to be taken at a height consistent with that of the workers' breathing zone and in close proximity to workers without interfering or obstructing their remediation tasks.

Community monitoring may take place in those residential and/or commercial locations immediately surrounding the incident site.

Unlike work area and community monitoring, site assessment does not necessarily represent ambient air monitoring near breathing zone level. Site assessment may involve a variety of different monitoring tasks intended to provide information that may help to delineate the nature and extent of the release (e.g., fence line monitoring, worst case determination, ground level, etc.).

Free-roaming handheld real-time air monitoring may also be conducted in a variety of areas based on levels of activity, proximity to the release, and site conditions. Portable fixed-location and/or handheld real-time locations may be established in the community in order to provide concentration averages that may be observed and analyzed over time in distinct geographic locations in the community. Portable fixed-detection systems may be utilized to monitor the scene from a remote location, if necessary.

Air Monitoring Techniques	
Procedure	**Description**
Real-time handheld survey	Staff members may utilize handheld instruments (e.g., colorimetric detector tubes) to measure airborne chemical concentrations. These handheld instruments will primarily be used to monitor the ambient air quality at breathing zone level. Additionally, measurements may be made at grade level, as well as in elevated workspaces, as indicated by chemical properties or site conditions. These techniques may also be used to verify detections observed by the network of portable fixed-detection systems.
Radio-telemetering network	A radio-telemetering network of fixed-detection systems may be deployed in locations where monitoring from a remote location would be beneficial. These instruments will relay readings back to a centralized location that is monitored by the third-party provider.
Fixed real-time monitoring locations	Multiple community locations may be identified and monitored at the same location approximately once per hour using handheld instruments. This allows the use of statistical analysis more effectively than with a random approach.

Most third-party environmental health and toxicology service providers have capabilities to collect ambient air samples, if necessary. These sampling methodologies may be utilized if the results from real-time air monitoring efforts indicate the potential for exposure above acceptable occupational or community exposure levels. These samples may be helpful in substantiating the impact on personnel or the public. After outdoor community CO_2 levels are sustained and continually measured below 5,000 ppm, initial indoor assessment real-time monitoring can be performed inside residences and other buildings potentially impacted by an incident, at the owners'/occupants' request. This confirmatory air monitoring allows the Unified Command to make decisions for safe return to homes and businesses following an evacuation.

10.5 Incident Management

With pre-determined emergency response procedures, including the isolation of upstream and downstream valves and adequate training and testing of their implementation, the public health threat of a CO_2 pipeline release will likely not exceed 24 hours. As such, the proactive incident management may not be able to be utilized. ICS should still be utilized by the incident commander with support from emergency response contractors and local first responders. Key components that ensure a successful response is carried out include the ability to operate within Unified Command with local, state, and federal agencies, the establishment of incident objectives, and the adoption of a site safety plan and incident action plan. Responding emergency response team members should focus on successful implementation of the stem on the Planning P (initial response), but still be prepared to progress through the entire planning process if the event lasts longer than expected (see below).

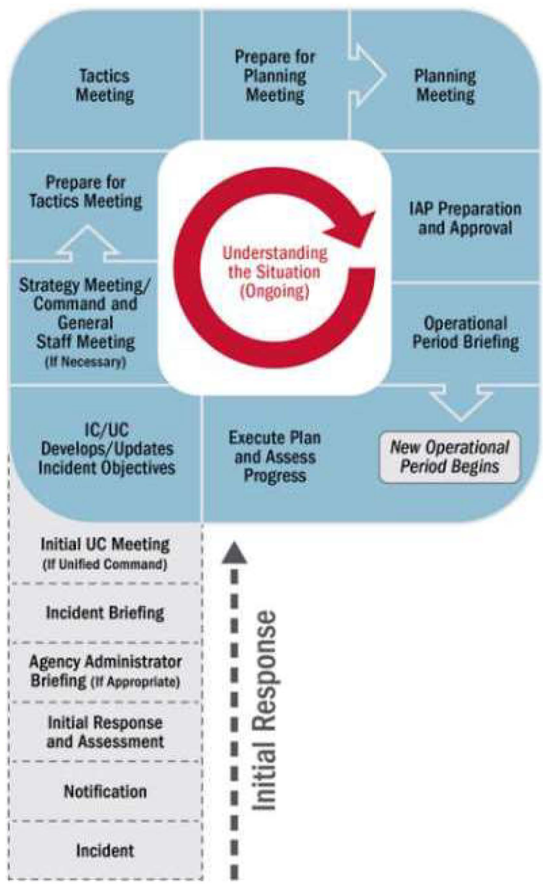

Figure 11—Planning P

Due to the anticipated short duration of a CO_2 pipeline-related incident, an off-site command post may not be established; instead, the command post will be established adjacent to the incident scene at a safe distance from known hazards, possibly on the tailgate of a truck or field office. Since much of the ICS documentation focuses on expanding events taking place over multiple operational periods, it may be beneficial to generate ICS forms that are able to be filled out quickly in the field by pipeline operators to document the objectives of Unified Command. One such method is to combine the components of the site safety plan the incident briefing form (ICS 201) into a singular document that allows for the critical components of the initial response to be identified, documented, and clearly communicated with response agencies and response personnel.

STATE OF NORTH DAKOTA
PUBLIC SERVICE COMMISSION

SCS Carbon Transport LLC
Midwest Carbon Express CO2 Project
Sitting Application

CASE NO. PU-22-391

CERTIFICATE OF SERVICE

I, the undersigned, being of legal age, hereby certify that a true and correct copy of the following:

1. Letter to S. Kahl forwarding documents for filing; and
2. Response of SCS Carbon Transport LLC to the Interrogatories and Requests for Production (Set 4) from Intervenors Represented by Knoll Leibel LLP and Jorde/Domina Law Group.

were, on May 23, 2024, filed with the North Dakota Public Service Commission and served electronically to the following:

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Dated this 23rd day of May, 2024.

FREDRIKSON & BYRON, P.A.

By: ______________________________

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