Carbon Dioxide (CO_2) Emergency Response Tactical Guidance Document

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

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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*
(correction made 8/15/2024 to change "40 CFR" to "49 CFR")

Additional Resources

— 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.

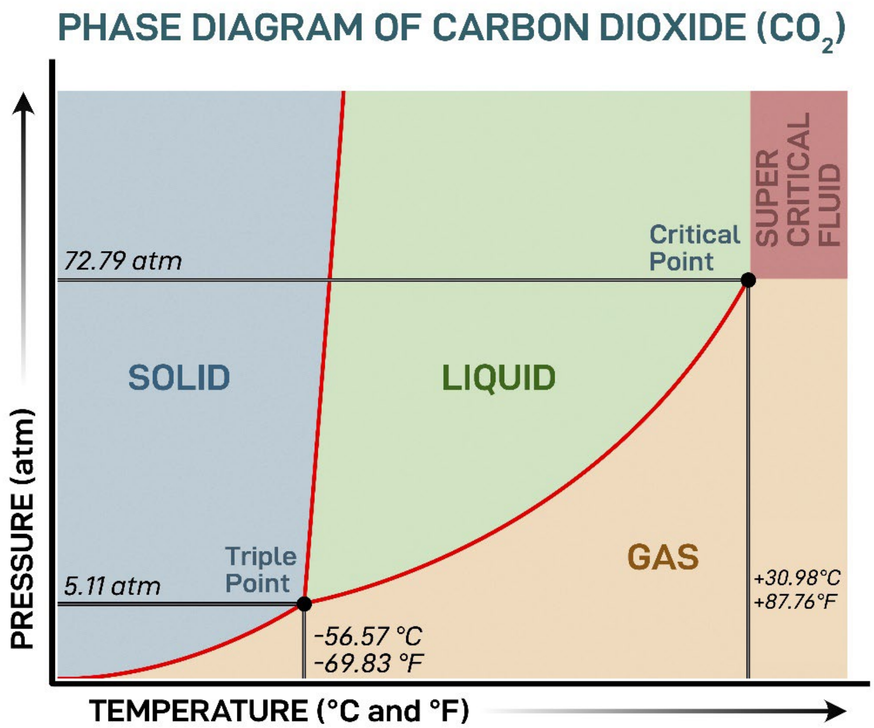

Figure 2—Phase Diagram of Carbon Dioxide

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 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 team (HAZMAT);

— excavator/contractor;

— 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, refer to API 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 and 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.

3.3 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:

[3] 49 CFR 195.452

[4] 49 CFR 195.446(h)(6)

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 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.

[5] 29 CFR 1910.120(q)
[6] 29 CFR 1910.120(q)(6)(I)

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 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.

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[7] 49 CFR 195.450 (Definitions) and 195.452

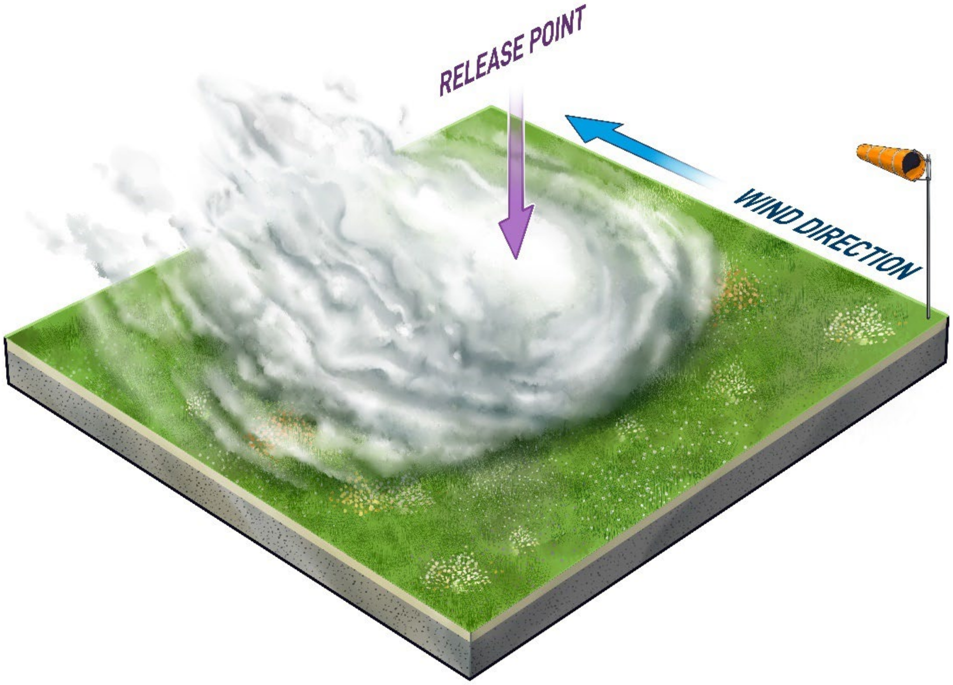

Figure 5—Transport and Dispersion of Released Carbon Dioxide on Flat Land

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.

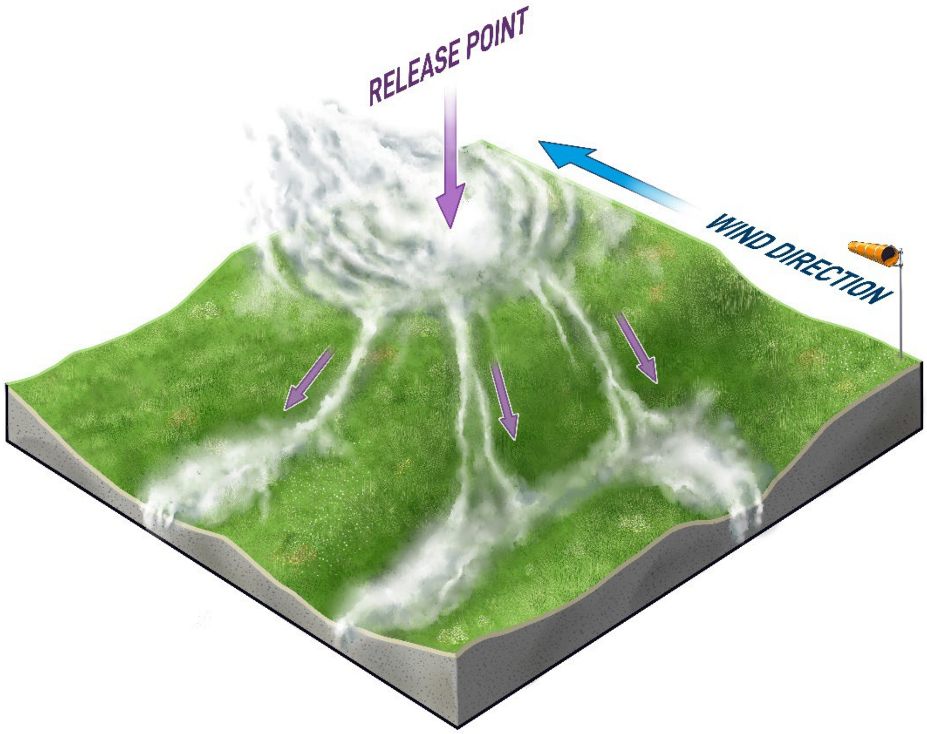

Figure 6—Transport and Dispersion of Released Carbon Dioxide with Topographical Features

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. 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;

— 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[9]:

— 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 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.

[9] 49 CFR 195.52

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.

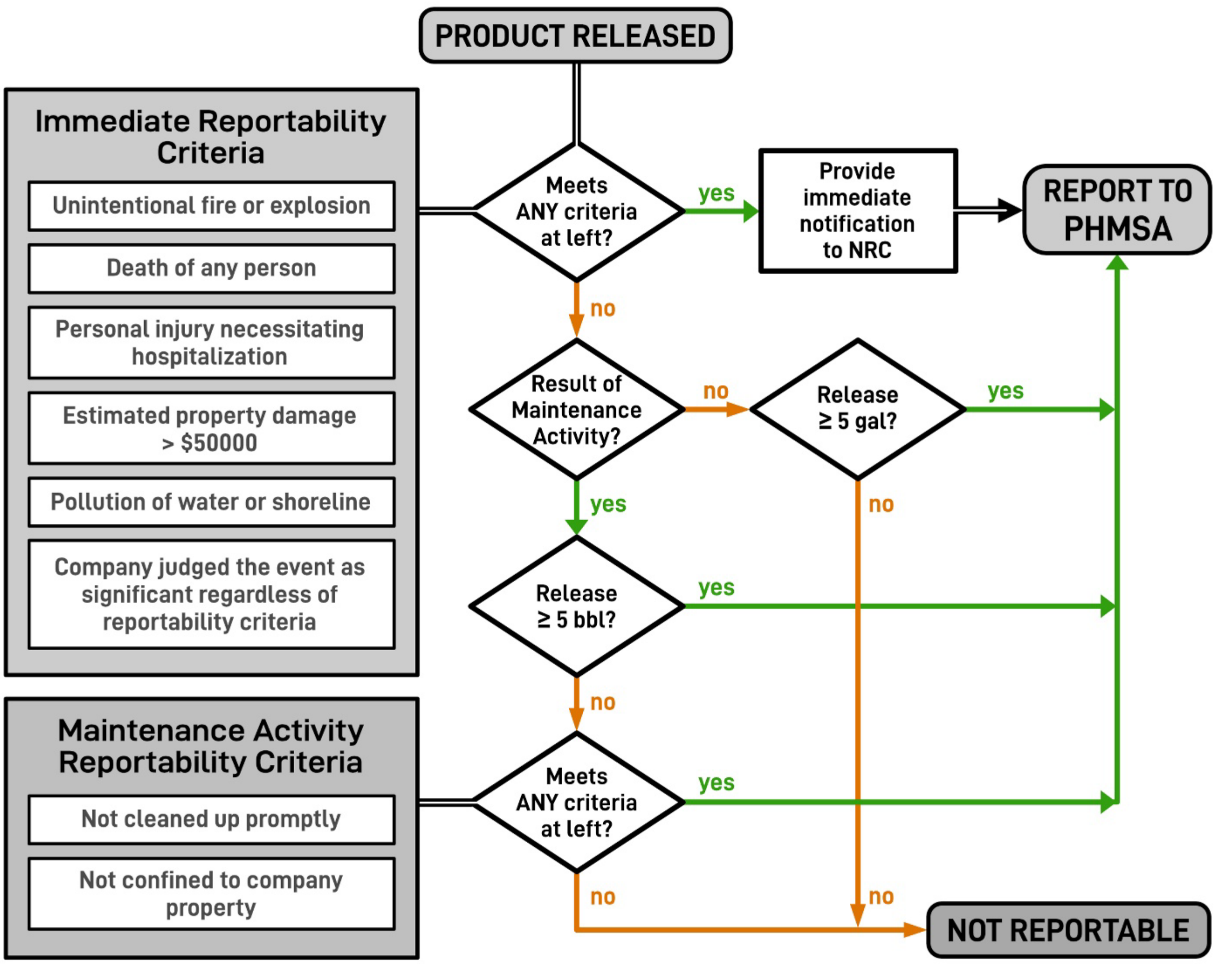

Figure 7—Incident Reporting Criteria

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 must 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[10] 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;

— stabilizing the incident;

[10] 40 CFR 195.402

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 planning 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.

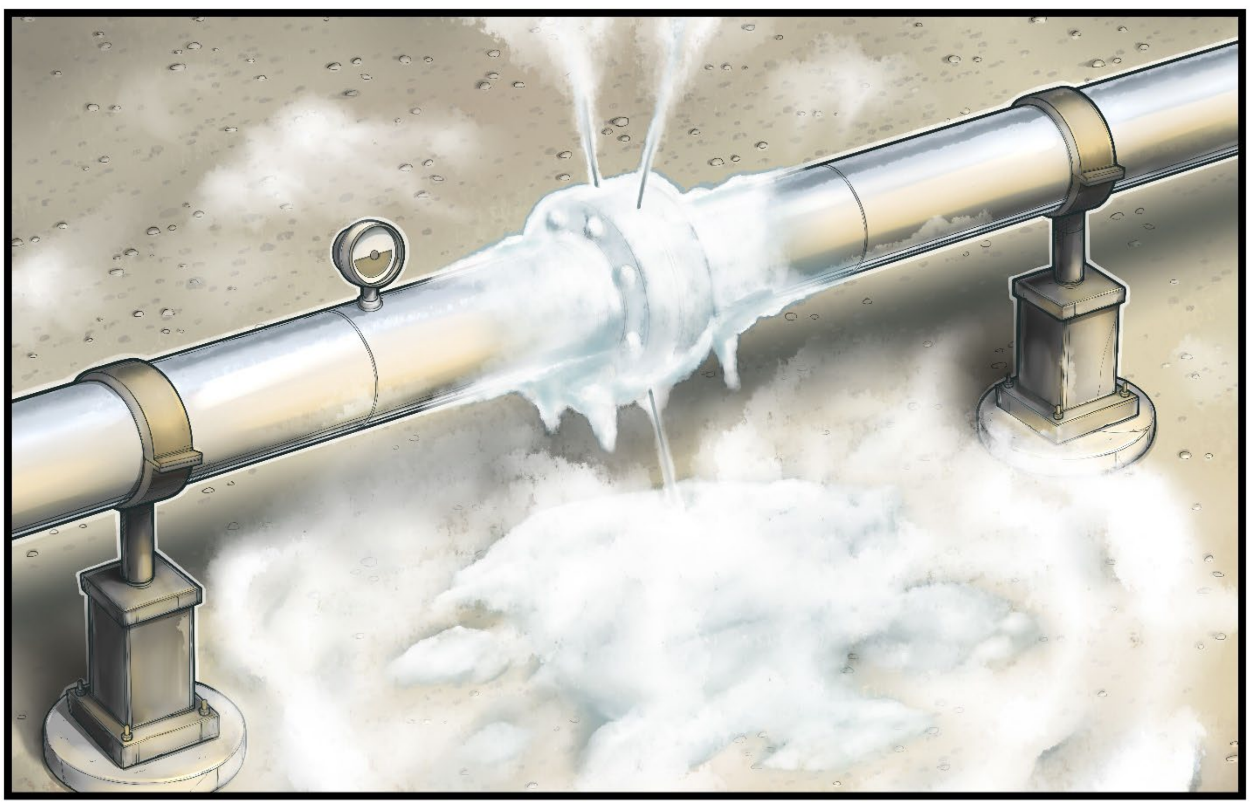

Figure 8—Icing of Flanges During a Release

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.

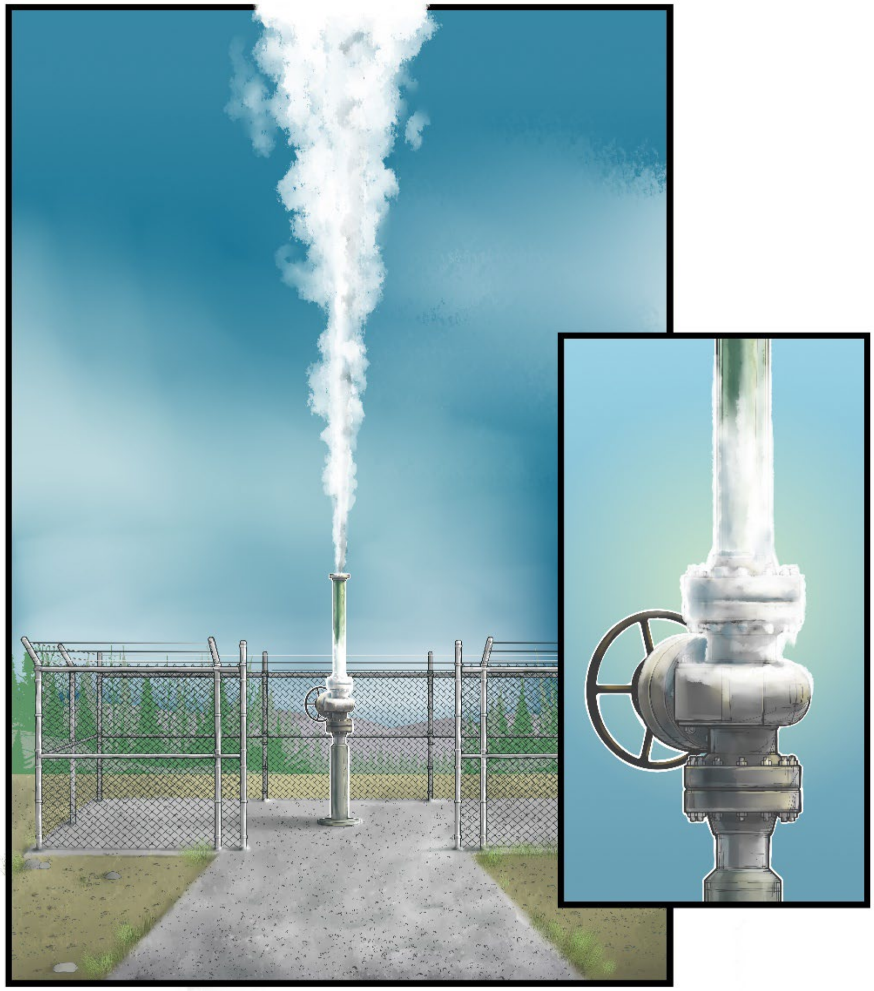

Figure 9—Controlled Venting Operations

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.

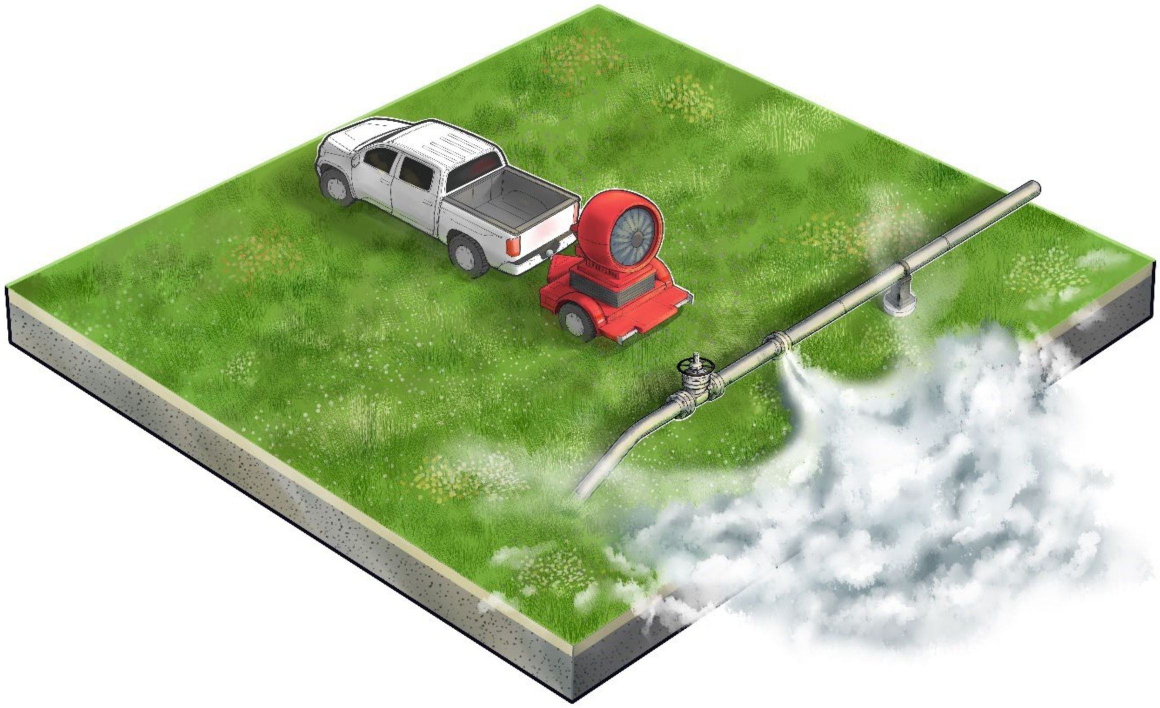

Figure 10—Forced Air Displacement Using a Trailer-mounted Fan

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).

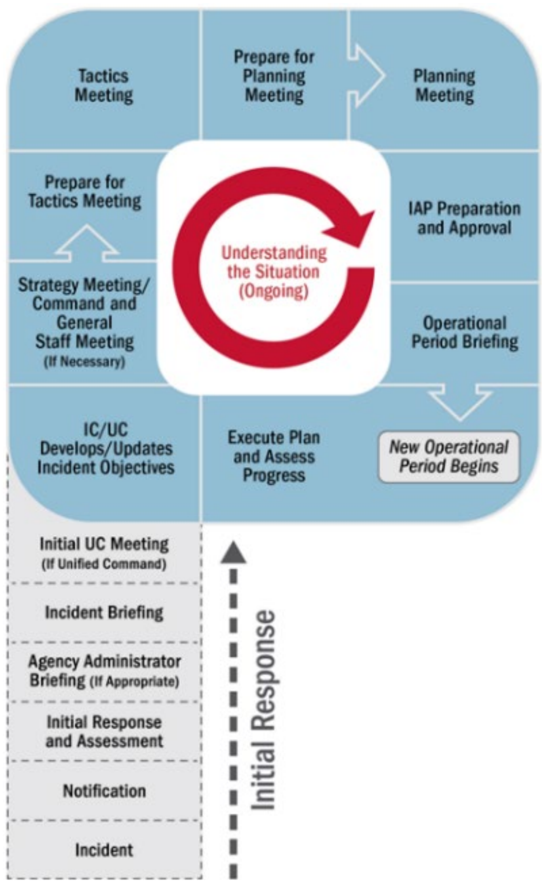

Figure 11—Planning P

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 and 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.