Appendix E

Carbon Dioxide Technical Report

APPENDIX E
CARBON DIOXIDE TECHNICAL REPORT
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1.0 INTRODUCTION

At least 90 percent of the carbon dioxide in the partially-treated syngas will be captured in a high-purity carbon dioxide stream during steady-state operation. It will be compressed and transported by pipeline off site for injection into deep underground oil reservoirs for enhanced oil recovery (EOR) and sequestration. Through the capture and sequestration of carbon dioxide, the Project will be meeting the state's objectives of producing baseload low-carbon power.

Currently, federal and state laws and regulations do not require modeling worst-case release scenarios for carbon dioxide (CO_2). Although not required, this analysis was performed to examine the potential risks associated with the worst-case release scenario in order to assess the possible consequences and implement appropriate safety systems to reduce the possibility of this remote event from occurring and to further reduce the potential hazard. This Appendix presents the Off-site Consequence Analysis (OCA) performed using the methodology prescribed under the California Accidental Release Prevention (CalARP) program and the federal Clean Air Act Risk Management Program (RMP).

2.0 MODELING

OCA modeling was performed to address the potential off-site impacts from a worst-case release scenario for carbon dioxide. The models provide an examination of the dispersion of carbon dioxide in the form of a vapor cloud. The modeling assumptions for a worst-case release scenario are that the total contents from the largest inventory (e.g., tank or pipe) are accidentally released into the atmosphere from a complete rupture of the vessel.

The models assumed worst-case atmospheric conditions during such a release, where applicable. These conditions provide conservative results, because these extreme and unlikely climatic conditions maximize the vaporization to create the vapor cloud and minimize its dispersion. For purposes of this analysis, the worst-case climate condition consists of an ambient temperature of 115 degrees Fahrenheit (ºF) (the highest average temperature in the Project area), a 50 percent average humidity, a 1.5 meter per second wind speed, and a level F atmospheric stability.

The following provides the specific modeling criteria, programs, and procedures applied for this analysis.

3.0 CARBON DIOXIDE

Carbon dioxide will be compressed and transported by pipeline off site for injection into deep underground oil reservoirs for EOR and sequestration. The pipeline will be transporting carbon dioxide from the Project Site through property owned by local oil producers to the custody transfer point. Carbon dioxide does not contain hazardous properties (i.e., toxicity, reactivity, flammability, or explosivity) that would result in classification as a hazardous material. Furthermore, because of the physical properties of carbon dioxide and the dissipation of carbon dioxide by ambient air, carbon dioxide concentrations rapidly decline in the event of a release. The following federal and state statutes and regulations were reviewed to determine whether or not carbon dioxide is a regulated substance:

- Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
- Superfund Amendments and Reauthorization Act (SARA)
- Emergency Planning and Community Right-To-Know Act of 1986
- Risk Management Program for Chemical Accidental Release Prevention
- California Accidental Release Prevention Program (Cal/ARP
- Title 22, California Code of Regulations, Section 66261.20 *et. seq*.

Although carbon dioxide is not a regulated hazardous material, an OCA was conducted to evaluate the potential impact area associated with a worst-case carbon dioxide release according to concentration levels of carbon dioxide established by the U.S. Occupational Safety & Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH). These concentrations are stated in terms of (1) Permissible Exposure Limit (PEL), (2) Threshold Limit Value (TLV), and (3) Short Term Exposure Limit (STEL). Both the PEL and TLV specify airborne concentration levels under which nearly all workers may be repeatedly exposed without potential adverse effects. The STEL represents the concentration to which workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, impaired judgment, or materially reduce work efficiency.

Exposure Limit for Carbon Dioxide	Concentration	Exposure Period
OSHA PEL	5,000 ppm	Time weighted average concentration for 8-hour work day
ACGIH TLV	5,000 ppm	Time weighted average concentration for normal 8-hour work day or 40-hour work week
OSHA STEL	30,000 ppm	Maximum concentration for 15 minute period (maximum of 4 periods per day with at least 60 minutes between exposure periods)

Notes:
ACGIH = American Conference of Governmental Industrial Hygienists
OSHA = Occupational Safety & Health Administration
PEL = Permissible Exposure Limit
ppm = parts per million
STEL = Short Term Exposure Limit
TLV = Threshold Limit Value

3.1 Carbon Dioxide Modeling

The extent of potential impact from the hypothetical worst-case release scenario evaluated was computed through the application of the U.S. Environmental Protection Agency (USEPA)-

approved Areal Locations of Hazardous Atmospheres (ALOHA) 5.4.1 air dispersion modeling program.

The modeling basis for the worst-case release scenario is a complete rupturing of the carbon dioxide pipeline under worst-case atmospheric and environmental conditions. The rupturing of the carbon dioxide pipeline is assumed to produce a 113 square-inch aperture (meaning a complete severing of the 12-inch diameter pipeline) through which carbon dioxide would escape. The atmospheric conditions modeled represent the least favorable conditions for the normal dissipation of a concentrated carbon dioxide release.

Modeling outputs derived from the use of the ALOHA 5.4.1 modeling program are provided in the results section of this document.

The modeling of the worst-case scenario demonstrated the following concentrations to be reached at the following distances during the release: (a) 5,000 parts per million (ppm) concentration level was presented at 5,280-feet, and (b) 30,000 ppm concentration was presented at 1,983-feet. These represent the maximum distances that these concentrations will reach during a worst-case scenario release, and the model demonstrates that the PEL or STEL will not be exceeded at or beyond the impact distances just noted. All points within these distances are within the controlled access area of the Project Site and the adjacent oil field. The model does not predict at what distance the PEL and STEL may be exceeded from the point of release up to the impact distances.

It is important to note that the ALOHA model does not simulate the PEL and STEL conditions. The ALOHA model provides an estimate for the maximum distance of dispersion for a peak concentration of a material during a set period of time (i.e., the time it takes to evacuate the entire process piping). The relevant standards (PEL and STEL) are based on specific time-weighted averaging times, whereas the ALOHA model predicts a peak concentration independent of a specific averaging time. Therefore, the model does not take into consideration the time factors during which an average concentration needs to be present in order to determine if the regulated PEL and STEL are met or exceeded.

Although the model shows the maximum distances at which certain peak concentrations will be present during a worst-case scenario release, the model demonstrates that the PEL or STEL will not be exceeded at or beyond the impact distances noted above. Conversely, the model does not predict at what distance the PEL and STEL may be exceeded from the point of release up to the impact distances noted above.

3.2 Mitigation Measures for the Carbon Dioxide Pipeline

The Project will incorporate mitigation measures to reasonably prevent and control the potential impacts of an accidental carbon dioxide release. Although very rare, accidents may result from third-party conduct, corrosion, or operator error. The Project will design, construct, operate, and maintain the carbon dioxide pipeline in accordance with applicable laws, ordinances, regulations, and standards (LORS). The following factors were considered in defining control and mitigation measures for pipeline safety:

- Pipeline Design Pressure and Temperature: The design pressure and temperature will be selected in accordance with prudent engineering practice and applicable LORS.

- Pipeline Routing: Pipeline route identification markers will be placed at regular intervals to identify the buried pipeline and the Project will comply with applicable regulatory requirements to reduce the likelihood of third-party damage. The entire pipeline route will be within the Project Site and adjacent oil fields, both of which have controlled access.
- Pipe Material Selection: The pipe will be constructed with steel that meets design criteria for operations internal pressures and external loads, and pressures anticipated for the pipeline system. The pipe will be constructed with materials in accordance with prudent engineering practice and applicable LORS.
- Internal-corrosion control: The Project will employ internal-corrosion control measures in accordance with prudent engineering practice and applicable LORS. An internal-corrosion inspection, monitoring, and assessment program will be established.
- Block Valves: Block-valves will be installed on the carbon dioxide pipeline to block-in the pipeline in the possibility of loss of integrity.
- Pipeline control: A Project control system will provide reliable and responsive controls to detect potential leaks. Real-time monitoring of key parameters, including pressure, temperature, and flow rate, enables timely intervention in the event of a release.

Industry experience to date demonstrates that carbon dioxide can be safely handled and stored, and suggests that the likelihood of an accidental release of carbon dioxide to be remote when proper handling procedures are being effectively applied. The implementation of appropriate prevention and control mitigation measures noted above will further reduce the likelihood and potential impact of an accidental pipeline release.

3.3 Carbon Dioxide Model Output

The ALOHA 5.4.1 air dispersion modeling program generated the following output:

SITE DATA:
Location: TUPMAN, CALIFORNIA
Building Air Exchanges Per Hour: 0.60 (unsheltered single storied)
Time: 1 July 2008 0703 hours PDT (using computer's clock)

CHEMICAL DATA:
Chemical Name: CARBON DIOXIDE - 2 Molecular Weight: 44.00 g/mol
Ambient Boiling Point: - 109.6° F
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 1.5 meters/second from se at 3 meters
Ground Roughness: open country Cloud Cover: 0 tenths
Air Temperature: 115°F
Stability Class: F (user override)
No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:
Non-flammable gas is escaping from pipe
Pipe Diameter: 12 inches Pipe Length: 13,200 feet
Unbroken end of the pipe is closed off
Pipe Roughness: smooth Hole Area: 113 sq in
Pipe Press: 2,814.7 psia Pipe Temperature: 115°F
Release Duration: 23 minutes
Max Average Sustained Release Rate: 86,900 pounds/min
(averaged over a minute or more)
Total Amount Released: 207,130 pounds

THREAT ZONE: (HEAVY GAS SELECTED)
Model Run: Heavy Gas
Orange: 661 yards --- (30,000 ppm)
Yellow: 1.0 miles --- (5,000 ppm)

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