

Environmental Assessment: Optimal Geological Environments for Carbon Dioxide Disposal in Brine Formations (Saline Aquifers) in the United States--Pilot Experiment in the Frio Formation, Houston Area

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Environmental Assessment

**Optimal Geological Environments for Carbon Dioxide Disposal in Brine Formations
(Saline Aquifers) in the United States—Pilot Experiment in the Frio Formation,
Houston Area**

Contract DE-AC26-98FT40417 Modification A008

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CONTENTS

1.0	Introduction.....	1
2.0	Purpose and Need for the Proposed Action	2
2.1	DOE's Purpose.....	2
2.2	DOE's Need for Action	3
2.3	DOE's Response	4
2.5	DOE's Decision	6
3.0	Alternatives, Including Proposed Action.....	7
3.1	Overview.....	7
3.2	Proposed Action.....	7
3.3	Overview and Project Plan.....	7
3.3.1	Preinjection Activities.....	9
3.3.2	Injection Activities.....	13
3.3.3	Postinjection Activities	15
3.4	Enabled Actions	16
3.5	Range of Reasonable Alternatives	16
3.5.1	The No-Action Alternative	17
4.0	Affected environment and the environmental consequences	18
4.1	Site Description.....	18
4.1.1	Field History	18
4.1.2	Surface Geology and Soils.....	19
4.1.2	Subsurface Geology	21
4.1.3	Groundwater	25
4.1.4	Climate.....	27
4.1.5	Access	27
4.1.5	Historical and Archeological Resources	28
4.1.6	Endangered Species	28
4.1.7	Flood Potential	28
4.1.8	Wetlands	29
4.2	Direct Effects	33
4.2.1	Surface Impacts.....	33
4.2.2	Subsurface Impacts	33
4.2.3	Potential Leakage Impacts	35
5.0	Regulatory Compliance	37
5.1	State Permitting Requirements	37
6.0	Cumulative and Indirect Effects and Long-Term Environmental Consequences	39
6.1	Direct Cumulative Effects.....	39
6.2	Indirect and Indirect-Cumulative Effects.....	40
6.2.1	Fate of Injected CO ₂	40
6.2.2	Postproject Well Disposition	45
6.2.3	Increase in Sequestration Activities in the Pilot Area	45
6.2.4	Increase in Domestic Sequestration Activities	45

7.0	Irreversible and Irretrievable Commitments of Resources	46
8.0	Environmental Consequences of the No- Action Alternative.....	47
9.0	Similar Actions and Actions Being Considered Under Other National Environmental Policy Act Reviews	48
10.0	Relationship of the Proposed Action to Applicable Federal, State, Regional, or Local Land Use Plans and Policies	49
11.0	Consultation and Public Participation.....	50
11.1	Consultation	50
	Agency contacted.....	50
11.2	Public Participation.....	51
	References.....	52
	APPENDIX A: MATERIAL SAFETY DATA SHEETS	
	APPENDIX B: AGENCY CONSULTATION CORRESPONDENCE.....	

Figures

1. Map of the southeast Texas coastal region	11
2. Aerial photograph of the area surrounding the project site.....	12
3. Photographs of planned project site	13
4. Map-view results of Tough2 numerical simulation	14
5. Map of oil and gas wells drilled in South Liberty field and surrounding area	19
6. Topographic map of the experiment site	20
7. Distribution of soil units at the experiment site	21
8. Type log from SGH #3	22
9. Structure-contour map of the southwest flank of the South Liberty salt dome	23
10. Detailed type log from SGH #3	24
11. Cross plot of residual gas saturation and porosity for 140 data points	25
12. Dip-oriented regional cross section through experiment site	26
13. Distribution of mapped wetland units at the experiment site	30
14. Representative photographs of upland vegetation assemblages from the experiment site and surroundings	31
15. Representative photographs of lowland vegetation assemblages near the experiment site	32
16. Numerical simulation model construction parameters for the “C” sand	41
17. CO ₂ saturation distributions around the injection well from 0.2 to 100 years after injection begins	42
18. CO ₂ saturation distributions around the injection well for low residual gas saturation case from 0.2 to 100 years after injection begins.....	43
19. CO ₂ saturation distributions in northeast-southwest section cross-sectional view of injection zone for low residual gas saturation case at 100 years after injection begins.....	43

Tables

1. Project team	6
2. Milestone description and work breakdown structure	8
3. Work sites and activities	9
4. Comparison of possible alternative actions	17
5. Tracer materials to be used and their concentrations	35
6. Agency and organization contacts	51

1.0 INTRODUCTION

This Environmental Assessment (EA) provides the results of an evaluation of the potential environmental consequences of a field experiment and of injection of CO₂ into a subsurface brine-bearing formation, a processes known as geologic sequestration. The U.S. Department of Energy (DOE) is proposing to fund this project to determine if geologic sequestration of CO₂ is safe and effective in reducing atmospheric releases, and if the sequestration process can be modeled, measured, and monitored. If approved, DOE would provide the \$3.4 million cost of the project.

This project was proposed by the Bureau of Economic Geology as Phase III of DOE-initiated competitive solicitation DE-RA26-98FT35008. Phase I and Phase II assessed the optimal geological environments for geologic sequestration in brine formations in the onshore U.S., and found that the upper Texas Gulf Coast was a regional with excellent potential for geologic sequestration. Phase III will test the Phase I and Phase II conclusions with a field experiment.

Increasing concentrations of CO₂ in the atmosphere are thought to have potential to force change toward a warmer global climate. These changes may have negative impacts on human systems as well as ecosystems. DOE is developing an understanding of the environmentally acceptable options

Geologic sequestration is one of the highly ranked technologies for stabilizing the amount of CO₂ released to the atmosphere as a waste from combustion of fossil fuel. In this method, CO₂ is captured from a stationary industrial source of CO₂, compressed, and injected into the subsurface. The injection site must be selected to have the geologic properties that will assure that the CO₂ will remain trapped in the subsurface and isolated from the atmosphere for thousands of years. The natural capacity of the subsurface to trap and retain buoyant fluids such as oil and natural gas is well known. Technologies for injection of fluids into the subsurface are widely applied both for waste disposal and for enhancing recovery of oil.

This field experiment is designed to closely monitor the performance of the subsurface in holding CO₂. To reduce risks, the injection is designed using the minimum volume of CO₂ that can be measured in the subsurface using a wide variety of techniques, and to be completed over a short period of time (less than 1 year). The results obtained from monitoring a small volume will provide assurance that in a similar geologic environment, a large volume can be safely and effectively injected and monitored over a longer time frame. Monitoring and modeling tools have been designed and will be tested at this site by researchers from Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), Lawrence Livermore National Laboratory (LLNL), and National Energy Technology Laboratory (NETL).

2.0 PURPOSE AND NEED FOR THE PROPOSED ACTION

2.1 DOE's Purpose

The concentration of carbon dioxide (CO₂) in the atmosphere has increased 17.4% over the past 60 years (Keeling and Whorf, 2002). The Intergovernmental Panel on Climate Change (2001) has concluded that these changes result principally from accumulation of anthropogenic CO₂ emitted to the atmosphere as a result of changing land use patterns and combustion of fossil fuels, such as coal, oil, and natural gas, to produce energy. Predictions of global energy use in the next century suggest that anthropogenic carbon emissions will continue to increase, resulting in continued rising atmospheric concentrations of CO₂ unless major changes are made in the way we produce and use energy (U.S. Department of Energy, 1999, p 1-1).

Uncertainty remains in predicting the effects of this change in composition of the atmosphere. However, there is significant risk that continued increase in atmospheric concentrations could force changes in global climate, which may have a variety of serious consequences (see U.S. Climate Change Science Program / U.S. Global Change Research [2003] <http://www.usgcrp.gov/usgcrp/nacc/education/default.htm> for regional summaries or the Intergovernmental Panel on Climate Change <http://www.ipcc.ch/> [2003]).

DOE has prepared several documents that consider U.S. energy policy and the options that can be evaluated in response to concerns over the impact of anthropogenic CO₂ releases on climate change. The National Energy Policy Development Group (2001) considered a broad spectrum of energy issues, and in chapter 3 (Protecting America's Environment) states that "Industry and the federal government are researching various new technologies that will reduce greenhouse gas emissions or sequester those emissions, in geologic formations, oceans, and elsewhere." The U.S. Department of Energy (1999) document "Carbon Sequestration" provides a detailed assessment of the role of carbon sequestration in reducing anthropogenic CO₂ emissions. Three categories of technologically driven solutions are proposed: (1) energy conservation and efficiency; (2) substituting lower carbon or carbon-free energy sources for current sources, for example switching to renewable energy sources, nuclear power, and low-carbon fuels; and (3) carbon sequestration, which removes CO₂ from combustion emissions and stores it directly underground or in the deep ocean or indirectly by enhanced uptake by soils, vegetation, and the oceans.

The purpose of the proposed action is to rigorously test the application of the third proposed technological solution, carbon sequestration, within a geologic formation. This test is a key component needed to increase scientific understanding of carbon sequestration to assure that this option is an effective method for reducing atmospheric concentrations of CO₂.

2.2 DOE's Need for Action

“The vision for the road map is to possess the scientific understanding of carbon sequestration and develop to the point of deployment those options that insure environmentally acceptable sequestration to reduce anthropogenic CO₂ emissions and/or atmospheric concentrations. The goal is to have the potential to sequester a significant fraction of the 1 Gt/year in 2025 and 4 Gt/year in 2050” (U.S. Department of Energy, 1999, p.1-1).

One option that has the potential to achieve DOE's goal is sequestration of CO₂ in geologic formations, such as oil and gas fields, coal beds, and porous brine-bearing formations (U.S. Department of Energy, 1999, p.5-1). Decades of reservoir characterization experience gained by U.S. industries in understanding the performance of the subsurface in containing gases and fluids help make geologic sequestration an attractive option. The ability of the subsurface to store oil and gas for geologically significant periods is well known, lending credibility to the concept that injected CO₂, which will be buoyant like oil and natural gas in most geological environments, could be sequestered for long periods (Hitchon, 1996). Technologies for introducing gas and fluids to the subsurface are also mature. For decades oil producers have injected CO₂ into oil reservoirs to act as a solvent and to enhance oil recovery (EOR), a process known as CO₂ EOR. In many parts of the U.S., surface water is protected from contamination by disposal of waste fluids into the subsurface. A permitting process, Underground Injection Control (UIC), assures the public that the disposal occurs in deep subsurface formations that are below and hydrologically isolated from potable water. CO₂ is already being sequestered geologically offshore in the North Sea, where approximately one million tonnes of CO₂ are stripped from natural gas and reinjected into the subsurface annually to prevent release to the atmosphere (U.S. Department of Energy, 1999, p. 5-2).

Although the processes of geologic sequestration are relatively well known, additional research is needed to fill gaps in our scientific understanding of carbon sequestration and to develop stakeholder experience with the process so that the technology is ready for deployment. Extensive laboratory and modeling studies have been completed to assess how CO₂ geologic sequestration would work in the subsurface (for example, Hitchon, 1996; U.S. Department of Energy, 1999). Comparing predictions from bench scale tests and numerical models with field results is necessary to validate the models and demonstrate that scientific understanding is correct.

Extensive experience with CO₂ injection for EOR is inadequate for this validation because the fate of the injected CO₂ is not quantified. CO₂ injected for EOR can be sorbed in the oil, held by capillary forces in pore space, trapped by buoyancy forces in stratigraphic or structural compartments, dissolved in pore water, produced and reused, or leaked from the injection zone. The absence of accounting for CO₂ fate in the complex EOR system leaves a gap in scientific understanding. It is generally assumed, but has never been demonstrated, that leakage of CO₂ from the injection zone is small relative to the other fates.

Another significant experience gap between EOR and the validation needed for full-scale CO₂ sequestration is the type of host rock. Hovorka and others (2000) (<http://www.beg.utexas.edu/environqlty/co2seq/dispslsaln.htm>) inventoried 21 geologic formations in the onshore U.S. that might serve as host injection intervals for CO₂ and

identified areas where these formations are near numerous and large CO₂ sources. Geologic formations that could most easily receive and retain the large volumes of CO₂ (1 to 4 Gt/year) are thick, porous, and permeable sandstones. Such sandstones underlie CO₂ sources on much of the Gulf of Mexico coast. Unfortunately, most experience with EOR is in lower permeability carbonate rocks in the interior basins distant from most anthropogenic sources. In the North Sea, CO₂ is injected into a thick, porous, and permeable sandstone, but it is not feasible to closely observe reservoir performance and CO₂ fate here because it is in an offshore setting where monitoring wells are not an economic possibility.

A third significant experience gap is in the process of permitting an injection well for CO₂ sequestration. Commercial and industrial disposal wells are commonly located at sites vertically or laterally isolated from hydrocarbon reservoirs and aquifers. All wells in the cone of influence are required to be properly completed or plugged to ensure that they will not leak. In contrast, CO₂ injection wells for EOR are located within producing oilfields and are intended to increase production at as many wells as possible. Regulators need to develop processes and gain experience with combined-objective projects—CO₂ beneficial use plus CO₂ disposal. This new approach requires development of methods needed to assure stakeholders that CO₂ injected for dual purposes is retained in the subsurface and that the beneficial uses of enhanced production are safely achieved.

To address these experience gaps, we are proposing a field experiment in a high-porosity, high-permeability formation similar to those that could eventually be used to sequester large volumes of CO₂. This project will be onshore, so that it can be closely monitored to determine whether the CO₂ remains within the injection zone and so that scientific understanding can be maximized. The demonstration will be done at a small scale to (1) pioneer the permitting process, (2) ensure that health and safety and environmental risks are minimized, (3) minimize costs during this phase before stakeholders are ready for full scale deployment, and (4) obtain results quickly so that experience can be used in moving to larger scale pilots. The pilot location is ideal because the subsurface conditions are as simple as possible, maximizing the chances of matching numerical model results with field observations.

2.3 DOE's Response

A team lead by the Bureau of Economic Geology at The University of Texas at Austin proposes to conduct a well-monitored, small-scale, short-duration CO₂ injection into brine-bearing sandstone of the Frio Formation in the Gulf Coast of Texas. The site is within the South Liberty oilfield, where extensive existing geotechnical data are available, and can be used to model and predict the expected behavior of the injected CO₂. Use of existing infrastructure and location within an operating field will minimize both cost and environmental impact. This site was proposed as Phase III of DOE-initiated competitive solicitation DE-RA26-98FT35008. Phase I and Phase II assessed the optimal geological environments for geologic sequestration in brine formations in the onshore U.S. (Hovorka and others, 2000). The Frio Formation along the upper Texas Gulf Coast was identified as an area where (a) large volume sequestration is needed because of the concentration of a variety of CO₂ sources and (b) it is feasible owing to the presence of a thick widespread high-permeability formation ideal for sequestration. The project team (table 1) has identified the following objectives for the injection experiment:

- Demonstrate that CO₂ can be injected into a saline formation without adverse health, safety, or environmental effects;
- Determine the subsurface location and distribution of the CO₂ cloud;
- Demonstrate understanding of conceptual models;
- Demonstrate field-test monitoring methods developed by national laboratories; and
- Develop experience necessary for success of large-scale CO₂ injection experiments.

A small-scale injection pilot in a brine-bearing interval of the high-permeability Frio Formation was proposed and is now being planned. The project team is diverse, consisting of staff at a State geologic survey, four national laboratories, a nonprofit Canadian research company, a small independent oil and gas producer, a major oil and gas producer and refiner, a large oilfield service company, and experts in the fields of deep subsurface waste disposal and EOR operation (table 1). This group includes geologists, geophysicists, and engineers experienced in detailed subsurface characterization and numerical description as well as in waste-isolation projects; experts in geochemical tracer testing; specialists in numerical modeling of CO₂ subsurface behavior and flow simulation; engineers and petrophysicists experienced in well drilling, completion, logging, and log interpretation; and geophysicists experienced in seismic and other geophysical methods of detection of CO₂.

The pilot project will inject 3,750 tons (2 million m³ or 71.2 million ft³) of CO₂ into a brine-bearing Frio sandstone at a depth of about 1,500 m (5,000 ft). The site is within an existing oilfield on the flank of a salt dome approximately 56 km (35 mi) northeast of Houston, Texas. Other nearby land uses include timber production and sparse rural residences, although no dwellings lie within a 0.5-km (0.3-mi) radius of the site. The injection interval has been characterized using numerous existing geophysical well logs and a 3-D seismic survey. Engineering plans for injection and monitoring activities have been completed. A numerical simulation model created by LBNL allows prediction of subsurface results for planning purposes. Baseline surface and subsurface seismic and geochemical surveys will be completed before injection; repeat surveys will be completed during and after injection to monitor CO₂ distribution, and the integrity of structural and stratigraphic seals of the injection interval will be assessed.

Proposed activities are consistent with current land use. No endangered species occur in the study area, and no known archeological sites are located within the study area. Direct impacts include (1) clearing of as much as 2 hectares (5 acres) of upland habitat for minor expansion of the well pad and clearing of narrow pathways to allow truck-mounted drilling-rig access for the 66 seismic shot holes and 3 shallow groundwater monitoring wells; (2) transporting of 75 truckloads of CO₂ over 79.2 km (49.1 mi) of public roads through commercial, industrial, and rural areas; and (3) transporting of 30 truckloads of produced brine and 60 truckloads of drilling mud less than 32 km (<20 mi) over mostly rural roads to permitted disposal wells. Modeling studies suggest that the injected CO₂ is likely to stay within the injection zone and migrate less than 200 m (<656 ft) from the injection well. Subsurface pressure increases under maximum injection rate scenarios are expected on the basis of modeling to be 35% below fracture-pressure limitations and 22% below pressures that might result in reactivation of nearby growth faults. Monitoring of formation pressure, temperature, and

near-well-bore CO₂ saturation will continue until changes become minimal, indicating significant stabilization of the subsurface physical environment. This stabilization is anticipated to occur less than 1 year after the end of injection.

Table 1. Project team.

Participant	Responsibility	Objective(s)
Bureau of Economic Geology (BEG), The University of Texas at Austin	Prime contractor. Coordination and reporting of all activities. Subsurface characterization.	Improve understanding of subsurface behavior and fate of injected CO ₂ .
Texas American Resources Company (TARC)	Operator of existing well and lessee of subsurface minerals.	Facilitate demonstration of additional uses for mature oil and gas fields.
Lawrence Berkeley National Laboratory (LBNL)	Model-predicted subsurface results. Seismic monitoring. Pressure transient testing. Noble gas tracer modeling and monitoring.	Optimize flow-modeling software for geologic sequestration. Demonstrate use of seismic to monitor CO ₂ plume.
Lawrence Livermore National Laboratory (LLNL)	Tracer geochemical modeling.	Demonstrate use of tracers in monitoring of CO ₂ migration.
Oak Ridge National Laboratory (ORNL)	Tracer tests. Stable isotope and perfluorocarbon geochemistry.	Demonstrate use of introduced tracers and naturally occurring isotopes in monitoring of CO ₂ migration.
National Energy Technology Laboratory (NETL)	Perfluorocarbon tracer geochemistry, surface monitoring.	Demonstrate use of tracers in monitoring of CO ₂ migration.
Alberta Research Council (ARC)	Geochemical sampling plan.	Advise on basis of past subsurface experience.
Sandia Technologies, LLC	Field-services engineering, safety, oversight, and coordination.	Apply experience in deep injection of wastes to CO ₂ sequestration.
W.A. Flanders, Transpetco Engineering of the Southwest, Inc.	Injection: engineering and oversight.	Apply CO ₂ EOR engineering to sequestration projects.
BP	Industry advisor. Supplier of CO ₂ from Texas City refinery through Praxair.	Advise on the basis of CCP JIP experience. Explore sequestration options.
Schlumberger	Industry sponsor.	Support sequestration projects and apply completion and logging techniques to sequestration.
U.S. Department of Energy, National Energy Technology Laboratory (NETL)	Project sponsor.	Demonstrate technologies for safe and effective geologic sequestration.

2.5 DOE's Decision

The decision to be made by DOE is whether to commit 100% of the \$2,509,215 required to conduct the field experiment activities of the “Optimal Geological Environments for Carbon Dioxide Disposal in Brine Formations (Saline Aquifers) in the United States—Pilot Experiment in the Frio Formation, Houston Area” project in Liberty County, Texas.

3.0 ALTERNATIVES, INCLUDING PROPOSED ACTION

3.1 Overview

DOE's need for a comprehensively monitored CO₂ injection experiment could be satisfied in several ways, one of which—the proposed action—is preferable. The proposed activity is set in an oilfield, where drilling and other subsurface activities have occurred for many decades and which are familiar to the community, where well-work-over and maintenance companies are headquartered, where a mature oilfield setting provides abundant subsurface data, and where many well bores are idle and, thus, potentially available for injection or monitoring activities. The short duration (less than 1 year) of field activities will minimally impact the environment and community but will return maximum amounts of scientific data needed to assess the feasibility of geologic sequestration.

Alternatives to the proposed action include: (1) conducting the same experiment at another field site in the same sedimentary basin, (2) conducting the experiment in another geographic area (different sedimentary basin), and (3) conducting the experiment in an oil- or gas-bearing interval. All are reasonable alternatives, but for various reasons are less attractive from an operational, scientific, or long-term DOE need perspective.

3.2 Proposed Action

The proposed action is for the U.S. Department of Energy (DOE) to provide funding to the team led by the Texas Bureau of Economic Geology (BEG) at the University of Texas at Austin to prepare the site, modify two existing wells, drill a new injection well, conduct preinjection baseline monitoring and testing using numerous tools, inject 3750 metric tons of CO₂ over a period of less than 60 days, conduct numerous monitoring activities during and after the injection, monitor until subsurface conditions begin to stabilize (expected within nine months of injection), and close and restore the site. The entire project will be completed in two years.

3.3 Overview and Project Plan

The bulk of the time associated with the 2-year-long proposed action will consist of office activities such as geologic interpretation, engineering design, procedure planning, post-experiment analysis, and publication and presentation of results. Minimal time, amounting to perhaps 7 months, will consist of field activities with potential environmental and social impacts, followed by low-impact monitoring activities. Table 2 provides a milestone description, work breakdown structure, and timeline for the experiment. The timeline is based upon completion of NEPA review during May 2003 and depends upon State regulatory approval, CO₂ availability, favorable weather, and drilling-rig availability. Site characterization and planning began in 2002. Review by two State agencies, the Railroad Commission of Texas (RRC—petroleum resource protection) and the Texas Commission on Environmental Quality (TCEQ—groundwater

protection, engineering review) will commence in the first months of 2003, and field activities will begin in May 2003. Two existing wells will be modified as monitoring wells and a new injection well will be drilled during the summer of 2003. The injection event will occur in a window between October 2003 and December 2003, with exact timing dependent upon seasonal availability of compressed food-grade CO₂ and other logistical considerations. Postinjection tests, analyses, and synthesis of results will continue through June 2004. Documentation and presentation of project results will begin in May 2004. The project is scheduled to be completed in September 2004. Site closure and restoration could begin as early as January 2004 and will be completed by September 2004.

Table 2. Milestone description and work breakdown structure.

Description*	Initiation date**	Completion date**
Task 1 – NEPA Review, Approval, and Permitting		
1. Prepare and submit Environmental Assessment	9/2002	4/2003
2. Prepare and submit UIC Class V application to TCEQ	2/2003	5/2003
3. Secure NEPA review and approval	4/2003	5/2003
4. Secure TCEQ review and approval	5/2003	6/2003
Task 2 – Pre-Field Mobilization Characterization		
1. Conduct geologic characterization of field site	3/2002	8/2002
2. Design geochemical sampling and tracer programs	6/2002	3/2003
3. Computer-simulate CO ₂ subsurface behavior	6/2002	3/2003
4. Design geophysical monitoring program	6/2002	3/2003
5. Design optimal field procedure and engineering plans	6/2002	3/2003
6. Develop safety plan and training schedule	4/2003	5/2003
Task 3 – Preinjection Field Activities		
1. Prepare site	6/2003	7/2003
2. Prepare monitor wells	6/2003	7/2003
3. Drill and complete injection well	6/2003	7/2003
4. Conduct baseline geophysical survey, fluid sampling	7/2003	7/2003
5. Conduct pressure-transient test	7/2003	9/2003
Task 4 – CO₂ Injection Experiment		
1. Implement safety plan	7/2003	7/2003
2. Install CO ₂ storage and injection equipment	9/2003	10/2003
3. Inject CO ₂	10/2003	12/2003
4. Perform postinjection testing	1/2004	9/2004
5. Analyze and interpret results	1/2004	4/2004
6. Site closure and restoration	1/2004	9/2004
6. Synthesize observations and results	4/2004	6/2004
7. Project final reporting and technology transfer	5/2004	9/2004
* Tasks condensed from contract modification A008		
** Tentative dates, based on start of field activities in June 2003, contingent upon completion of the NEPA review, State regulatory approval, CO ₂ availability, weather conditions, and rig availability.		

3.3.1 Preinjection Activities

Analysis of geologic and geophysical data acquired to characterize the site will be conducted at the Bureau of Economic Geology (BEG) in Austin, Texas (table 3). Activities include literature review, computer workstation use, and limited transportation to and from offices of team members and the field site. Geochemical tracer design, geophysical monitoring design, simulation of CO₂ subsurface behavior, and field planning/engineering design will require similar activities at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee; Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California; Lawrence Livermore National Laboratory (LLNL) in Livermore, California; National Energy Technology Laboratory (NETL) in Pittsburgh, Pennsylvania and Morgantown West Virginia; Alberta Research Council (ARC) in Calgary, Alberta, Canada; and Sandia Technologies, LLC in Houston, Texas. Project planning, data collection, engineering design, and administrative support will take place in Texas American Resources Company offices in Austin and Houston, Texas. Log engineering design and data interpretation will occur in the Ridgefield, Connecticut, offices of Schlumberger-Doll Research. Field-support services (well logging) will originate from the Schlumberger Oilfield Services office in Liberty, Texas, approximately 11.25 km (7 mi) from the field site. BEG's Houston Core Research Center (1611 West Little York Road, Houston, Texas) will serve as a nearby facility during field activities for office work and staging/handling of geochemical samples. BP project advisors will be located in Houston, Texas. The project will be managed from DOE National Energy Technology laboratory (NETL) offices in Pittsburgh, Pennsylvania, or Morgantown, West Virginia.

Table 3. Work sites and activities.

Location	Team member	Activity
Dayton, Texas	All	Field activities
Austin, Texas	Bureau of Economic Geology	Office activities
Berkeley, California	Lawrence Berkeley N.L.	Office activities
Livermore, California	Lawrence Livermore N.L.	Office activities
Oak Ridge, Tennessee	Oak Ridge N.L.	Office and laboratory activities
Houston, Texas	Sandia Technologies, LLC	Office activities
Houston, Texas	Bureau of Economic Geology, Houston Core Research Center	Office and laboratory activities
Austin and Houston, Texas	Texas American Resources Company	Office activities
Calgary, Alberta, Canada	Alberta Research Council	Office activities
Ridgefield, Connecticut	Schlumberger-Doll Research	Office activities
Liberty, Texas	Schlumberger Oilfield Services	Office and laboratory activities
Houston, Texas	BP	Office activities
Pittsburgh, Pennsylvania, or Morgantown, West Virginia	NETL	Office and laboratory activities
Texas City, Texas	BP, Praxair	Refinery and gas processing

The field site is located in Liberty County, Texas, about 56 km (35 mi) northeast of Houston (fig. 1), near the town of Dayton. The site lies on a 30 m × 30 m (100 ft × 100 ft) clearing within a low-relief upland area dominated by small deciduous trees and is 400 m (1,312 ft) west of wetlands of the Trinity River floodplain margin (figs. 2, 3). The area has been an active oilfield from 1951 to present and is sparsely populated. Residential

neighborhoods have been developed over the past 2 decades to the north, southwest, and south of the site (fig. 2), but no residences lie within 0.5 km (0.3 mi) of the site. Approximately 250 land blocks within 2 km (3.2 mi) of the site are platted for residences. Intermittent logging has occurred in the vicinity for decades; an idle lumber mill lies about 0.4 km (0.25 mi) north of the site. The area west of highway FM 1409 (fig. 2) is primarily agricultural. The project will impact less than 2 additional hectares (5 acres) within an oilfield where oil and gas activities have impacted 6,980 hectares (17,280 acres). State and Federal records indicate no known archeological sites or endangered species at or near the site. Groundwater is within a few meters of the ground surface.

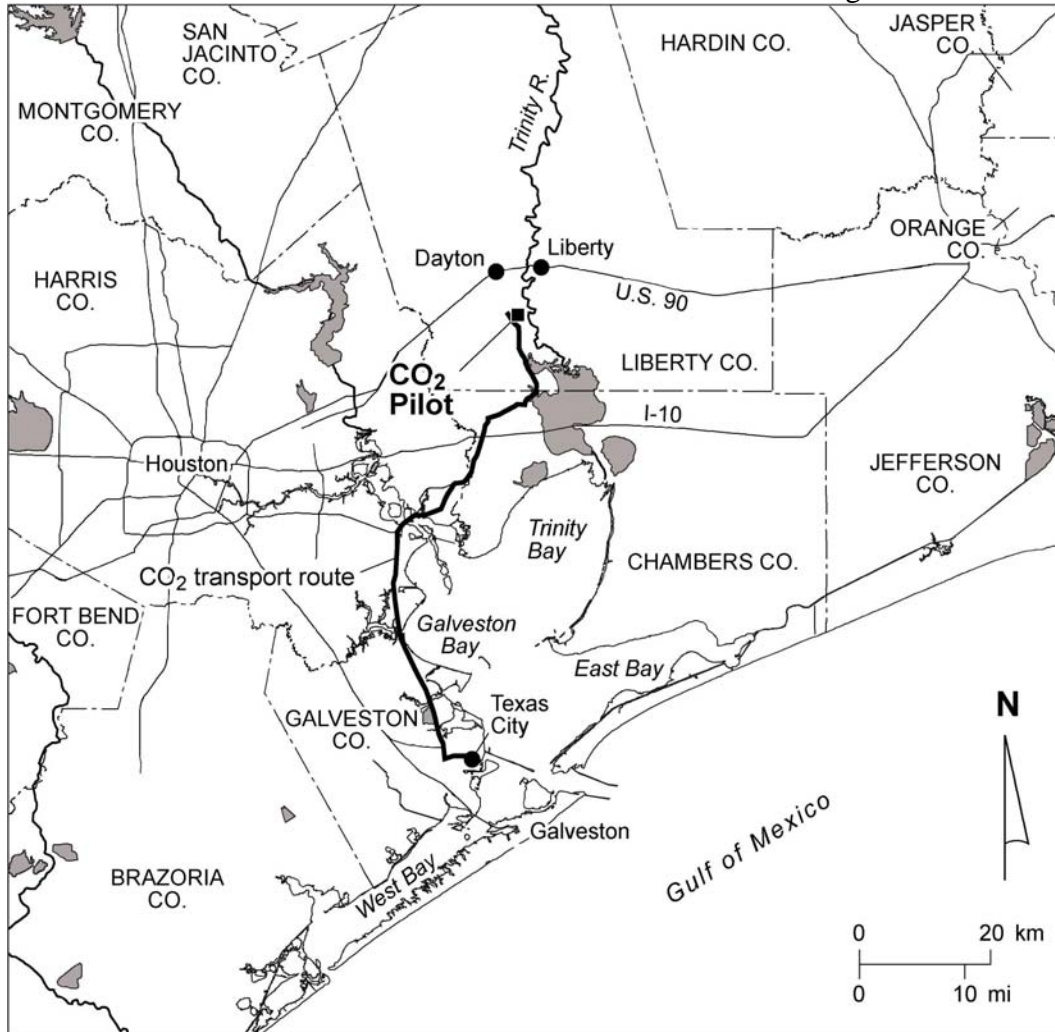


Figure 1. Map of the southeast Texas coastal region showing the location of the CO₂ pilot project, including the transportation route.

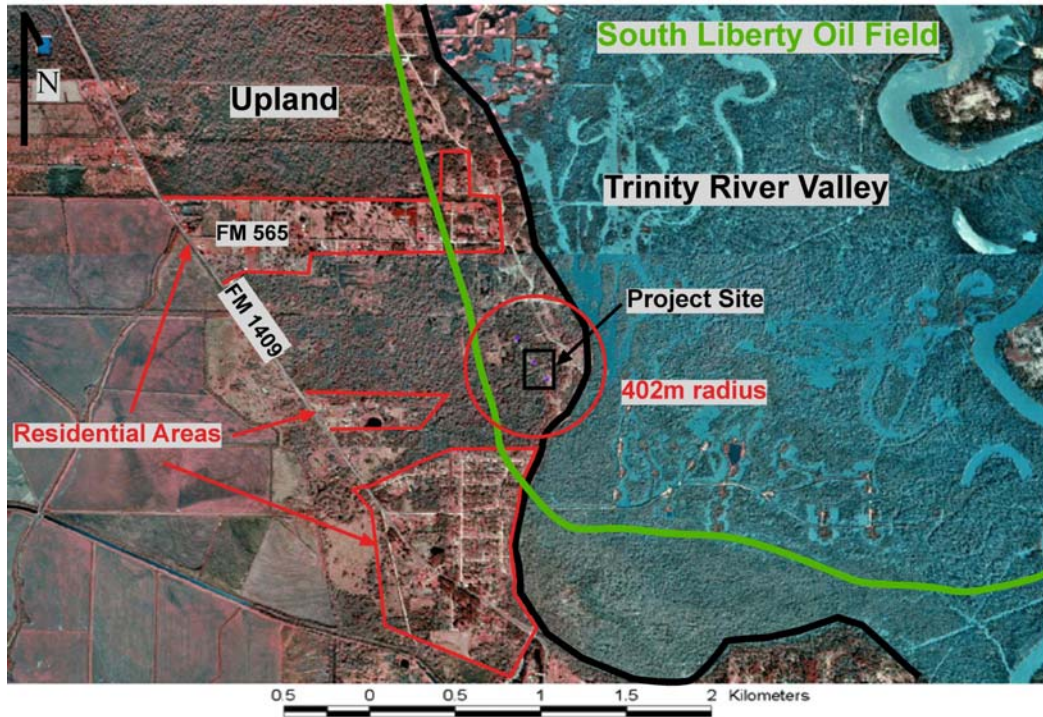


Figure 2. Aerial photograph of the area surrounding the project site showing major land features, roads, residential areas, the South Liberty oilfield outline, and the 402 m (0.25 mi) radius of the Area of Review. Aerial photo base modified from Texas Natural Resources Information System.

Site preparation will include improving about 1 km (~0.6 mi) of unpaved lease road by adding road base and grading and incrementally expanding one well pad, which will require clearing of no more than 0.4 hectares (1 acre) of vegetation. Expansion of the well pad and associated loss of vegetation has been minimized by additional expenditures to directionally drill the injection well from the margin of an existing pad, instead of clearing a new pad and building an access road within the vegetated upland.

Soil gas, pore water, and shallow groundwater will be sampled and analyzed prior to CO₂ injection to establish background CO₂ concentrations. Because background values vary seasonally with changes in biologic activity, a sample grid will be established and resampled over several months before and after injection. These points will also be monitored throughout the injection and postinjection phases. Shallow auger holes will be used to sample soil gas. Three shallow water wells will be drilled to sample groundwater following TCEQ monitoring well protocols.

Two existing wells, Sun-Gulf-Humble #4 and #3 (SGH 4, SGH 3, figs. 2, 3) will be converted to monitoring wells, requiring mobilization of a truck-mounted work-over rig to the well pad along lease roads. SGH 4 is the primary monitoring well; the new injection well will be drilled 30 m (100 ft) south of SGH 4. SGH 3 is 135 m (440 ft) southeast of SGH 4. Minor modifications will be made to this well to facilitate limited plume monitoring. Standard oilfield techniques will be implemented to determine casing condition, cement the well-bore annulus in the injection zone, and perforate that same

zone to prepare for monitoring. These activities will occur at depth, within the saline aquifer, well below and isolated from potentially potable groundwater.

Standard oilfield techniques and equipment will be employed to drill and complete an injection well on the same pad as SGH 4 (fig. 2). A shallow drilling-mud pit will be constructed adjacent to the well pad and lined in accordance with TCEQ requirements to prevent subsurface infiltration. The drilling mud will be water based. The volume of well cuttings (natural earth materials extracted during well drilling) is estimated to be 400 m³ (550 yd³). Cuttings will be buried on site as municipal solid waste in accordance with Texas Administrative Code Chapter 330. Drilling fluids, estimated to be less than 7,000 barrels, will be trucked to an RRC-authorized disposal well within 48 km (30 mi) of the project site. The new well will be cemented and perforated according to oil-industry standards. Minor amounts of excess nonhazardous material and debris will be removed from the site to a municipal landfill.

Newly established perforations in the injection well and monitor well will undergo a Mechanical Integrity Test (MIT) to verify casing-to-formation bond and ensure that injected materials will escape from the intended zone through the well annulus. Part of the routine MIT involves injection into the perforated zone at 1,500 m (5,000 ft) depth of 20 cc of ¹³¹I solution containing a total of 20 millicuries of radiation. This isotope has an 8-day half-life. The wells will sit idle for at least 2 weeks before production or injection of fluids begins, preventing return of hazardous levels of radioactivity to the surface. Radioactivity of produced fluids will be tested to assure that exposure levels conform to acceptable levels in Article 213 of the DOE Radiological Control Manual.

A series of extraction and injection tests will be conducted to evaluate subsurface fluid characteristics and pressure response within the injection interval. Brine produced during each pumping test, equaling no more than 3,000 barrels (351 m³), will be sampled, temporarily stored on site, then reinjected with a groundwater tracer into the original well in a subsequent injection test.

Two baseline geophysical surveys, a crosswell seismic survey and a 3-D vertical seismic profile (VSP), will be conducted before injecting of CO₂. The crosswell survey will consist of a downhole seismic source (high-frequency oscillating) in the SGH 4 monitoring well and seismic detectors placed in the injection well. The 3-D VSP will employ a surface seismic source and the injection-well detectors. As many as 66 18-m-deep (60-ft) shot holes will be drilled along four lines passing through the injection well and extending up to 400 m (1,312 ft) from the well (see Direct Effects section). A small jeep-mounted rig will be used to drill the shot holes near existing lease roads wherever possible, impacting less than 0.8 hectares (<2 acres). A maximum charge of 1.5 kg (3 lb) of biodegradable explosive (Dynoseis, consisting of sodium perchlorate and diethylene glycol [MSDS in Appendix A]) will produce the seismic energy for the survey. After detonation, shot holes will be filled with soil and the area compacted.

A



B



Figure 3. Photographs of the planned project site. (A) View, looking north, of well pad where existing monitor well SHG #4 is located. New well will be drilled on a southward extension of this pad. (B) View, looking northwest, of well pad where existing monitoring well SHG #3 is located—the two water-storage tanks visible were used when the well was a salt-water disposal well.

3.3.2 Injection Activities

A maximum of 3,750 tons (71.2 MMcf) of CO₂ will be injected intermittently into the subsurface over a maximum period of 60 days at rates not exceeding about 8.5 tons/hr (161 Mcf/hr). Downhole pressure increases will not exceed 116.4 bar (1,688 psi). This pressure is established by TCEQ regulation and is about 7 bar (100 psi) below the

calculated fracture pressure of the formation. TCEQ regulations also require that pressure increases within the 402-m (one-quarter-mi) radius area of review (AOR) not exceed a calculated value of 11.4 bar (165 psi), assuming a hydraulic gradient of 0.098 bar/m (0.433 psi/ft). Flow simulations by LBNL using TOUGH2 (Pruess and others, 1999; Hovorka and others, 2001) and formation-specific petrophysical properties calculated pressure response under proposed injection rates and durations. Figure 4 is a map view of the modeled pressure increase for a conservative scenario; it assumes that a slightly larger volume of 5,000 tonnes, rather than the 3,750 tonnes planned, is injected at the maximum rate over 20 days. The northeast, northwest, and southeast model boundaries are faulted and considered no-flow boundaries. The southwest boundary is open (unfaulted) and allows pressure dissipation. Maximum pressure increase at the injection well is 20.8 bar (304 psi), less than 20% of the regulated limit. Maximum pressure increase within the fault block at 402 m (0.25 mi) from the well is less than 6 bar (<87 psi), about half of the regulated limit. Subsequent models to be constructed before injection will be refined to include more detailed geologic information from an existing 3-D seismic volume, hydrologic tests of the injection formation, and information from core and log data in the new injection well. These model refinements, combined with pressure monitoring during injection, will ensure that the experiment is performed within regulatory requirements.

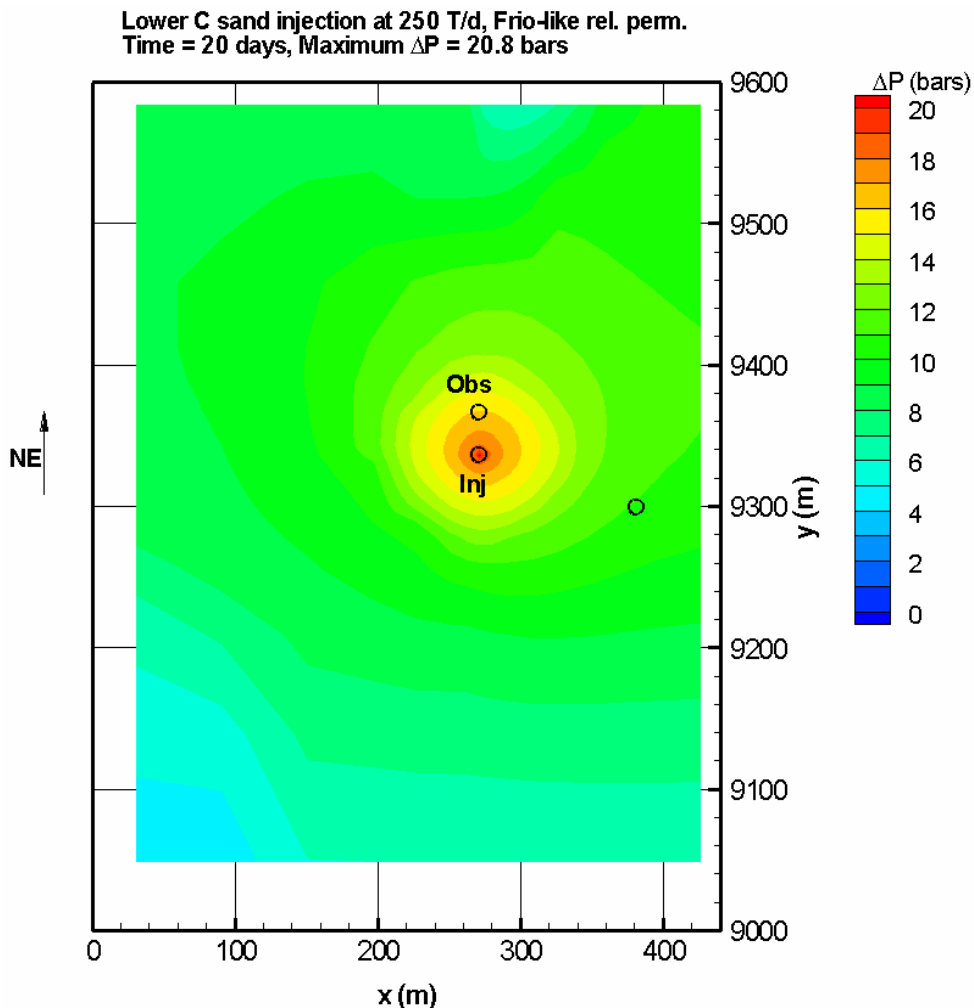


Figure 4. Map-view results of Tough2 numerical simulation showing incremental pressure increases in the injection interval after 20 days of injecting 250 tonnes per day. Note that the total injection volume modeled is 5,000 tonnes, more than the proposed 3,750 tonnes, to investigate upper limits of pressure increase, here calculated to be 20.8 bars (304 psi).

CO₂ for injection will be delivered to the site by commercial truck and temporarily stored in a 1,000-barrel pressure tank placed on a 6 × 24 m (20 × 80 ft) concrete pad. The CO₂, at 15 bar (220 psig) and –19°C (–3°F), will be compressed prior to injection by a pad- or skid-mounted pump taking up a space no more than 3 × 6 m (10 × 20 ft). Both the tank and pump will be removed following injection.

The injection of CO₂ will be suspended several times during the experiment to allow for downhole logging, sampling, and geophysical measurements. During these suspensions, produced formation brine will be injected to prevent return of CO₂ gases to the surface through the well bore. Standard oilfield procedures will be used to log and sample the well. 3-D VSP surveys will be repeated during injection to monitor CO₂ plume behavior.

The focal point of the proposed activity is monitoring of the injected CO₂ to understand its subsurface flow paths. Formation temperature and pressure will be recorded nearly constantly to determine formation response. Additionally, tracers will be injected with the CO₂ in minor amounts, and both the injection and monitoring wells will be sampled to identify the tracer and CO₂ concentrations. Geochemical tracer techniques will include (1) isotopic profiles of injected CO₂, (2) introduced noble gases, and (3) introduced perfluorocarbons. A maximum of 3,000 barrels of fluid in one monitoring well (SGH 4) will be produced by nitrogen lift during the injection period to monitor tracer and CO₂ concentration. These fluids will not be reinjected in the formation because of their potential to interfere with long-term monitoring. They will be trucked to a TCEQ-permitted UIC Class 1 nonhazardous well within 32 km (20 mi) of the site and disposed of into a subsurface formation.

3.3.3 Postinjection Activities

Following CO₂ injection, downhole fluid samples will be taken from the injection zone and the immediately overlying zone in both the injection well and primary monitoring well (SGH 4). Purging of the well bore to obtain fresh samples from the formation may yield up to 172 barrels of formation brine, which will be transported to a TCEQ-permitted disposal well.

The existing completions will remain open in the injection and monitoring wells for a period anticipated to be less than 1 year to allow extended monitoring. Monitoring will include pressure and temperature measurements and perhaps other activities that may include well logging, crosswell or surface seismic surveys, or geochemical sampling and analyses. Monitoring of CO₂ in the wells will decrease in frequency as changes in pressures and concentrations become minimal, indicating significant stabilization of the subsurface physical environment. This stabilization is anticipated to occur less than 1 year after the end of injection. Shallow-groundwater dissolved gas and soil-gas concentrations will be monitored throughout this time at sample points established during preinjection field activities. Impacts of surface seismic surveys and geochemical sampling (waste formation brine) will be treated as previously described.

Following the completion of downhole logging and sampling, the injection and monitoring zone perforations will be plugged by cement following standard oil-industry practices. The wells will either be plugged and abandoned according to RRC rules or converted to a use approved by the appropriate agency.

Other postinjection activities will include additional office work to analyze and interpret results at the various team members sites (Table 3). Results and interpretations will be synthesized by the Bureau of Economic Geology, and a final project report prepared. Technology transfer to interested parties will continue sporadically until project completion in September, 2004.

3.4 Enabled Actions

[NETL will add text here](#)

3.5 Range of Reasonable Alternatives

The proposed experiment is the culmination of 3 years of research effort in geologic sequestration in brine-bearing formations. That research progressively identified the ideal pilot setting. Reasonable alternatives, including the no-action option, are listed in table 4, along with comments on limitations of each. Alternatives range from siting the experiment in an adjacent area to conducting it in a hydrocarbon-bearing formation.

Table 4. Comparison of possible alternative actions

Alternatives	Comments
Alternate location in same basin	Need oilfield setting. Would need to find other operators willing to host experiment and supply data.
Injection in a different basin	Other large basins having significant CO ₂ sources needing sequestration have limited subsurface data and service-industry infrastructure.
Injection in an oil or gas reservoir	Presence of hydrocarbons in even minor concentrations interferes with critical fluid flow characteristics and rock-water interactions being investigated.
No action	Large-scale sequestration efforts suffer increased risks or substantial delays, reducing U.S. options for climate change mitigation.

Considering the nomination of the Frio Formation in the upper Texas Gulf Coast as a programmatically advantageous setting, one ready alternative would be to conduct the experiment in another area of dense subsurface control, perhaps closer to a major CO₂ source. The small fault blocks associated with salt domes in this basin provide significant benefits by providing a more closed compartment. Small volumes of injected material have a larger pressure response because the pressure is not as rapidly dispersed by an unnecessarily large pore volume. Similarly, flanks of salt domes commonly have steeper dips, accentuating the response of the buoyant injected CO₂ plume to the effects of gravity—a key parameter being evaluated. There are many salt-dome settings in this area, but the proposed location is the only one in which an operator was located who was interested in hosting the experiment and providing access to idle wells.

Many other basins exist across the U.S. that contain formations suited to sequestration (Hovorka and others, 2000). Few of these basins, however, combine a high concentration of CO₂ sources with the abundance of subsurface data available in the form of well logs and 3-D seismic data. Fewer still have a robust well-servicing industry, which reduces experiment cost through a competitive business climate and relatively low mobilization costs.

Another alternative is to conduct the experiment in the same basin as that proposed but use existing infrastructure and completed wells in an oil or gas reservoir. This option would reduce well-construction costs and potentially add value by enhancing hydrocarbon production as result of the injection. Other such projects are under way, but the daily activity in such settings makes detailed scientific monitoring difficult. The background electromagnetic and seismic noise reduces the achievable resolution of geophysical surveys. Additionally, experiments require periods in which wells are idle, resulting in loss of revenue for producers. Most important, the presence of hydrocarbons substantially affects CO₂ sorption, pressure response, and flow processes that are the objectives of the project. The presence of a native gas phase in the formation significantly increases the compressibility of the formation fluid, making response to injection difficult to predict and interpret. The presence of oil in the formation fluid complicates multiphase flow effects.

3.5.1 The No-Action Alternative

No action, meaning that the proposed project is not carried out in any setting, would delay planned larger-scale sequestration pilots by perhaps several years. The increased understanding of subsurface behavior of CO₂ would not be gained, nor could an example of successful and safe sequestration, on any scale, be offered to the public in support of a larger, more expensive project. The complexities of a larger pilot might translate to long delays in public and regulatory approval, thereby jeopardizing goals of rapid action on climate change issues. A 3-year delay in initiating large-scale sequestration efforts would increase CO₂ emissions by approximately 5% and atmospheric concentrations of CO₂ would increase by as much as 6 ppm before any stabilization effort would be started.

4.0 AFFECTED ENVIRONMENT AND THE ENVIRONMENTAL CONSEQUENCES OF THE PROPOSED ACTION

4.1 Site Description

The experiment is planned for South Liberty field in southern Liberty County, Texas, a largely rural county with an estimated population of 72,620 in 2001 (U.S. Census Bureau, 2001). The site is located on an upland adjacent to the Trinity River valley on the coastal-plain physiographic province. The site and the immediately surrounding area are within an oilfield that have been active since 1951 and are sparsely populated. Low-density residential neighborhoods have been developed over the past 2 decades to the north, southwest, and south (fig. 2) of the site. No residences lie within 0.5 km (0.3 mi) of the site. Approximately 250 land blocks within 2 km (1.25 mi) of the site are platted for residences. Timber has been harvested sporadically in the vicinity for many decades; an idle lumber mill is located about 0.4 km (0.25 mi) north of the site. The area west of highway FM 1409 (fig. 2) has historically been used for agriculture.

The project site is about 25 km (~15.5 mi) upstream of Trinity Bay, 65 km (40.3 mi) inland from the Gulf of Mexico, 60 km (37 mi) northeast of downtown Houston (fig. 1), and nearest the small communities of Dayton (7.5 km, or 4.5 mi, to the northwest) and Liberty (9 km, or 5.5 mi, to the northeast). Liberty County is on the northeast margin of the heavily populated Houston metropolitan area. Harris County, home of most of Houston's citizens, had an estimated 2001 population of 3,460,589; populations estimated for adjacent counties within the regional impact area are 255,865 for Galveston County and 26,859 for Chambers County (U.S. Census Bureau, 2001).

4.1.1 Field History

South Liberty field was discovered in 1925. The first commercial production was from the Oligocene Frio Formation shallow on the east flank of a piercement salt dome, and a significant drilling boom followed (Halbouty, 1962). Attention was drawn to the area in 1901 by surface shows of sulfur, oil, and gas, and by the discovery of Spindletop Dome. South Liberty cumulative oil production for 1925 was 4,416,000 barrels of oil. Production steadily declined through the mid 1940's, but discoveries of oil in the deeper Eocene Yegua and Cockfield Formations on all flanks of the dome in 1948 and 1949 reinvigorated the field (Halbouty, 1962). A large number of the wells in the pilot area were drilled in 1950 and 1951 as a new drilling boom spread. Annual production peaked at 5,271,847 barrels in 1958 and has been gradually declining since then. Annual production for 2001 was 253,000 barrels of oil and 437 million ft³ of gas (Railroad Commission of Texas, 2002).

No production has been found over the top of the dome (caprock area), where salt rises to within 84 m (275 ft) of the surface (Halbouty, 1962). According to a Texas Railroad Commission database, there are 654 wells in South Liberty field (fig. 5). About 55 leases are currently producing (there may be multiple oil wells per lease, but only one gas well per lease), with a large number of wells, perhaps several hundred, standing idle.

From January 1, 1998, through January 1, 2003, 11 wells have been permitted within the field, all on the east and north flanks of the dome, with at least 5 of those permits granted in 2002. Exploration for deeper oil or gas objectives continues, as evidenced by the increase in well permits in 2002 and the recent completion of a large 3-dimensional seismic reflection survey in the area.

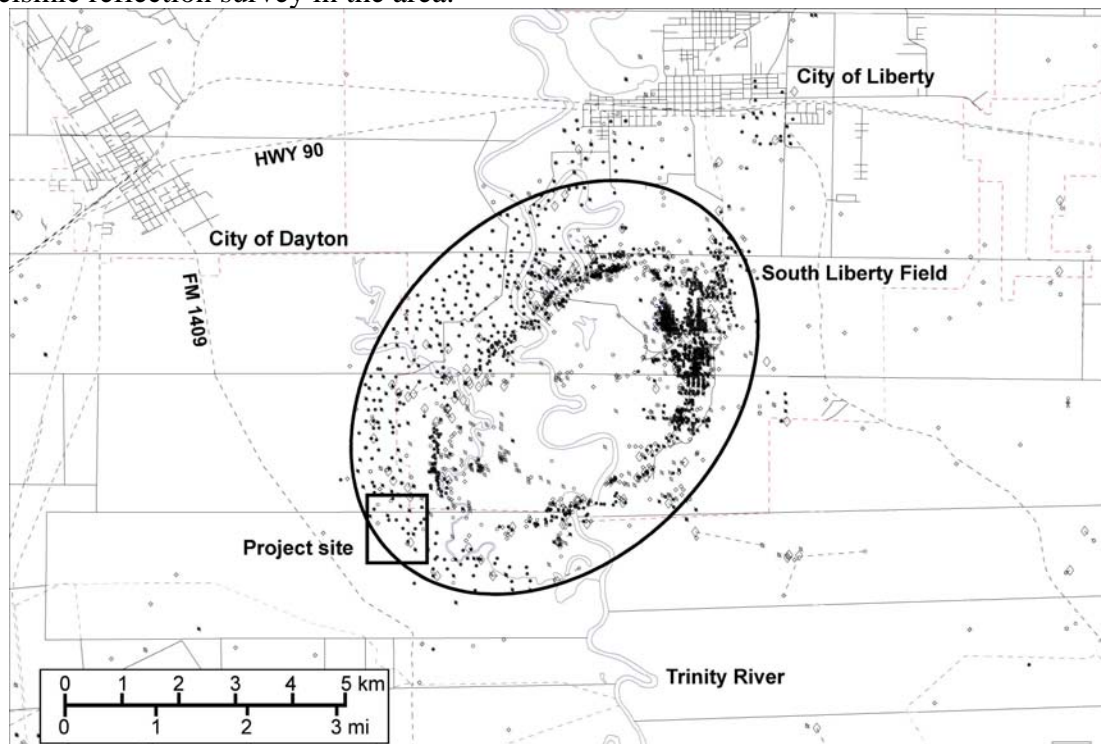


Figure 5. Map of oil and gas wells drilled in South Liberty field and surrounding area. Modified from Railroad Commission of Texas (2002).

4.1.2 Surface Geology and Soils

The proposed new CO₂ injection well and existing monitoring well are located on the Beaumont Formation (Aronow and Barnes, 1982), a Pleistocene fluvial-deltaic depositional system composed of fine sandy channels and interchannel muds. Fisher and others (1972) mapped the site as a heavily to sparsely tree-covered meander-belt sand. The site is about 300 m (~1,000 ft) west of the erosional bluff marking the geomorphic boundary between the Pleistocene upland at surface elevations of about 20 m (~66 ft) above sea level and the floodplain of the Trinity River at elevations of 2 to 6 m (6.6 to 20 ft) above sea level (fig. 6). The main channel of the Trinity River passes about 2,700 m (~1.7 mi) east of the site. Depositional units within the floodplain, mapped as Quaternary alluvium by Aronow and Barnes (1982), include tree-covered meander-belt sand, overbank flood-basin mud, and mud-filled abandoned channels (Fisher and others, 1972).

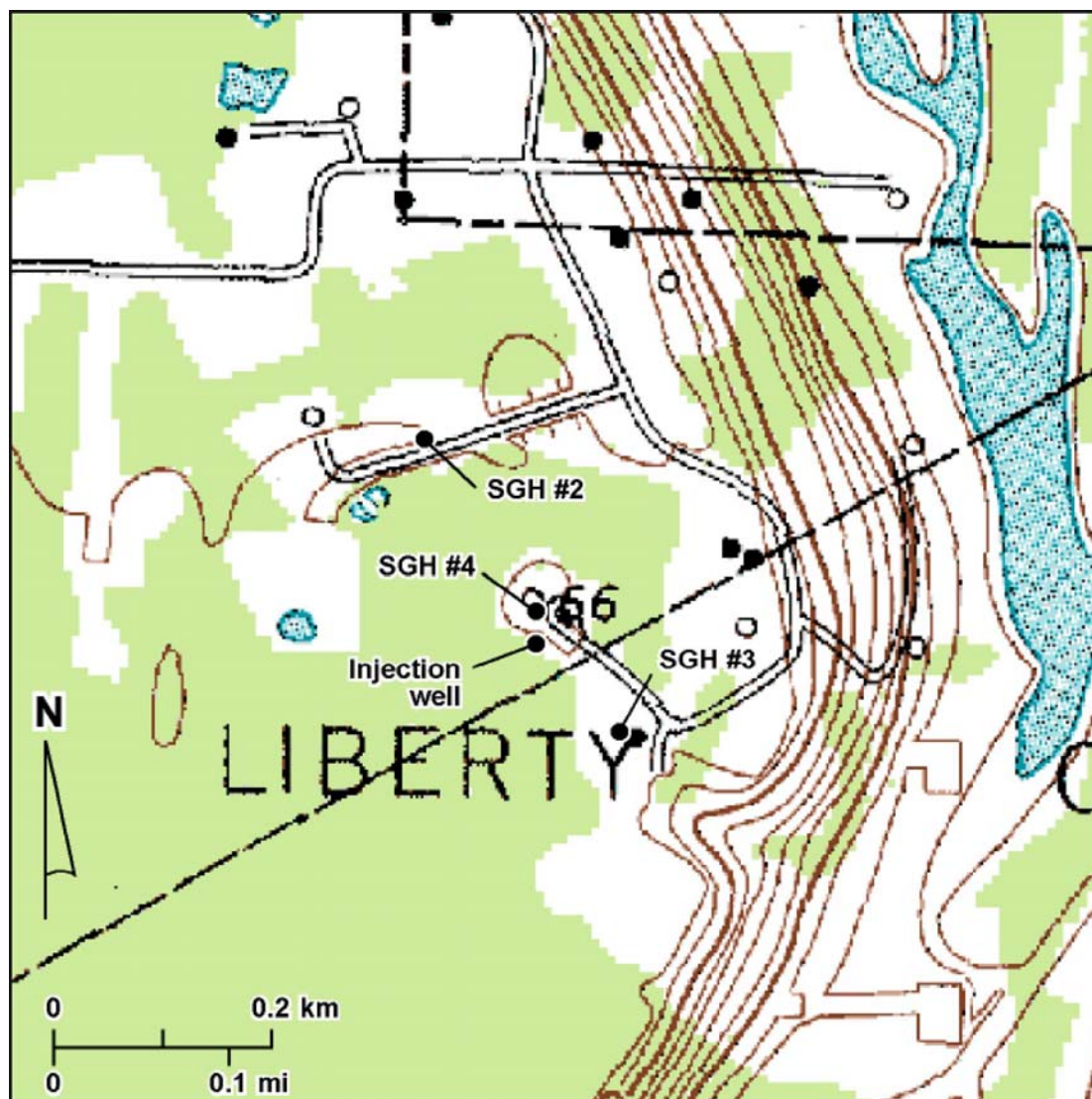


Figure 6. Topographic map of the experiment site showing bluff to east of the site and a small lake (stippled area) within the Trinity River valley. Note also locations of existing wells to be converted to monitor wells, SGH #4 and #3, and location of the new CO₂ injection well, about 30 m (100 ft) south of SGH #4. Gray shading designates vegetated areas. Contour interval is 5 ft. Modified from U.S. Geological Survey Moss Bluff 7.5-minute quadrangle.

The Natural Resources Conservation Service has mapped three soil units at and near the site (U.S. Department of Agriculture, 1996), as shown in figure 7. On the upland is the Aldine-Aris complex, a thick soil with texture ranging from very fine sandy loam to clay (Aldine) and sandy clay loam to clay (Aris). Geologic maps indicate that the dominant soil texture at the site is sandy loam rather than clay. This soil unit is considered to be very slowly permeable and has a high water-holding capacity. The depth to water, where present, is less than 1 m (<3 ft). Organic matter content is 2 percent or less.

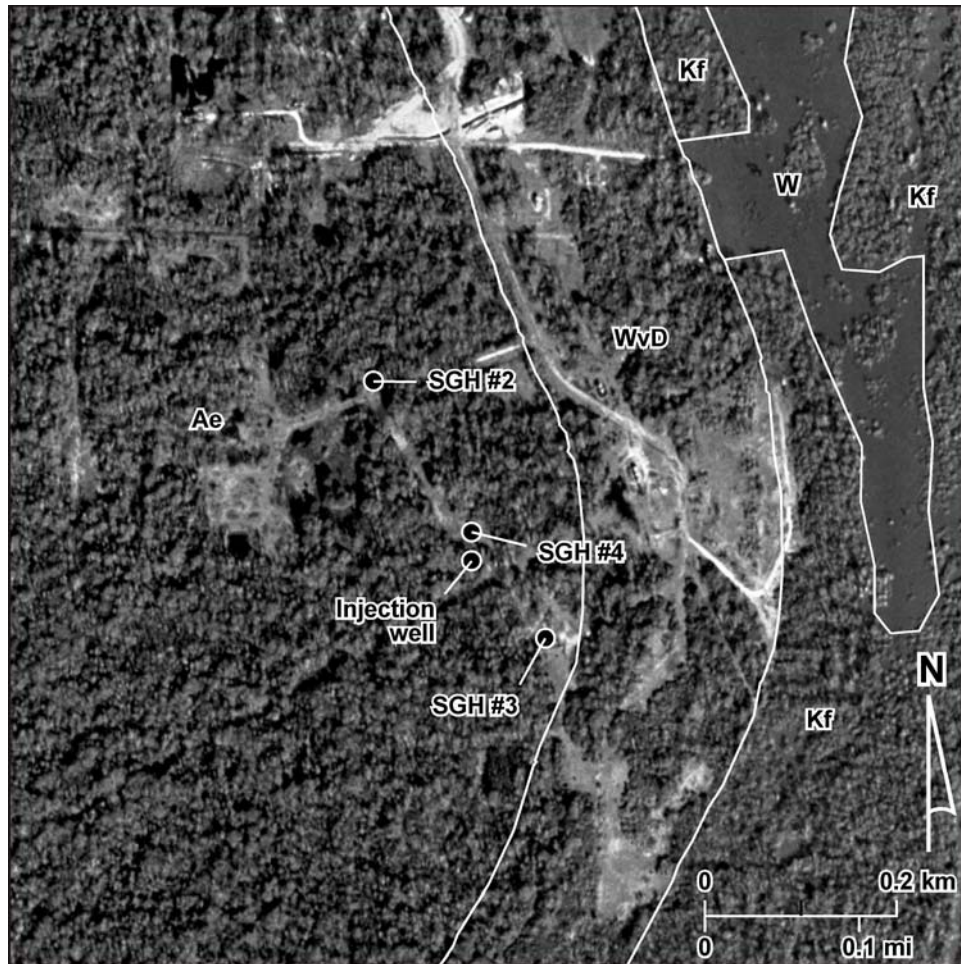


Figure 7. Distribution of soil units at the experiment site. Soil units are those of the Natural Resources Conservation Service (U.S. Department of Agriculture, 1996). W = water; Ae = Aldine-Aris complex; Kf = Kaman clay; and WvD = Woodville fine sandy loam. Aerial photo base modified from Texas Natural Resources Information System.

Soils of the Woodville fine sandy loam are mapped for the bluff separating the upland experiment site and the Trinity floodplain. This soil, with a surface slope of 5 to 8 percent, has a thin sandy surface layer overlying clay substrata. Permeability is classified as very slow; water-holding capacity is high. Depth to water, where present, is 2 m (6.6 ft) or more.

The Trinity floodplain adjacent to the site is classified as either Kaman clay or open water. The Kaman clay is a very deep, wet, and poorly drained unit that is frequently flooded. It is classified as clay to silty clay with organic content of 3 percent or less. It has high water-holding capacity.

4.1.2 Subsurface Geology

The proposed injection will take place in brine-bearing sandstones near the top of the approximately 600-m-thick (~2,000-ft) Oligocene Frio Formation at about 1,500 m

(~5,000 ft) below ground surface, on the southwest flank of the South Liberty salt dome. Hydrocarbon production in this part of the field comes from sandstones of the Eocene-age Yegua/Cockfield and Cook Mountain Formations between 2,500 and 2,750 m (8,200 and 9,000 ft) below ground level (fig. 8). The interval between the production (Yegua/Cockfield) and injection (Frio) formations is a shale-dominated section that includes the Eocene Jackson and Oligocene Vicksburg formations (fig. 8). The Frio is overlain by the 75-m-thick (250-ft) Oligocene Anahuac Shale, which, in turn, is overlain by an approximately 1,300-m-thick (~4,200-ft) interval of Miocene interbedded sandstones and shales (projected from cross sections in Morton and others, 1985). These include, in order of oldest (deepest) to youngest (shallowest), the Oakville (~470 m [~1,500 ft] thick), Fleming (~565 m [~1,850 ft] thick), and Goliad Formations (~245 m [~800 ft] thick). Above these units is the sand-dominated interval extending to the surface and including the Pliocene Willis Formation (~60 m [~200 ft] thick; Galloway and others, 1991; Guevara-Sanchez, 1974), the Pleistocene Lissie (~45 m [~150 ft] thick), and the Beaumont (~25 m [~80 ft] thick; Guevara-Sanchez, 1974) Formations.

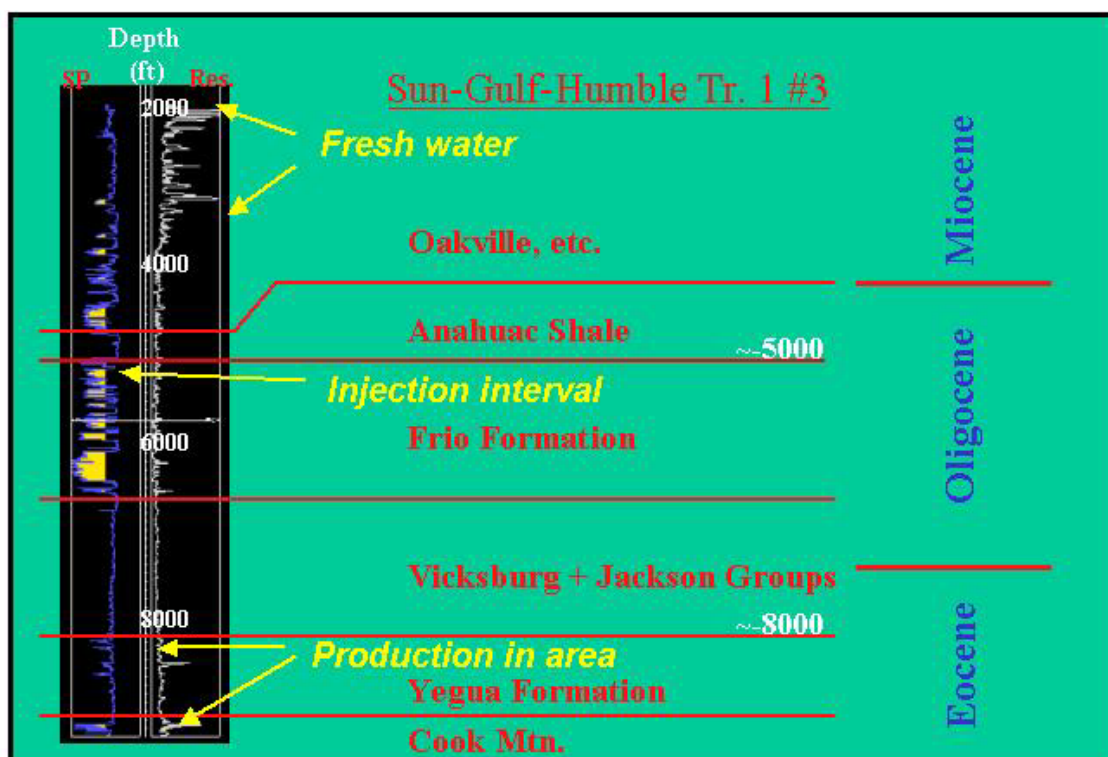


Figure 8. Type log from SGH #3 showing depth to the injection interval, underlying oil and gas production, and fresh-water aquifers substantially above the injection interval.

Typical structure within the central and upper Texas Gulf Coastal Plain dips gently toward the Gulf of Mexico and is cut every few kilometers by northeast-trending, down-to-the-coast growth faults. Along the upper Texas coast (including the study area), the growth-fault pattern is disrupted by numerous salt domes. The pilot area lies on the south flank of the South Liberty salt dome. The Frio Formation dips southerly to slightly southeasterly at high angles (greater than 30°) near the salt-dome flank, decreasing south and west of the pilot location to a dip of less than 5°. The salt flank is cut by a series of

normal faults that radiate from the salt dome and typically dip and throw to the west-northwest (fig. 9). Major fault offsets vary from 90 to more than 120 m (300 to >400 ft), decreasing away from the dome as dips flatten. Minor fault offsets detectable with well logs and seismic correlation range from 15 to 45 m (50 to 150 ft), with many of these faults dying out not far south of the pilot area (fig. 9).

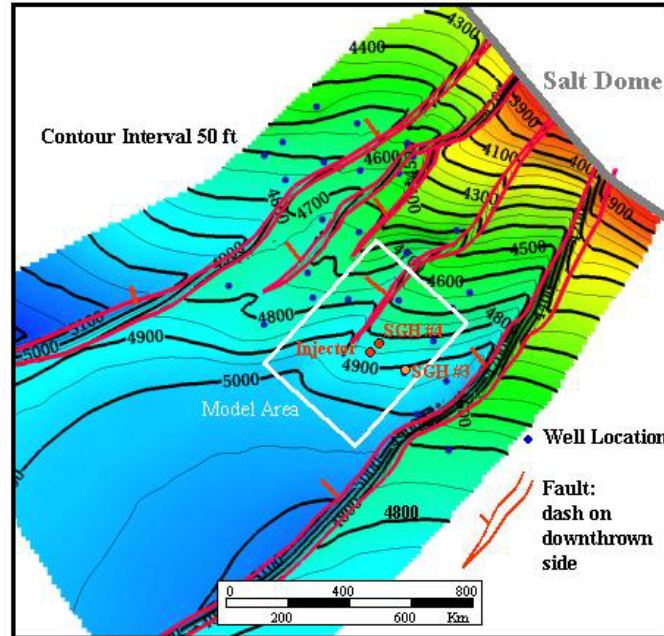


Figure 9. Structure-contour map of the southwest flank of the South Liberty salt dome, showing the relationship of experiment well locations to faults and the edge of the salt dome. White rectangle indicates the extent of the numerical model. Contour interval is 50 ft.

Individual sandstones at the top of the Frio (the injection zone) range from less than 3 to more than 15 m (<10 to >50 ft) thick and are separated by laterally continuous shale beds from 1 to more than 4 m (3 to >15 ft) thick. Sandstones at the project site have been given informal letter designations, “A” being the shallowest (fig. 10). CO₂ will be injected into the thicker “C” sandstone, and both the “C” and “B” sandstones will be monitored for response. Although hydrocarbons have been encountered in the “A” and “B” sandstones in nearby fault blocks adjacent to the salt dome, no indications of hydrocarbons have been found in logs from the “C” sandstone.

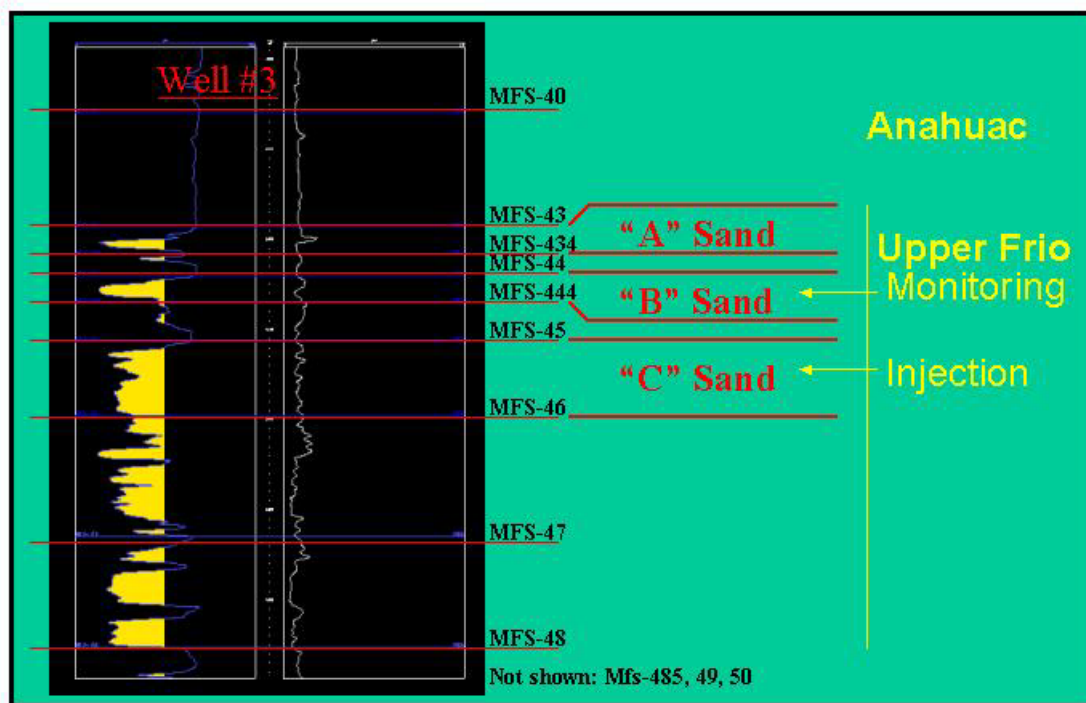


Figure 10. Detailed type log from SGH #3 showing interval nomenclature, correlated horizons (MFS), and sandstones (yellow on SP curve).

Sandstones are generally laterally continuous over 1 km (0.6 mi) or more and were deposited in fluvial and deltaic settings (Galloway and others, 1982). Sandstone framework compositions are dominantly subarkose to lithic arkose, having quartz compositions between 45 and 80 percent (Loucks and others, 1984). Regional formation-water salinity trends (Morton and Land, 1987) and log-derived, site-specific data indicate that these sandstones contain waters with more than 120,000 ppm total dissolved solids. Log-derived porosities range from about 20 to more than 30 percent, averaging about 29 percent. Although no core from the area immediately surrounds the injection site, sandstones with similar log character but deeper depths in a cored well in adjacent Chambers County have permeabilities ranging from 50 millidarcies (md) to several darcies. We anticipate that Frio sandstones in the pilot area will have permeabilities of several hundred to nearly 1,000 md. Permeabilities will have a large impact on pressure response and distribution of the injected CO₂, as will residual gas saturations. On the basis of log-derived porosities and a porosity–residual-saturation relationship derived from the literature (fig. 11), we anticipate residual-gas saturations for the injected CO₂ of approximately 30 percent. Residual saturations could be as low as 5 percent, so this fact is being considered in modeling as an end-member possibility. Pressures and temperatures in the injection interval are expected to be about 151 bar (2,195 psi) and 66° C (151° F) on the basis of regional gradients of 0.099 bar/m (0.439 psi/ft) and 3.32° C/100 m (1.82° F/100 ft). Values will be measured in project wells during initial field activities to verify these estimates.

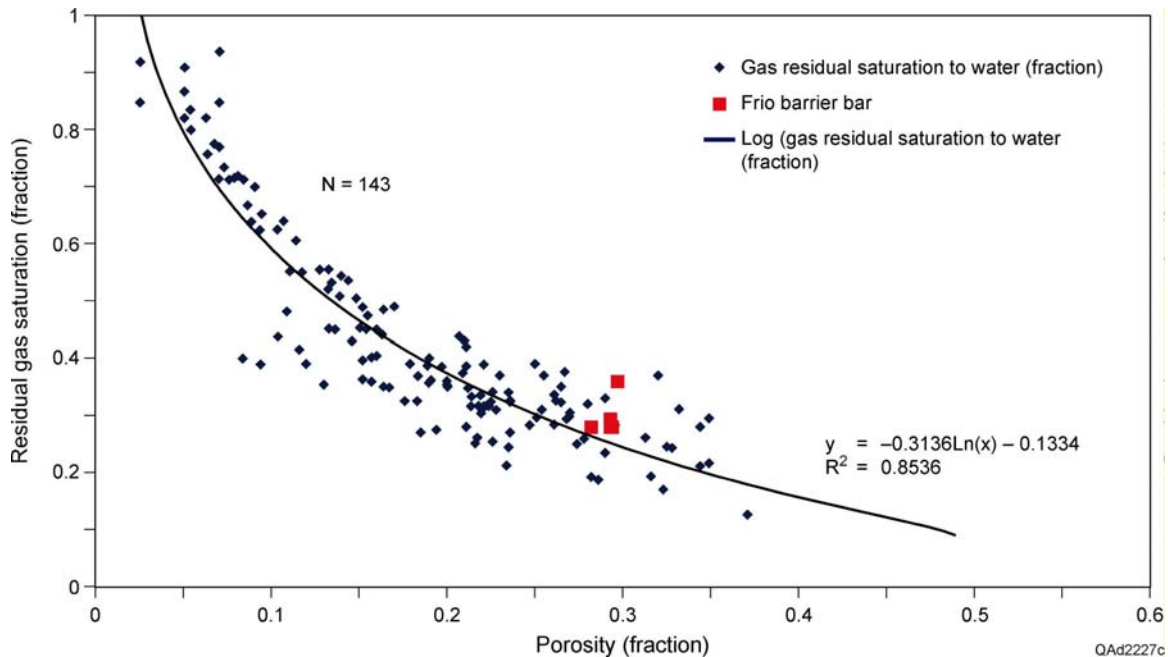


Figure 11. Cross plot of residual gas saturation and porosity for 140 data points collected from the literature and 4 data points from a Frio sandstone core recovered from a well about 32 km (~20 mi) south of the experiment site. The accumulated points indicate a logarithmic relationship with a high correlation coefficient of 0.85.

4.1.3 Groundwater

Fresh-water aquifers in the pilot area include the Alluvium and Beaumont, upper and lower Chicot, and Evangeline Formations (Dutton, 1990). The first and uppermost extends to the base of the Beaumont (see Dutton, 1990). The upper Chicot extends to the upper part of the Lissie, and the lower Chicot includes the remainder of the Lissie and Willis Formations (fig. 12; Carr and others, 1985). The Evangeline aquifer includes the Goliad and the upper part of the Fleming Formation (Dutton, 1990). The base of usable-quality water, defined as containing less than 3,000 mg/L (<3,000 ppm) total dissolved solids (TDS), is at a depth of about 670 m (~2,200 ft) (Baker, 1979). Below the Evangeline aquifer is the Burkeville confining unit near the middle of the Fleming Formation. Below this is the Jasper aquifer, which includes the lower part of the Fleming Formation and the upper part of the Oakville Formation (fig. 12; Baker, 1979). The base of potentially usable-quality water (also referred to as the base of the lowermost USDW), defined by having less than 10,000 mg/L (<10,000 ppm) TDS, is at a depth of about 1,035 m (~3,400 ft). This is about 500 m (~1,600 ft) above the injection zone and is separated from it by more than 75 m (>250 ft) of Anahuac Shale Formation.

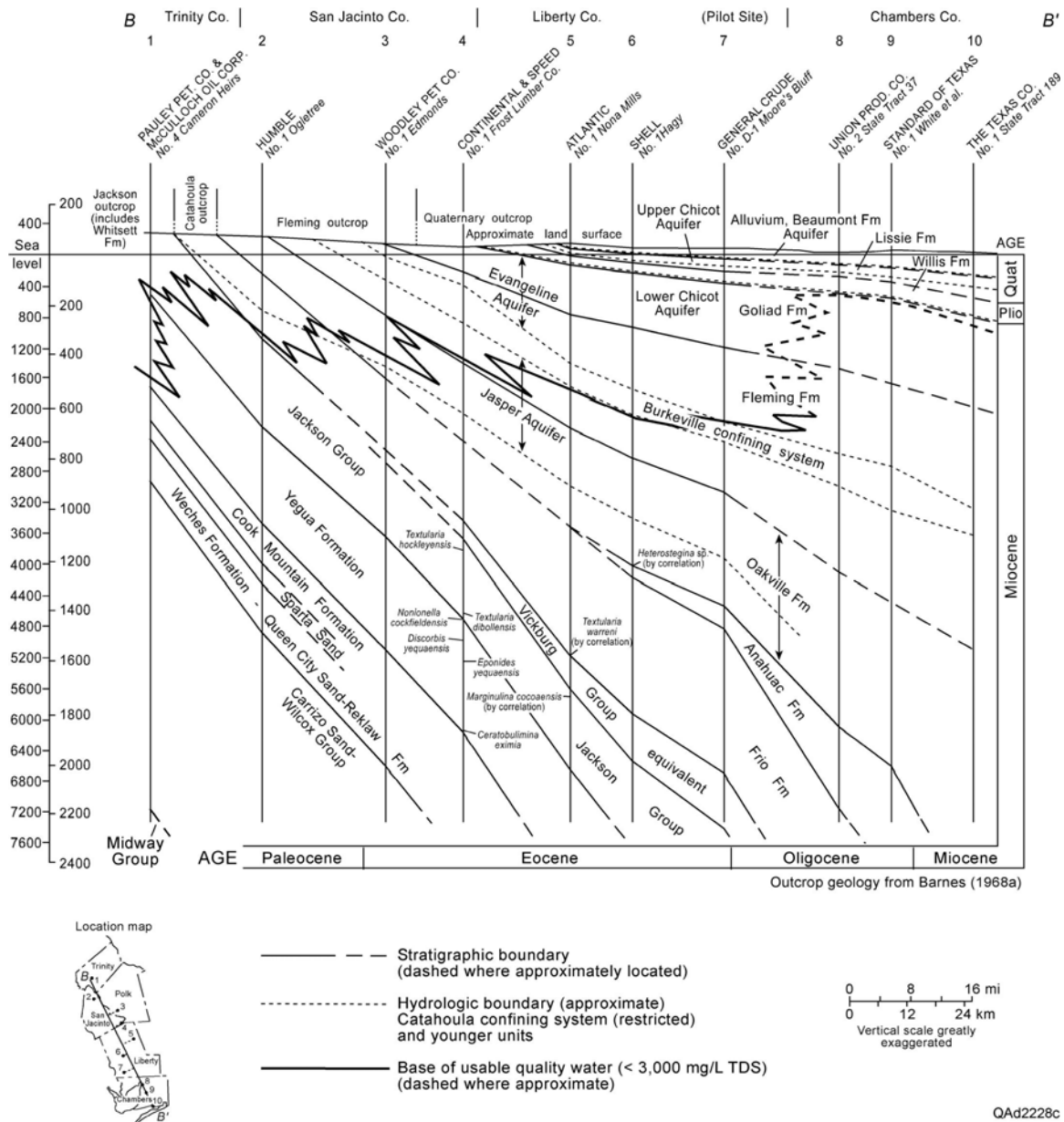


Figure 12. Dip-oriented regional cross section through experiment site showing relationship of stratigraphic units to hydrologic units. Modified from Baker (1979). Some stratigraphy and thicknesses for units above the Anahuac taken from Morton and others (1985), Galloway and others (1991), and Guevara-Sanchez (1974).

Depth to groundwater is uncertain and will be investigated prior to CO₂ injection. The amount of unsaturated section in the shallow subsurface is important because it acts as a buffer if CO₂ were to leak from the deep subsurface (see Potential Leakage Impacts). Saturation profile most likely varies across the site area depending on season, geomorphic position, and surface elevation. Information from mapped soil types suggests that water-saturated soil lies less than 1 m below ground level at the injection and monitoring wells. With the interbedded sand/clay nature of the shallow subsurface, this shallow water is likely to represent a perched water table. The nearest residential water

well (well 64-02-102) is located about 1,250 m (~4,100 ft) northwest of the injection well. This well, drilled in 1972 to a depth of 73 m (240 ft), produces water from the Chicot aquifer. Water level in this well bore is 8 m (26 ft) below ground surface. If this aquifer is unconfined in this location, a substantial unsaturated zone could exist. Finally, the level of standing water in the adjacent Trinity River floodplain, commonly about 10m (~30 ft) below the project area, may indicate the approximate top of the saturated zone. Depth to water will be determined during drilling of initial shot holes for seismic acquisition.

4.1.4 Climate

As part of the upper coast climatic province (Bomar, 1983), Liberty County experiences a warm, temperate, and humid climate. In January, historically the coldest month, temperatures range from an average low of 4.9° C (41° F) to an average high of 16.6° C (62° F) (Bomar, 1983). In July, historically the warmest month, temperatures range from an average low of 22.5° C (72° F) to an average high of 34.2° C (94° F) (Bomar, 1983). Temperatures fall below the freezing point of water an average of 11 times each year between the average date of the first freeze (December 6) and the average date of the last freeze (February 15). Recorded temperature extremes are a low of -15° C (5° F) in January 1940 and a high of 41.7° C (107° F) in August 1980.

Average wind vectors are from the north-northwest at 13 km/hr (8 mi/hr) in January, from the south-southeast at 14 km/hr (8.7 mi/hr) in April, from the south at 11 km/hr (6.8 mi/hr) in June, and from the east-southeast at 10 km/hr (6.2 mi/hr) in October (Bomar, 1983). Highest wind speeds occur during the approach and passage of cold fronts, which are most common from October through March. Extreme weather conditions are associated with the occasional tropical storm, which brings torrential rains, high, sustained winds, and tornadoes to the area. Hurricane season begins on June 1 and ends on December 1. Tropical storms are most common in the months of June, August, and September.

Average annual rainfall in the Houston area is 114 cm/yr (44.5 in/yr) (Bomar, 1983). The months of May and September have the highest historical rainfall averages.

4.1.5 Access

The experiment site is located on existing well sites accessed using privately owned lease roads in the active South Liberty Oilfield. Access to the field is from Texas Farm-to-Market Road 1409 between Dayton, where FM 1409 intersects U.S. Highway 90, and Mont Belvieu. The major transportation routes in this area are Interstate Highway 10, which passes about 15 km (~9.3 mi) south of the site, and U.S. 90, which passes about 7 km (~4.3 mi) north of the site. At its nearest point, FM 1409 is about 1.3 km (~0.8 mi) southwest of the experiment site.

The planned transport route for trucks carrying CO₂ for injection at the site (fig. 1) will be from the supply plant in Texas City (Galveston County) onto Texas 146. This major state highway passes through the cities of Texas City and Kemah in Galveston County, Seabrook, La Porte, and Baytown in Harris County, and Mont Belvieu in Chambers County for a cumulative route distance of 55 km (34 mi). At Mont Belvieu, the route turns east onto Loop 207 for 1.3 km (0.8 mi) before turning east again onto FM 565 for a distance of 6 km (3.7 mi) to the intersection with FM 1409. The route turns north

onto FM 1409 and continues to the lease road entrance 16.9 km (10.5 mi) from the intersection with FM 565. Total distance from plant to site is 79.2 km (49.1 mi).

4.1.5 Historical and Archeological Resources

The Texas Archeological Research Laboratory (TARL), The University of Texas at Austin, is the curator of archeological and historical sites for the State of Texas. Upon review of site maps and the location of the proposed experiment, TARL staff determined that “within one kilometer (0.6 mi) of the proposed delineated project area, there are no recorded archeological or historical sites. No sites are registered as State Archeological Landmarks or are listed in the National Register of Historic Places.” Copies of the review request, accompanying site maps, and the determination response letter are included in Appendix B. The areas of the drilling pad, mud pit, and seismic shot lines will be surveyed by project archeologists before site work begins.

4.1.6 Endangered Species

Staff from the Clear Lake Ecological Services Field Office of the U.S. Fish and Wildlife Service have reviewed the experiment location and have determined that “no federally listed or proposed threatened or endangered species are likely to occur at the project site. The project site is not located within officially designated critical habitat.” Copies of the review request, accompanying maps, and the determination letter are attached in Appendix B.

4.1.7 Flood Potential

The western margin of the floodplain of the Trinity River lies about 400 m (~1,300 ft) east of the experiment site. The current channel of the river itself is about 2.7 km (~1.7 mi) east of the site. The principal flood risk for the site is related to Trinity River flooding. The normal and peak stream flow of the Trinity River in this area is relatively well known because there is a stream-gauging station on the Trinity at Liberty (U.S. Geological Survey station 08067000) that has been in operation since 1940.

The drainage area for the Trinity River above the Liberty station totals 45,242 km² (17,644 mi²) (Dougherty, 1980). Maximum discharge measured at the Liberty gauge was 3,230 m³/s (114,084 ft³/s) on May 12, 1942, which corresponded to a gauge height of 8.955 m (29.37 ft). The gauge datum is 0.68 m (2.23 ft) below mean sea level. Peak flood elevation at Liberty was 8.275 m (27.14 ft) above sea level. Dougherty (1980) stated that the 1942 discharge maximum was the greatest since at least 1903. The most recent discharge data in Dougherty (1980) are from 1975. In 1994, more recent data reported from the U.S. Geological Survey's National Water Information System (<http://waterdata.usgs.gov/nwis/>) show that peak discharge since 1975 was 3,823 m³/s (135,028 ft³/s), corresponding to a gauge height of 9.45 m (31.00 ft) and an elevation of 8.77 m (28.77 ft) above the 1929 National Geodetic Vertical Datum. Over the century represented in the pre- and post-1975 monitoring, the peak flood elevation was sufficient to inundate the floodplain adjacent to the experiment site at typical elevations of 2 to 6 m (6.5 to 20 ft) above sea level. Trinity water elevations reached during the extreme floods of 1942 and 1994 were more than 10 m (>33 ft) below the land-surface elevation of about 20 m (~66 ft) above sea level at the experiment site on the upland.

4.1.8 Wetlands

The experiment site, located in a low-relief, high-rainfall area on the upland adjacent to the Trinity River valley, is near wetlands identified both in the *Atlas of the Submerged Lands of Texas* (White and others, 1985) and on wetland maps published by the U.S. Fish and Wildlife Service. White and others (1985) depicted the experiment site as an upland environment that is about 400 m (~1,300 ft) west of the Trinity River floodplain margin and elevated 14 to 18 m (46 to 59 ft) above it. Wetlands on the modern floodplain nearest the site are classified as WL (woodlands in fluvial areas), where water-tolerant trees and shrubs are found on river floodplains and in poorly drained areas, and as FH (high marsh), where fresh-water plants make up the vegetation assemblage.

National Wetlands Inventory maps (U.S. Fish and Wildlife Service, 1997; see Cowardin and others, 1979, for basis) depict the wetlands habitats at the experiment site at the 7.5-minute quadrangle scale (fig. 13). Mapped units at the site are classified as U (upland); adjacent and nearby mapped units are PFO1A, PEM1C, and PUBFx on the upland, PFO1C on the bluff, and PFO1/2F and PEM1F on the Trinity floodplain adjacent to the site. The “U” classification, which encompasses the actual experiment site (fig. 14a), denotes an upland environment (nonwetland). Unit PFO1A is mapped on the topographic upland adjacent to the “U” (upland) unit but is classified as a palustrine forested unit with broad-leaved deciduous trees (fig. 14b). The Palustrine System designation (units beginning with the letter P) includes “all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens” (Cowardin and others, 1979). Unit PEM1C, located 100 m (325 ft) west of the site, is classified as a palustrine, emergent, persistent, and seasonally flooded wetland. Unit PUBFx, located about 200 m (~650 ft) west of the site, is classified as an excavated, semipermanently flooded palustrine wetland with an unconsolidated bottom.

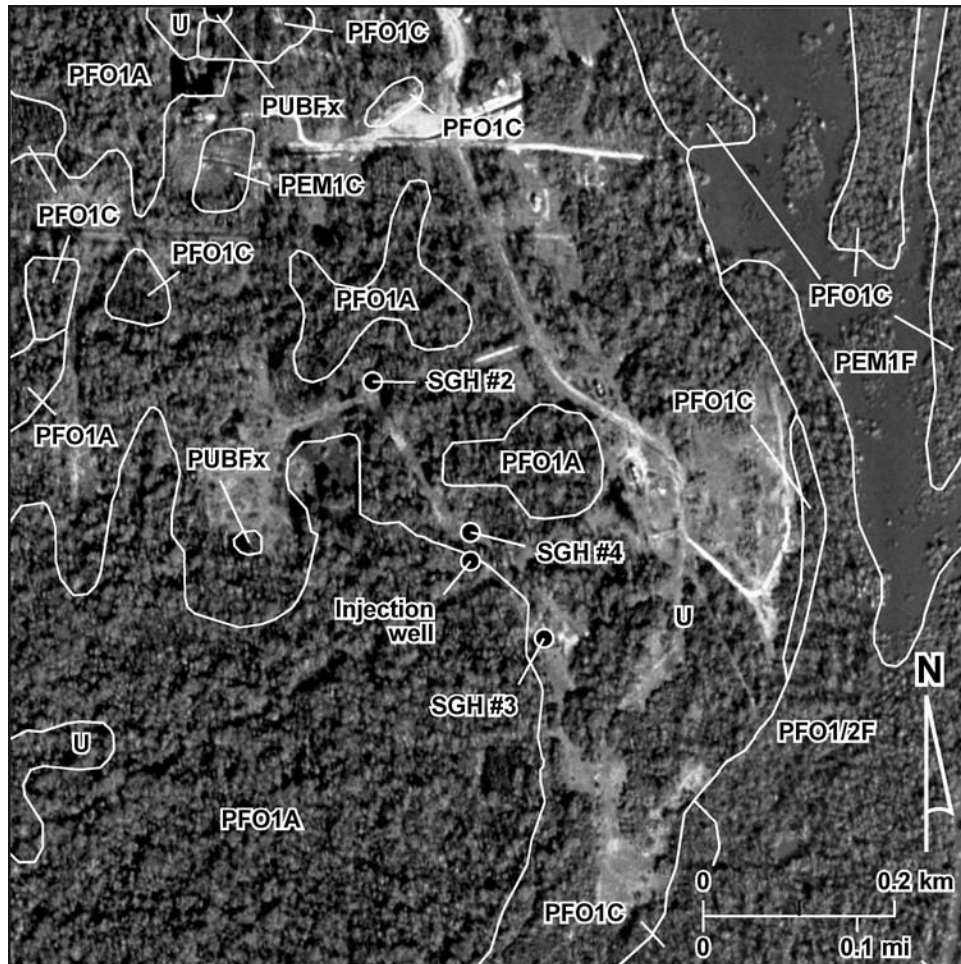


Figure 13. Distribution of mapped wetlands units at the experiment site. Wetlands units are those of the National Wetlands Inventory (U.S. Fish and Wildlife Service, 1997). PEM1C = palustrine, emergent, seasonally flooded; PEM1F = palustrine, emergent, semipermanently flooded; PFO1A = palustrine, forested, broad-leaved deciduous trees; PFO1C = palustrine, forested, broad-leaved deciduous trees, seasonally flooded; PFO1/2F = palustrine, forested, broad- and needle-leaved deciduous trees, semipermanently flooded; PUBFx = palustrine, excavated, semipermanently flooded, unconsolidated bottom; and U = upland (nonwetland). Aerial photo base modified from Texas Natural Resources Information System.

A



B



Figure 14. Representative photographs of upland vegetation assemblages from the experiment site and surroundings. (A) Upland environment (“U” classification) at the injection site. (B) Mixture of broad-leaved deciduous trees and evergreen trees (Unit PF01A) about 100 m (~330 ft) north of the experiment site. Photos taken during February 2002.

A



B



Figure 15. Representative photographs of lowland vegetation assemblages near the experiment site. (A) Unit PF01C, a palustrine wetland on the bluff between the upland area of the experiment site and the Trinity River floodplain. (B) Unit PEM1F, a semipermanent flooded palustrine emergent habitat within the Trinity River floodplain, at the Sun Fee Lot 45 #1 well pad. Raised well platform accommodates occasional flooding. Photos taken during February 2002.

On the bluff between the upland and the Trinity floodplain, unit PFO1C designates a palustrine wetland composed of broad-leaved deciduous trees that is seasonally flooded (fig. 15a). On the Trinity floodplain, unit PFO1/2F designates a forested palustrine wetland with broad- and needle-leaved deciduous vegetation that is semipermanently flooded. The other nearby floodplain unit, PEM1F, denotes a persistent, semipermanently flooded palustrine emergent habitat (fig. 15b).

4.2 Direct Effects

Direct environmental effects from the proposed action include (1) surface impacts, (2) agents introduced into the subsurface, and (3) leakage of introduced agents back to the surface or groundwater. Risks of unacceptable impacts from proposed activities are low.

4.2.1 Surface Impacts

As noted previously, construction impacts on archeological sites, endangered species, and wetlands are nonexistent or negligible. Traffic impacts from delivery of CO₂ to the site and removal of wastes to disposal facilities are minor. Risks of significant surface leaks of CO₂ are minor, but effects on human health could be significant. The presence of large volumes of compressed CO₂ during the 30-day-or-less injection phase represents a significant health and safety concern because of the high injection pressures (up to 168 bar or 2,454 psi) and asphyxiation hazard posed.

CO₂ is a nontoxic inert gas that is essential for fundamental biological processes in all living things (Benson and others, 2003). Exposure to elevated concentrations can cause adverse reactions. At concentrations between 3 and 5% (30,000 and 50,000 ppm), humans experience discomfort and impacts on respiratory rate. Loss of consciousness can occur above 5% (50,000 ppm) and occurs within seconds at concentrations above 25 to 30%, at which point death is imminent (Benson and others., 2003). CO₂ is denser than air and can concentrate in low-lying or confined areas if not dispersed or mixed with air by winds. Contingency plans for large-scale CO₂ leaks will be prepared by Sandia Technologies, complete with an audible and visual warning system, escape procedures, and emergency notification plans. A site-safety training plan designed by a safety expert with substantial experience in CO₂ EOR operations will be administered to all on-site personnel. In addition, the site will be staffed by trained personnel at all times during the time when CO₂ is being stored or injected at the site. Relevant health and safety procedures, such as the Emergency Planning and Community Right-to-Know Act (EPCRA, or SARA Title III), will be followed.

4.2.2 Subsurface Impacts

Direct effects to the subsurface environment from introduction of CO₂ will have minimal environmental impact because of the relatively small volume introduced and the isolated nature of the setting. Introduced tracer materials will have negligible impacts because of the small volumes and benign nature of the materials. Table 5 lists the chemicals selected as tracers, along with any potential harmful impacts. These include perfluorocarbons and noble gases. MSDS sheets for these materials are provided in Appendix A. None of these materials is listed in 40 CFR 261 Subpart D.

Table 5. Tracer materials to be used and their concentrations.

Tracer	Concentration (Injectate)	Concentration (Produced Fluids)	Maximum total weight	Comments
FLUTEC-TG PMCH (perfluoromethylcyclohexane)	30 ug/mL (30 ppm)	1 ng/mL (1 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG PTMCH (perfluoro-1,3,5-trimethylcyclohexane)	30 ug/mL (30 ppm)	1 ng/mL (1 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG o-PDMCH (perfluoro-1,2-dimethylcyclohexane)	30 ug/mL (30 ppm)	1 ng/mL (1 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG m-PDMCH (perfluoro-1,3-dimethylcyclohexane)	7 ug/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG p-PDMCH (perfluoro-1,4-dimethylcyclohexane)	7 ug/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG PMCP (perfluoromethylcyclopentane)	30 ug/mL (30 ppm)	1 ng/mL (1 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG PDMCB (perfluorodimethylcyclobutane)	7 ug/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
FLUTEC-TG PECH (perfluoroethylcyclohexane)	7 ug/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Maximum total Perfluoro-carbons: 60 kg.	No known human- or eco-toxicity
²⁰ Ne (Neon 20)	30.3 ppm	Variable	0.63 kg	No known human- or eco-toxicity
³⁶ Ar (Argon 36)	164 ppm	Variable	3.42 kg	No known human- or eco-toxicity
⁸⁴ Kr (Krypton 84)	7.64 ppm	Variable	0.16 kg	No known human- or eco-toxicity
¹³² Xe (Xenon 132)	0.4 ppm	Variable	0.01 kg	No known human- or eco-toxicity
Eosin	1 ppm	5 ppb	10kg	No known human- or eco-toxicity

Perfluorocarbons are used in human medical treatments, and noble gases are chemically inactive. A maximum total of 60 kg (132 lb) of perfluorocarbon tracers will be used during the experiment, with maximum concentrations in the injectate of 30 ug/mL (30 ppm) and those at the monitoring well at the radial distance of 30 m (100 ft) lower than 1 ng/mL (1 ppb). A maximum of 4.22 kg (9.33 lb) of noble gases will be used. Concentrations in the injectate will range from 0.04 to 164 ppm, depending on the gas type. Concentrations at the monitor well will vary from 100 % of the gas phase initially to no concentration several days after injected gases reach the monitor well. Eosin fluorescent dye approved for use in groundwater tracing and has been widely used in

drinking water and environmentally sensitive areas. Less than 10 kg will be added to the hydrologic test brine before reinjection to the subsurface, producing concentrations in the ppm range.

Shot holes for the 3-D VSP will leave minor amounts of residue within shallow saturated zones. A biodegradable explosive such as Dynoseis®, which contains sodium perchlorate and diethylene glycol, will be used instead of more traditional and less expensive, but potentially more harmful, explosives such as Pentalite. Shot holes will be filled following use, and the soil compacted.

4.2.3 Potential Leakage Impacts

Risks associated with return of injected CO₂ to groundwater or the surface are low. The injection zone is overlain by a 75-m-thick (250-ft) shale and approximately 1,375 m (~4,500 ft) of interbedded sandstone and shale that serve as alternating barriers to vertical migration and sinks for any escaped CO₂. Incremental pressures throughout the injection phase will be controlled and below regulatory limits established by TCEQ in adherence to U.S. Environmental Protection Agency rules. Limits are designed to prevent migration of injected fluids out of the injection zone over a 10,000-year period. Numerical modeling indicates that CO₂ will not travel more than 200 m (>650 ft) from the injection well. Under experiment conditions, faults will not be conduits for fluid or gas escape. Monitoring, which is the central focus of this experiment, will provide assurance that the CO₂ in the subsurface is performing as predicted. Preinjection engineering and during-injection monitoring will provide assurance that the wells are not leaking fluids or gasses.

To evaluate the potential impact of a leak at a theoretical site where these assurances are not present, we have investigated the fate and transport of a release from the injection interval equivalent to 10% of the total CO₂ injected. The most likely case is that the rising gas would be retained in the pores of the sandstones through which it ascends by capillary forces and residual saturation effects. If the gas were to rise along a conduit in which it had little contact with porous rock, a significant percentage could reach either the groundwater or the ground surface.

If the CO₂ were to ascend into an aquifer, impacts would be minor. Dissolution of CO₂ in water decreases pH (increases acidity) slightly. Chemical reactions between the acid waters and the surrounding rock moderate this reaction, limiting pH changes. Modeling by LLNL (K. Knauss, LLNL, personal communication) indicates that pH would be reduced from 6.74 to 5.28 for a radial distance of less than 20 m (<65 ft) from the leak point, assuming an aquifer of 6-m (20-ft) thickness, salinity of <1,000 ppm, and rate of leakage equivalent to rate of injection. A statewide database of water well locations maintained by the Texas Water Development Board records no water wells within 1 km (0.6 mi) of the proposed injection well. The nearest known residential water well (well 64-02-102) is located on the Pleistocene upland about 1,250 m (~4,100 ft) northwest of the injection well. This well, drilled in 1972 to a depth of 73.2 m (240 ft), produces water from the Chicot aquifer. A field survey will be conducted prior to injection operations to locate undocumented water wells within a 402-m (0.25 mi) radius of the injection well. Any wells within this area will be monitored for changes in pH during the experiment. We will drill three monitoring wells near the injection well to monitor shallow groundwater.

In the unlikely event that CO₂ were to ascend to ground surface, impacts would be minor. Numerical modeling by Oldenburg and others (2002a, b) demonstrates that CO₂ rising from the subsurface will collect in the unsaturated zone and spread laterally, accumulating to nearly 100% vapor concentration in the shallow soil because its density is greater than that of air. Only when the unsaturated-zone pore space is filled with CO₂ would significant flux to the atmosphere occur (Oldenburg, 2002a). Under conditions of significant leakage, topographic lows and enclosed subsurface structures such as basements could accumulate significant concentrations of CO₂ from the unsaturated zone. Any such points within 400 m (0.25 mi) of the experiment site will be identified and monitored during and following CO₂ injection.

Increasing concentrations of CO₂ in soil gas could forewarn of a potential flux to the atmosphere. The grid of groundwater and soil-gas sample points established on the well pad and at other potential leak sites (see Preinjection Activities section) will be monitored throughout the injection and postinjection phases.

At the end of a long chain of unlikely events is the possibility that CO₂ might seep into the atmosphere because high flux rates through groundwater or limited pore space in the unsaturated zone fills the unsaturated zone, creating flux to the surface. Oldenburg and others (2002a) modeled a scenario where subsurface flux rates equivalent to 10% of project volumes returned to the surface over a 1-year period. CO₂ concentrations at ground level near the leak site would be nearly 100%, but would dissipate to background atmospheric concentrations within about 28 m (~90 ft) in wind speeds typical of the experiment location (7.2 km/hr).

Impacts of introduced agents that might leak to the groundwater or surface are negligible. As shown in table 5, perfluorocarbon and noble gas tracers to be used have no known toxicity.

5.0 REGULATORY COMPLIANCE

5.1 State Permitting Requirements

State permitting requirements have been discussed with the two Texas agencies that have possible jurisdiction over the drilling and injection activities envisioned for this experiment. Discussions regarding State regulatory requirements have been held with Richard Ginn, Director of Underground Injection Control (UIC) at the Railroad Commission of Texas (RRC) and Ben Knape, Team Leader, UIC Permits, Texas Commission on Environmental Quality (TCEQ).

The UIC program consists of five classes of wells, from I to V, each generally requiring a permit for operation under Texas Water Code, Chapter 27, and Texas Health and Safety Code, Chapter 361 (Class II wells fall under different codes). Federal guidelines for UIC wells have been established by the Environmental Protection Agency (EPA). The Texas Commission on Environmental Quality (TCEQ) and the Texas Railroad Commission (RRC) have been delegated authority by EPA under delegated programs to administer UIC programs in Texas that are at least as stringent as those adopted by EPA. Additional rules governing the various classes can be found in Title 30 of the Texas Administrative Code, Chapter 331, with supporting information and rules in Chapters 1–100, 281, and 305. Class I wells are used for long-term injection of hazardous and nonhazardous wastes and are permitted by the State environmental quality agency (TCEQ). Class II wells are designated for injection of water or other chemicals into existing oil and gas reservoirs or injection of oilfield wastes into nonreservoir intervals and are permitted by the State oil and gas regulatory agency (RRC). UIC Class III is reserved for wells that inject fluids for extraction of minerals other than oil and gas. The Class IV category applies to wells that dispose of hazardous wastes above formations that contain underground sources of drinking water and are generally prohibited. Class V wells are those that are not included in Classes I through IV. Class V wells have numerous purposes ranging from disposal of storm runoff and motor vehicle waste to aquifer recharge and remediation. One Class V category is “experimental” wells for subsurface fluid distribution, under which this project will be permitted.

Because the injection interval is not an oil or gas reservoir, and because the source of the injected CO₂ is postrefinery, the project falls under the jurisdiction of the UIC program at TCEQ. Further discussions with TCEQ regarding the short duration of the experiment and the small volume of gas injected resulted in a request for us to submit an application for a Class V well, accompanied by a report providing relevant additional information typically required in Class I filings. A public information meeting will also be held in the community, hosted by the Bureau of Economic Geology, wherein local citizens, public officials, local and regional political representatives, and other interested stakeholders are invited to review the project plan and provide nonbinding comment. Public comment will be considered, and any appropriate adjustments to the field plan will be made.

The TCEQ Class V application includes responsible-party contact information, well-site information, downhole design, and a review of hydrogeological data, including information about formation water chemistry, relationship to aquifers, and locations of injection or water wells within a one-quarter-mile radius. The additional report to be delivered to TCEQ will include

- a detailed land-ownership map with contact information,
- additional detailed site information (relationship of the site to government entities and jurisdictions),
- contact information for local government agencies and political representatives,
- financial assurance for site closure,
- a concise description of the geologic and hydrogeologic setting,
- engineering drawings and plans for surface and subsurface equipment approved by a registered professional engineer,
- a discussion of injection zone mechanics that includes flow-simulation model results indicating expected changes in pressure and injectate saturations through time,
- an Area-Of-Review (AOR) study documenting all wells and their current condition within 402 m (0.25 mi) of the pilot wells,
- a discussion of injected fluids and their expected reactivity with formation and construction materials, and
- a letter from the RRC indicating that activities will not adversely affect any known hydrocarbon accumulations.

6.0 CUMULATIVE AND INDIRECT EFFECTS AND LONG-TERM ENVIRONMENTAL CONSEQUENCES

Cumulative impacts are those that result from the incremental impact of the proposed project when added to other past, present, and reasonably foreseeable future actions. They include direct impacts caused by the proposed action and that occur at the same time and place as the project and indirect impacts that can reasonably be foreseen that result from the proposed project and that occur later in time or farther in distance from the project site. Direct cumulative effects of this proposed project are limited because of the short duration of field activities, and are expected to span only several months, with the injection phase lasting less than 1 month. Indirect cumulative effects predominantly relate to long-term fate of the injected CO₂ and the risk of it escaping from the injection zone, as well as the difficult-to-foresee impacts of project success on the number of active domestic sequestration projects.

6.1 Direct Cumulative Effects

Direct cumulative effects considered include traffic impacts of CO₂ transportation, traffic and capacity impacts associated with disposal of produced water, impacts on flora and fauna of proposed field activities, and noise- and light-pollution impacts of nighttime operations.

Cumulative transportation impacts are minimal, and specific actions will be taken to mitigate anticipated effects. The 10 CO₂ truckloads per day during the comparatively short injection phase are minor in comparison to moderate to heavy commercial, agricultural, industrial, and private traffic on planned routes. Transport during typical commuting hours will be avoided along Highway 146 between Seabrook and the east end of Baytown.

Disposal of less than 30 truckloads of produced brine, a nonhazardous material, will entail an approximately 22.5-km (~14-mi) drive along public rural roads over 4 days and will not result in significant cumulative effects. A maximum of 595 barrels (5 truckloads) of produced water will be disposed of each day into a commercial UIC Class I nonhazardous disposal well with capacity for up to 950,000 gallons per day that typically receives other deliveries amounting to less than 150,000 gallons per day. A maximum of 7,000 barrels (bbl) (60 truckloads) of drilling fluids will be disposed of at a TCEQ-permitted disposal facility approximately 48 km (30 mi) from the field site. Drilling-fluid disposal will be spread over at least 6 days, reducing traffic impacts. The disposal well has a capacity of 20,000 bbl/day with a typical use of 1,200 bbl/day. Delivery of about 1,000 bbl/day should have no cumulative impact on the facility.

Cumulative effects to flora and fauna will be minor and local. The project will impact less than 2 additional hectares (5 acres) of habitat in an oilfield where exploration and development activities span an area of 6,980 hectares (17,280 acres).

Drilling, work-over, and CO₂ injection activities may occur at night. Associated light and noise impacts are minimized by the 0.6-km (0.35-mi) distance between the well

site and the nearest residence and the limited duration of intensive drilling and injection activities.

6.2 Indirect and Indirect-Cumulative Effects

Indirect and indirect-cumulative effects include the long-term fate of injected CO₂, the postproject disposition of the three wells used, the potential for increased drilling and land use in the project area associated with potential project success, and the impacts of increased sequestration activities throughout the U.S.

6.2.1 Fate of Injected CO₂

A primary goal of the project is to document the fate of injected CO₂. Numerical modeling and accumulated knowledge of behavior of fluids and gases in the subsurface suggest that the CO₂ will stay within the injection zone and travel less than 200 m (650 ft) from the injection well (Doughty and Pruess, 2003). Alternative models have been constructed to investigate possible but unexpected scenarios, including leaks upward such as (1) through overlying formations, (2) along well-bore annuli, and (3) along faults. Factors that diminish the escape risk include (1) the presence of the 75-m-thick (250-ft) Anahuac Shale with documented capability to retain gases for geologic time spans above the injection zone and the overlying 1,475-m-thick (4,500-ft) section of interbedded sandstones and shales, (2) the presence of remnant drilling mud in well-bore annuli of a density sufficient to contain anticipated pressure increases outside the 402-m (0.25-mi) Area of Review (AOR) established by TCEQ, and (3) planned maximum fluid pressures 22 percent below those calculated to induce seismicity and fault leakage. No significant identifiable risks to human health, safety, or the environment have resulted from these alternative scenarios. Discussions in the Direct Effects section address impacts of an unlikely release of all CO₂ to the surface or an aquifer. Numerical models will be refined using site-specific data after field activities begin but before any CO₂ is injected.

Subsurface numerical models were constructed at Lawrence Berkeley National Laboratory using TOUGH2 code (Doughty and Pruess, 2003). The models incorporate reasonable scientific assumptions (Pruess and others, 1999; Holtz, 2003) and geologic assessments based on regional knowledge of the injection horizon (Doughty and others, 2000; Hovorka and others, 2000; Doughty and Pruess, 2003) and site-specific geotechnical data derived from well logs and a 3-D seismic survey (fig. 16). Knowledge of subsurface fluid behavior comes from the multitude of engineering and geologic studies done of subsurface-oil and gas-reservoir characteristics.

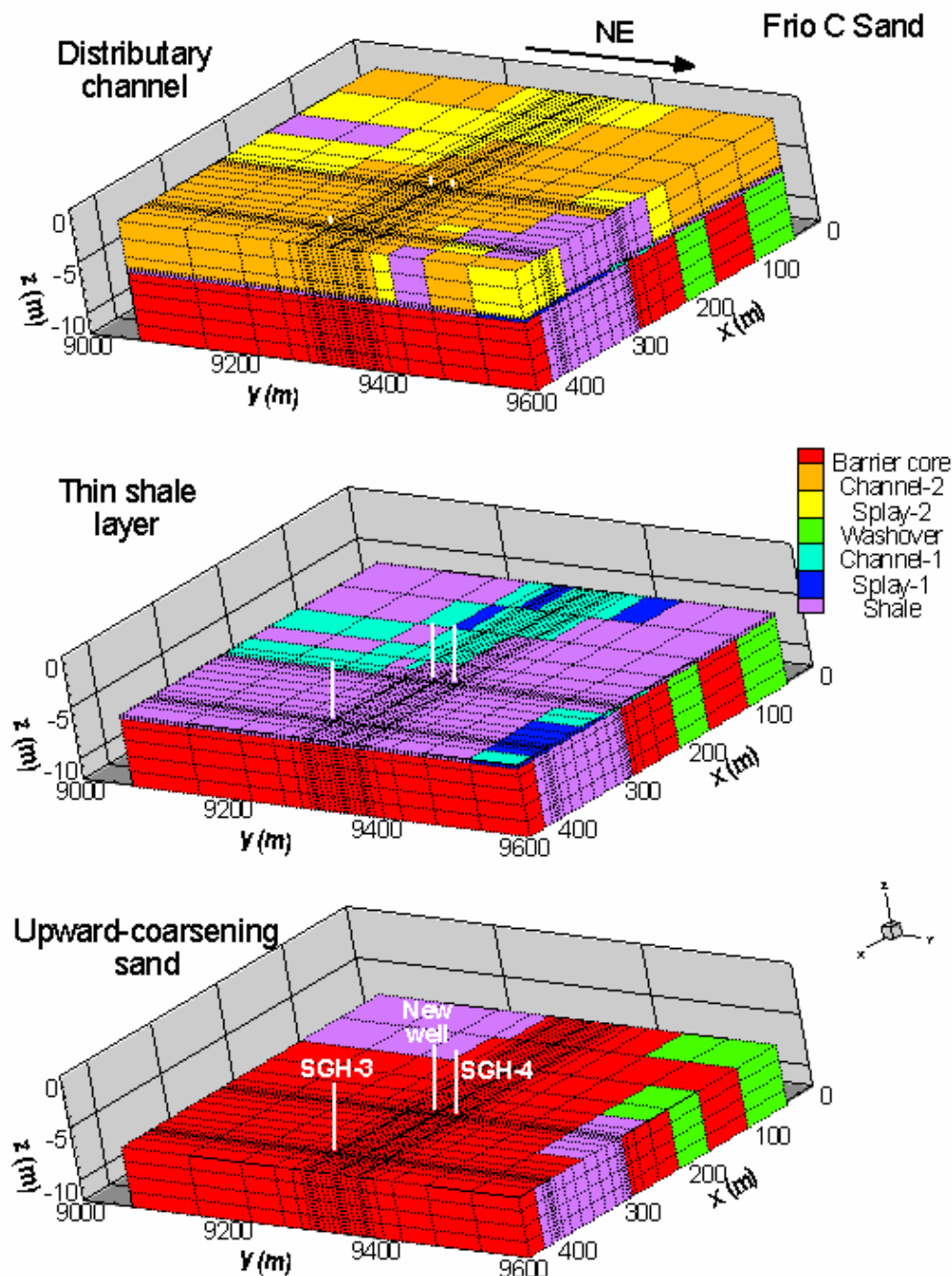


Figure 16. Numerical simulation model construction parameters for the “C” sand (injection interval). A thin shale in the middle of the sandstone separates a lower upward-coarsening sandstone deposited in a probable delta front setting from a dominantly upward-fining sandstone deposited in a distributary channel. North is toward the right side of the images. Grid refinement around well bores allows greater detail in imaging injection response. Simulation grid prepared by Christine Doughty, LBNL.

Models show that the CO₂ injected into the subsurface during the experiment will behave buoyantly because of its low density (0.6 grams/cm³) compared with that of native formation brines (1.075 grams/cm³). The buoyant plume of concentrated immiscible CO₂ will migrate updip within the injected stratigraphic interval toward the salt dome (fig. 9). Some percentage of the CO₂ will be left behind the migrating plume as it is trapped in rock pores by capillary behavior and relative permeability effects (Wardlaw, 1982; Holtz, 2002). Holtz (2003) indicated that, for the ranges of porosities in the injection interval, as much as 30% of the pore space will sequester the CO₂ in what is termed *residual saturation*. Numerical flow simulation models constructed on this basis suggest that the plume will stop moving entirely within 5 years after moving less than 200 m (<650 ft) updip (fig. 17). The CO₂ will remain in place at least until local geologic conditions change significantly, a time period expected to exceed 1,000 years.

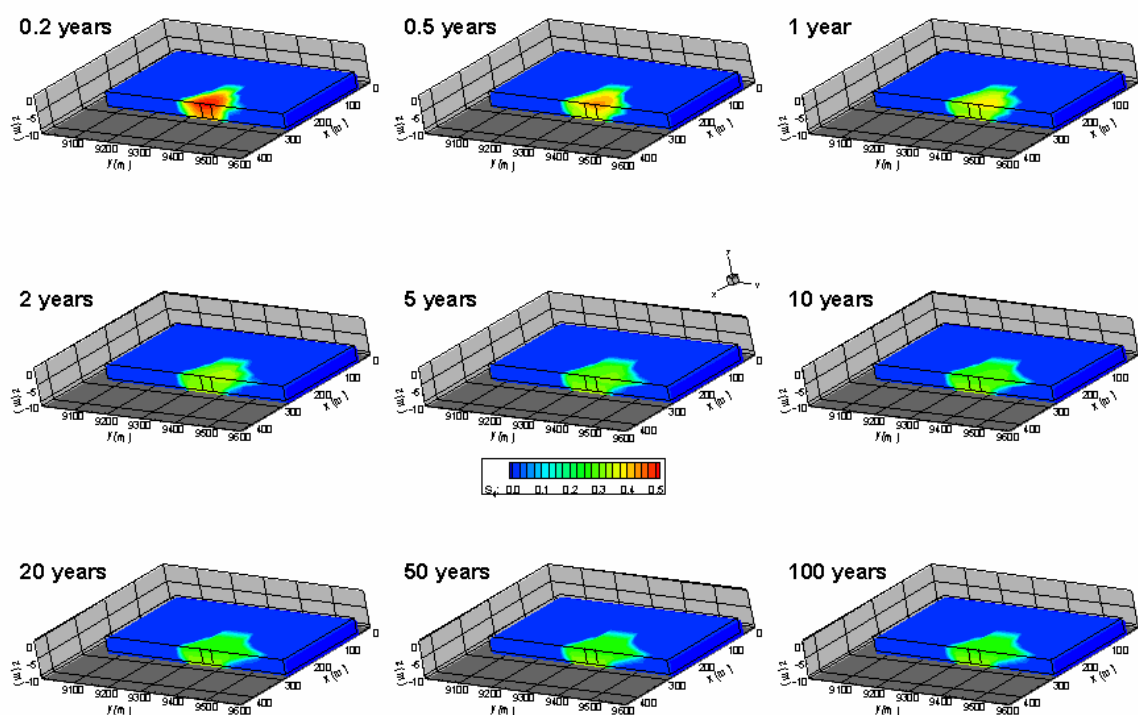


Figure 17. CO₂ saturation distributions around the injection well from 0.2 to 100 years after injection begins. Model uses best estimates of porosity and residual gas saturation. The model block is tilted up toward the northeast. Note that very little movement of the plume occurs after the initial injection period. Simulation results from TOUGH2 prepared by Christine Doughty, LBNL.

If the current understanding of residual saturation behavior or subsurface pressure conditions is inaccurate, the CO₂ could continue migrating updip to the north within the injection interval. The faults to the northwest and southeast of the injection well would focus the plume as it moves up and is trapped against the salt dome. Such a scenario

could be produced, as shown by numerical modeling, if residual saturation were actually 5%, as opposed to the 30% estimated (figs. 18, 19).

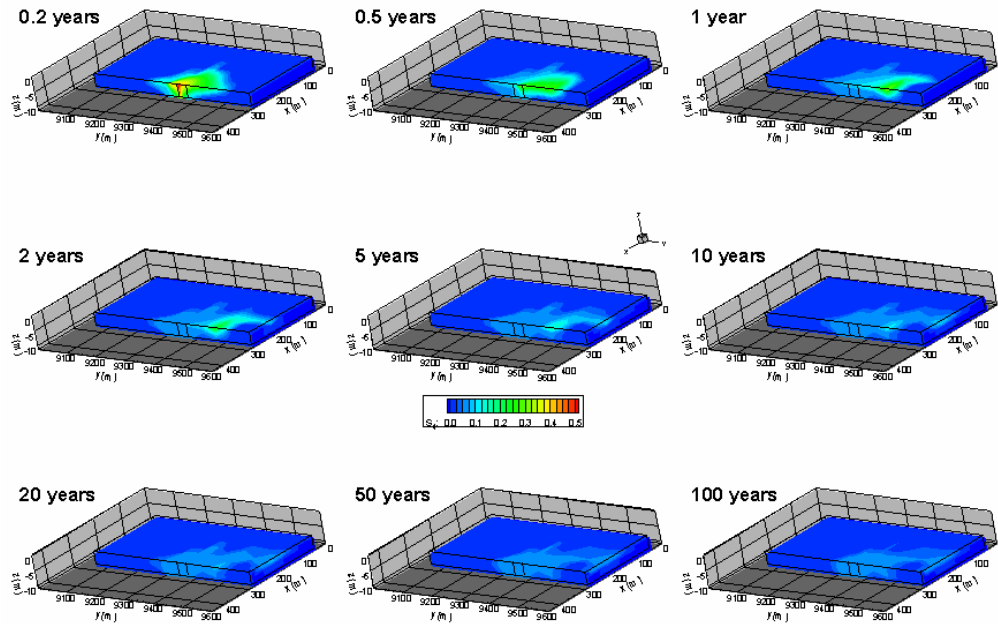


Figure 18. CO₂ saturation distributions around the injection well for low-residual gas saturation case from 0.2 to 100 years after injection begins. Model uses best estimates of porosity and a maximum of 5% residual gas saturation. The model block is tilted up toward the northeast. Note that the plume continues to migrate updip for perhaps 10 years before being immobilized by the residual gas saturation effect. Simulation results from TOUGH2 prepared by Christine Doughty, LBNL

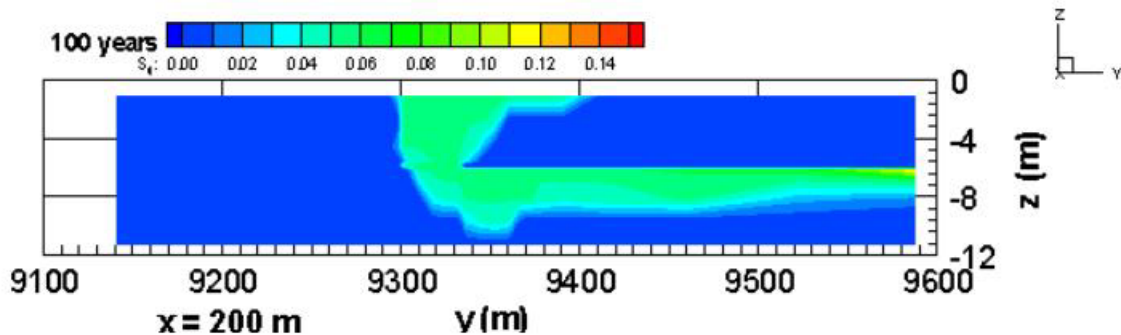


Figure 19. CO₂ saturation distributions in northeast-southwest (dip) section cross-sectional view of injection zone for low residual gas saturation case at 100 years after injection begins. Updip is to the right in this section through the center axis of the model. CO₂ has escaped from the lower half of the “C” sandstone through a theoretical break in a thin shale midway up the sandstone body. Only the plume in this half of the sandstone has sufficient volume to continue migrating to the updip end of the model. Simulation results from TOUGH2 prepared by Christine Doughty, LBNL.

. In such a mobile plume, the dominant risk is that the plume might encounter a conduit leading up and out of the injection zone. Possible conduits include (1) cross-formational flow (discontinuous seal), (2) well-bore annuli, and (3) faults, including the interface between the formation and the salt dome. Each is unlikely, for the following reasons:

- In addition to the two 3-m-thick (10-ft) laterally continuous shales separating the injection zone from overlying sandstones in the Frio Formation, the injection zone is overlain by the 75-m-thick (250-ft) Anahuac Shale. This shale has retained both oil and gas over geologic periods of time at the South Liberty Salt Dome, as evidenced by the presence of oil and gas reservoirs in the uppermost Frio sandstones (Halbouty, 1962). Additionally, maximum subsurface pressures, on the basis of LBNL models, during the experiment of 169 bar (2,469 psi) are 35% below the fracture pressure as calculated by the Eaton method (Eaton, 1969).
- Well bores within the 402-m (0.25-mi) Area of Review (AOR) established by the TCEQ will be assessed for proper completion or abandonment using RRC file data and will be remediated if found to be noncompliant. Annuli of surrounding wells outside the AOR are filled with 9 lb/gal drilling mud present in the well before emplacement of casing. Incremental formation pressures outside the AOR during the experiment of less than 10 bar or 141 psi are 12% below the Critical Incremental Pressure of 11.4 bar (166.4 psi) required to overcome the hydrostatic head of the mud column. This rationale for assessment of upward leakage potential was established by TCEQ for UIC operations. Adherence to these conditions is a prerequisite of the Class V application approval. For a Class V well to qualify for a TCEQ permit, wells within the AOR must have cemented casing emplaced below the base of Usable Quality Groundwater (TDS < 3,000 ppm). In the unlikely event that CO₂ did overcome mud-column heads in the annulus, the cemented casing would prevent the gas from entering aquifers.
- ambient confining pressures keep faults at depths greater than 1 km (~ 3,000 ft) closed to fluid migration unless fluids are injected into the fault plane at excessive fluid pressures (Rasmussen, 1997) or unless the fault slips (Hooper, 1991). A lack of fault scarps at the surface indicates that faults in the area have not been active in the recent geologic past. Injection-induced excess fluid pressures can reactivate faults (Wesson and Nicholson, 1987). Maximum fluid pressures of 169 bar (2,469 psi) associated with the proposed project are 22% below the 264 bar (3,853 psi) calculated by the Wesson and Nicholson (1987) method as likely to induce seismicity.
- If unforeseen events were to occur and the CO₂ gradually escaped to an aquifer or to the surface, impacts would be minor and limited in geographic extent. The conditions of immediate escape of CO₂ have been addressed previously in the Direct Effects section. Cumulative or indirect impacts, by definition, would occur over longer periods of time and have less impact than that described previously. Following completion of injection, subsurface pressure anomalies will decay as the pressure pulse is absorbed by the surrounding formation volume. Potential for rapid leakage is reduced as the plume spreads and pressures decline. Gradual leakage would be at substantially reduced rates, increasing chances for broad, slow dispersion in water-saturated sediments or near-surface soils and preventing buildup of dangerous levels of CO₂ in the air around the experiment site.

As discussed previously in the Direct Effects section, groundwater-dissolved gases and soil gases will be monitored for increases in CO₂ above baseline values. This and other monitoring will decrease in frequency as measurable pressure and temperature effects in the subsurface decay over time. Monitoring will cease when asymptotic values of change occur, which is anticipated within 1 year after the end of injection.

6.2.2 Postproject Well Disposition

Following project completion, the three wells used in the project will be abandoned in, accordance with Rule 14, section 3.14 of the RRC “Statewide Rules for Oil, Gas, and Geothermal Operations,” or converted to another use authorized by DOE, RRC, and TCEQ. Neither of these alternatives would have significant cumulative effect on the South Liberty oilfield, where similar activities are routine for the hundreds of existing wells in the field.

6.2.3 Increase in Sequestration Activities in the Pilot Area

The pilot site was not selected because of any perceived potential for larger-scale operations in the same area, but because it possessed suitable technical attributes for a small-scale project. Success of the pilot may increase interest in larger projects, perhaps in the same general area. Any such project would require considerable further study, including assessing potential environmental impact and obtaining disposal permits.

6.2.4 Increase in Domestic Sequestration Activities

With the success of this and other sequestration experiments, government and industry will have the option to manage atmospheric CO₂ concentrations through geologic sequestration. Operation costs will dictate that sequestration will be distributed in many areas near major CO₂ sources. Many of these areas are likely to be existing oil and gas fields, where impacts would be incremental and minimal. Where CO₂ sources are present but oil and gas fields absent, sequestration options include (1) piping or trucking to some distant location where an existing oil or gas field can be used or (2) drilling a well to inject CO₂ into a brine-bearing formation locally. Economic and logistical lessons learned from the proposed experiment will help determine which of these approaches is most feasible.

7.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Principal resources employed in the proposed CO₂ injection and monitoring experiment are: (1) the materials (steel, water, and cement) required to drill a new injection well and refit the existing monitoring well; (2) the CO₂ required to create the subsurface plume; (3) the fossil fuels consumed in drilling, refitting, and sampling wells and in transporting CO₂ and wastes; and (4) minor amounts of timber cleared during extension of well pads and drilling of shot holes for the 3-D VSP. For the new injection well, several truckloads of caliche road base will be needed to expand the existing well pad to drill a new well, up to 6,000 barrels of water for drilling mud will be needed to advance the drill bit to an estimated depth of 1,820 m (6,000 ft) and return cuttings to the surface, steel surface and injection casing will be installed to protect shallow, fresh groundwater and permit injection at the selected stratigraphic interval, and steel wellhead valves and pipes will be installed to allow CO₂ injection. The 3,750 tons of CO₂ to be consumed represents a commercial market value of approximately \$375,000. CO₂ to be used for the project would otherwise have been vented to the atmosphere as a waste. Fossil fuels, primarily diesel, will be used by the drilling and work-over rigs and by the trucks hauling 165 loads of CO₂, produced water, and drilling fluids.

8.0 ENVIRONMENTAL CONSEQUENCES OF THE NO- ACTION ALTERNATIVE

Under the No- Action Alternative, there would be no change in current hydrocarbon extraction activities or other uses at the South Liberty Oilfield. The minimal local environmental consequences associated with drilling a new well (well-pad expansion, mud-pit excavation, and well drilling) would be avoided. The experiment to inject 3,750 tons of CO₂ into a subsurface saline aquifer, monitor the lateral migration of the CO₂ plume, and assess the performance of stratigraphic sealing horizons in sequestering CO₂ underground would not be conducted. The 3,750 tons of CO₂ that would have been injected into the subsurface would be released to the atmosphere. Underground CO₂ sequestration in saline aquifers is one of the viable approaches being evaluated for maintaining or reducing climate-altering greenhouse gas concentrations in the atmosphere. In addition to losing the opportunity to sequester a small amount of CO₂ in a geological repository, we lose the opportunity to evaluate the technical approach and feasibility of CO₂ sequestration in a saline aquifer specifically selected for its favorable sequestration potential.

9.0 SIMILAR ACTIONS AND ACTIONS BEING CONSIDERED UNDER OTHER NATIONAL ENVIRONMENTAL POLICY ACT REVIEWS

The proposed action, for DOE support in evaluating the suitability of CO₂ sequestration in deep saline aquifers, is not similar to any other action being considered (or currently being implemented) by DOE.

This action is not a segment of any other action for which review under NEPA would be required. This project will help provide information for a large-scale geologic sequestration project being planned for West Virginia. The West Virginia project, supported by DOE and being conducted by American Electric Power Company (AEP) and Battelle Memorial Institute, is in the data-collection phase, which does not require NEPA review.

10.0 RELATIONSHIP OF THE PROPOSED ACTION TO APPLICABLE FEDERAL, STATE, REGIONAL, OR LOCAL LAND USE PLANS AND POLICIES

The proposed project requires no substantive change in the current land use as an operating oilfield. The proposed incremental enlargement of an existing well pad, the drilling of a new well, and monitoring of CO₂ at an existing well represent no substantive change to the current use of the land. Similar drilling and fluid-extraction activities have been ongoing in the area since hydrocarbon production began in the 1920's.

11.0 CONSULTATION AND PUBLIC PARTICIPATION

11.1 Consultation

The agencies and organizations contacted during environmental assessment of the proposed project are identified in table 6. Copies of correspondence exchanged with those agencies and organizations are provided in Appendix B.

Table 6. Agency and organization contacts.

No.	Agency contacted	Date	Author	Response Date	Author
1	Texas Archeological Research Laboratory	10/4/2002	Paine	10/7/2002	Azulay
2	U.S. Fish and Wildlife Service	10/9/2002	Paine	10/30/2002	Morgan
3	U.S. Army Corps of Engineers	10/9/2002	Paine	10/9/2002	Dunn
4	Texas Commission on Environmental Quality (Underground Injection Control Section)	Many	Knox	Many	Fred Duffy
5	Texas Commission on Environmental Quality (surface casing and groundwater protection)	12/6/2002	Paine, Knox		Traylor
6	Railroad Commission of Texas	Many	Hovorka, Knox	Many	Ginn
7	Liberty County		Knox		
8	City of Dayton		Knox		
9	City of Liberty		Knox		
10	Texas Department of Health (Radiation Control Section)	3/24/03	Knox	3/24/03	R. Cortez

11.2 Public Participation

A draft Environmental Assessment was issued on [REDACTED] and made available for public review and comment. Copies of the document were provided for review at area libraries and on the Department of Energy/NEGL Web page at www.netl.doe.gov. An announcement of availability (Public Notice) was published in area newspapers.

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**MATERIAL SAFETY DATA SHEET**

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PRODUCT NAME: KRYPTON**1. Chemical Product and Company Identification**

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (908) 464-8100**24-HOUR EMERGENCY TELEPHONE NUMBER:**
CHEMTREC (800) 424-9300**TELEPHONE NUMBER:** (905) 501-1700**24-HOUR EMERGENCY TELEPHONE NUMBER:**
(905) 501-0802**EMERGENCY RESPONSE PLAN NO:** 20101**PRODUCT NAME:** KRYPTON**CHEMICAL NAME:** Krypton**COMMON NAMES/SYNONYMS:** Krypton, compressed**TDG (Canada) CLASSIFICATION:** 2.2**WHMIS CLASSIFICATION:** A**PREPARED BY:** Loss Control (908)464-8100/(905)501-1700**PREPARATION DATE:** 6/1/95**REVIEW DATES:** 6/7/96**2. Composition, Information on Ingredients**

INGREDIENT	% VOLUME	PEL-OSHA ¹	TLV-ACGIH ²	LD ₅₀ or LC ₅₀ Route/Species
Krypton FORMULA: Kr CAS: 7439-90-9 RTECS #: Not Available	99.95 to 99.995	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)² As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents**3. Hazards Identification****EMERGENCY OVERVIEW**

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

ROUTE OF ENTRY:

Skin Contact No	Skin Absorption No	Eye Contact No	Inhalation Yes	Ingestion No
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MSDS: G-54**Revised:** 6/7/96

Page 1 of 6

PRODUCT NAME: KRYPTON

HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No IARC: No OSHA: No

EYE EFFECTS:

None known.

SKIN EFFECTS:

None known.

INGESTION EFFECTS:

None known. Ingestion is unlikely as product is gas at room temperature.

INHALATION EFFECTS:

Product is a non-toxic simple asphyxiant. High concentrations may exclude an adequate supply of oxygen to the lungs. Effect of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

HMIS HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

RATINGS SYSTEM

0 = No Hazard
1 = Slight Hazard
2 = Moderate Hazard
3 = Serious Hazard
4 = Severe Hazard

4. First Aid Measures**EYES:**

None required.

SKIN:

None required.

PRODUCT NAME: KRYPTON

INGESTION:

None required.

INHALATION:

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None		UEL(%): None
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:

None. Nonflammable

EXTINGUISHING MEDIA:

None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical classification:

Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

PRODUCT NAME: KRYPTON

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125°F (52°C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS¹:

INGREDIENT	% VOLUME	PEL-OSHA²	TLV-ACGIH³	LD₅₀ or LC₅₀ Route/Species
Krypton FORMULA: Kr CAS: 7439-90-9 RTECS #: Not Available	99.95 to 99.995	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ Refer to individual state or provincial regulations, as applicable, for limits which may be more stringent than those listed here.

² As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

³ As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:

Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:

Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:

Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:

Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:

Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure at STP	: Not Available	
Vapor density (Air = 1)	: 2.92	
Evaporation point	: Not Available	
Boiling point	: -244	°F
	: -153.3	°C
Freezing point	: -250.9	°F
	: -157.2	°C
pH	: Not Applicable	
Specific gravity	: Not Available	
Oil/water partition coefficient	: Not Available	
Solubility (H2O)	: Negligible	
Odor threshold	: Not Applicable	
Odor and appearance	: An odorless, colorless gas	

10. Stability and Reactivity

STABILITY:

Stable

INCOMPATIBLE MATERIALS:

None

HAZARDOUS POLYMERIZATION:

Does not occur

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

PRODUCT NAME: KRYPTON

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Krypton, compressed	Krypton, compressed
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 1056	UN 1056
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:

Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

DISCLAIMER OF EXPRESSED AND IMPLIED WARRANTIES:

Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to the accuracy or completeness of the information contained herein, and assume no responsibility regarding the suitability of this information for the user's intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for their particular purpose(s).

**MATERIAL SAFETY DATA SHEET**

Distributed by: **MSDS:000004**
Machine & Welding Supply Co.
P.O. Box 1708 Phone: (910) 892-4016
Hwy 301 South Fax: (910)892-3575
Dunn, NC 28335 Internet: www.mwsc.com

PRODUCT NAME: ARGON**1. Chemical Product and Company Identification**

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (908) 464-8100**24-HOUR EMERGENCY TELEPHONE NUMBER:**
CHEMTREC (800) 424-9300**TELEPHONE NUMBER:** (905) 501-1700**24-HOUR EMERGENCY TELEPHONE NUMBER:**
(905) 501-0802**EMERGENCY RESPONSE PLAN NO:** 20101**PRODUCT NAME:** ARGON**CHEMICAL NAME:** Argon**COMMON NAMES/SYNONYMS:** Argon, compressed**TDG (Canada) CLASSIFICATION:** 2.2**WHMIS CLASSIFICATION:** A**PREPARED BY:** Loss Control (908)464-8100/(905)501-1700**PREPARATION DATE:** 6/1/95**REVIEW DATES:** 6/7/96**2. Composition, Information on Ingredients**

INGREDIENT	% VOLUME	PEL-OSHA ¹	TLV-ACGIH ²	LD ₅₀ or LC ₅₀ Route/Species
Argon FORMULA: Ar CAS: 7440-37-1 RTECS #: CF2300000	100.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)² As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents**3. Hazards Identification****EMERGENCY OVERVIEW**

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

PRODUCT NAME: ARGON

ROUTE OF ENTRY:

Skin Contact Yes	Skin Absorption No	Eye Contact Yes	Inhalation Yes	Ingestion No
---------------------	-----------------------	--------------------	-------------------	-----------------

HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No IARC: No OSHA: No

EYE EFFECTS:

No adverse effects anticipated.

SKIN EFFECTS:

No adverse effects anticipated.

INGESTION EFFECTS:

No adverse effects anticipated.

INHALATION EFFECTS:

Product is a non-toxic simple asphyxiant. Effects of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

HMIS HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

RATINGS SYSTEM

0 = No Hazard
1 = Slight Hazard
2 = Moderate Hazard
3 = Serious Hazard
4 = Severe Hazard

4. First Aid Measures**EYES:**

Never introduce ointment or oil into the eyes without medical advice! If pain is present, refer the victim to an ophthalmologist for treatment and follow up.

SKIN:

None anticipated.

INGESTION:

Ingestion is unlikely as product is a gas at room temperature.

INHALATION:

MSDS: G-6

Revised: 6/7/96

PRODUCT NAME: ARGON

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None		UEL(%): None
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:

None. Nonflammable

EXTINGUISHING MEDIA:

None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical classification:

Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125 °F (52 °C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

MSDS: G-6

Revised: 6/7/96

PRODUCT NAME: ARGON

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS¹:

INGREDIENT	% VOLUME	PEL-OSHA ²	TLV-ACGIH ³	LD ₅₀ or LC ₅₀ Route/Species
Argon FORMULA: Ar CAS: 7440-37-1 RTECS #: CF2300000	100.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ Refer to individual state of provincial regulations, as applicable, for limits which may be more stringent than those listed here.

² As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

³ As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:

Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:

Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:

Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:

Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:

Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure	: Not Available	
Vapor density (Air = 1)	: 1.38	
Evaporation point	: Not Available	
Boiling point	: -302.6	°F
	: -185.9	°C
Freezing point	: -308.9	°F
	: -189.4	°C
pH	: Not Applicable	
Specific gravity	: Not Available	
Oil/water partition coefficient	: Not Available	
Solubility (H2O)	: Slight	
Odor threshold	: Not Applicable	
Odor and appearance	: Colorless, odorless gas	

10. Stability and Reactivity

STABILITY:

Stable

INCOMPATIBLE MATERIALS:

None

HAZARDOUS POLYMERIZATION:

Does not occur.

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

PRODUCT NAME: ARGON

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Argon, compressed	Argon, compressed
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 1006	UN 1006
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:

Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

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FAX NO.

DRILLING SERVICES

P. 02

PAGE 02/04

DYNO
Dyno Nobel Inc

MATERIAL SAFETY DATA SHEET
DYNO NOBEL INC
11TH FLOOR CROSSROADS TOWER
SALT LAKE CITY, UTAH 84144
801-364-4900 TELEX 388353
FOR 24 HOUR EMERGENCY CALL 800-424-9300

MSDS# 1093

DATE: 02/05/06

Supersedes MSDS
1093 12/20/05

SECTION I - PRODUCT IDENTIFICATION

Trade Name(s): DYNOSIS™

Product Class: Seismic Explosive

Product Appearance & Odor: White solid with no odor.

DOT Hazard Shipping Description: Substance, Explosives n.o.s.
(Sodium Perchlorate/Diethylene Glycol)
1.1D UN0475

SECTION II - HAZARDOUS INGREDIENTS

Ingredients:	CAS#	% (Range)	TLV-ACGIH
Sodium Perchlorate	7601-89-0	66-72	No Value Established
Diethylene Glycol	111-46-6	22-27	No Value Established

Ingredients, other than those mentioned above, as used in this product are not hazardous as defined under current Department of Labor regulations.

SECTION III - PHYSICAL DATA

Boiling Point: N/A

Vapor Pressure: N/A

Vapor Density: (Air = 1) N/A

Density: 1.85 - 1.85 g/cc

Percent Volatile by Volume: <5

Solubility in Water: Completely soluble

Evaporation Rate (Butyl Acetate = 1): <1

N/A = Not Applicable or Not Available

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

DYNO NOBEL MSDS# 1093
02/05/96
Page 2 of 3

Flash Point: N/A

Flammable Limits: N/A

Extinguishing Media: (See Special Fire Fighting Procedures section).

Special Fire Fighting Procedures: Do not attempt to fight fires involving explosive materials. Evacuate all personnel to predetermined safe location, no less than 2,500 feet.

Unusual Fire and Explosion Hazards: Can explode under fire conditions. Burning material may produce toxic vapors.

SECTION V - HEALTH HAZARD DATAEffects of Overexposure

Eyes: Can cause irritation, redness, and tearing.

Skin: Prolonged contact may cause irritation.

Ingestion: Large amounts may be harmful if swallowed.

Inhalation: May cause dizziness, nausea, intestinal upset.

Systemic or Other Effects: None known.

Emergency and First Aid Procedures

Eyes: Irrigate with running water for at least 15 minutes. If irritation persists seek medical attention.

Skin: Wash with soap and water.

Ingestion: Induce vomiting, seek medical attention.

Inhalation: Remove to fresh air.

Special Considerations: None.

SECTION VI - REACTIVITY DATA

Stability: Stable under normal conditions, may explode when subjected to fire or supersonic shock, or high energy projectile impact especially when confined or in large quantities.

Conditions to Avoid: Keep away from heat, flame, ignition sources, and strong shock.

Materials to Avoid (Incompatibility): Strong acids and alkali.

Hazardous Decomposition Products: Nitrous Oxides (NO₂), Carbon Monoxide (CO), Chlorine (Cl₂), Hydrogen Chloride (HCl)

Hazardous Polymerization: N/A

SECTION VII - SPILL OR LEAK PROCEDURES

DYNO NOBEL MSDS# 1093
02/05/96
Page 3 of 3

Steps to be taken in Case Material is Released or Spilled: In case of fire evacuate area not less than 2,500 feet. Protect from all ignition sources. Notify authorities in accordance to emergency response procedures. Only personnel trained in emergency response should respond. If no fire danger is present, and product is undamaged and/or uncontaminated, repackage product in original packaging or other clean DOT approved container. Ensure that a complete account of product has been made and is verified. Follow applicable Federal, State, and local spill reporting requirements.

Waste Disposal Method: Disposal must comply with Federal, State, and local regulations. If product becomes a waste, it is potentially regulated as a hazardous waste as defined under the Resource Conservation and Recovery Act (RCRA) Title II, Subtitle C.

SECTION VIII - SPECIAL PROTECTION INFORMATION

Ventilation: General room ventilation is normally adequate.

Respiratory Protection: None normally required.

Protective Clothing: Non-permeable gloves and work clothing which reduce skin contact are suggested.

Eye Protection: Safety glasses are suggested.

Other Precautions Required: N/A

SECTION IX - SPECIAL PRECAUTIONS

Precautions to be taken in handling and storage: Store in cool, dry location. Store in compliance with all local, State, and Federal regulations. Keep away from flames, heat, ignition sources or strong shock.

Other Precautions: It is recommended that users of explosives material be familiar with the Institute of Makers of Explosives Safety Library publications.

SECTION X - SPECIAL INFORMATION

This product contains the following substances that are subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

Chemical Name

CAS Number

% By Weight

None Applicable

DYNO NOBEL INC. Disclaimer

The statements contained herein are offered for information purposes only and are intended only for persons having related technical skills. Because conditions and manner of use are outside our control, it is the user's responsibility to determine the conditions of safe use of the product. While the information is believed to be correct, DYNO NOBEL Inc. shall in no event be responsible for any damages whatsoever, directly or indirectly, resulting from the publication or use of or reliance upon data contained herein. No warranty, either expressed or implied, of merchantability, or fitness, or of any nature with respect to the product, or to the data, is made herein.

**** SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION ****

MSDS Name: **Eosin Y**

Catalog Numbers:

S71268, S71268-1, S71271-1, BP2419-100, BP2419-25, E511 100, E511 25,
E511-100, E511-25, E511100, E51125, NC9487912, NC9671661, S712681, S712711,
XXE51110KG

Synonyms:

Acid Red 87; Bromoeosine; Disodium **Eosine**; **Eosine** Yellowish;
Tetrabromfluorescein, CI 45380.

Company Identification: Fisher Scientific

1 Reagent Lane
Fairlawn, NJ 07410

For information, call: 201-796-7100

Emergency Number: 201-796-7100

For CHEMTREC assistance, call: 800-424-9300

For International CHEMTREC assistance, call: 703-527-3887

**** SECTION 2 - COMPOSITION, INFORMATION ON INGREDIENTS ****

CAS#		Chemical Name	%
EINECS#			
17372-87-1	241-409-6	ACID RED 87	100

Hazard Symbols: None Listed.

Risk Phrases: None Listed.

**** SECTION 3 - HAZARDS IDENTIFICATION ****

EMERGENCY OVERVIEW

Appearance: red to brown.

Caution! The toxicological properties of this material have not been fully investigated. May cause eye and skin irritation. May cause respiratory and digestive tract irritation.

Target Organs: No data found.

Potential Health Effects

Eye:

May cause eye irritation. This product contains an anionic dye.

Similar dyes have not caused injury to the cornea or conjunctiva in documented exposure cases with human or rabbit eyes.

Skin:

May cause skin irritation.

Ingestion:

May cause gastrointestinal irritation with nausea, vomiting

and
diarrhea. The toxicological properties of this substance have
not
been fully investigated.

Inhalation:

May cause respiratory tract irritation. The toxicological
properties
of this substance have not been fully investigated.

Chronic:

No information found.

**** SECTION 4 - FIRST AID MEASURES ****

Eyes:

Flush eyes with plenty of water for at least 15 minutes,
occasionally lifting the upper and lower eyelids. Get medical
aid.

Skin:

Flush skin with plenty of soap and water for at least 15
minutes
while removing contaminated clothing and shoes. Get medical
aid if
irritation develops or persists.

Ingestion:

If victim is conscious and alert, give 2-4 cupfuls of milk or
water.

Get medical aid immediately.

Inhalation:

Remove from exposure to fresh air immediately. If not
breathing,
give artificial respiration. If breathing is difficult, give
oxygen.

Get medical aid.

Notes to Physician:

The use of sodium chloride as antidotal treatment for bromine
salt
overdose should be made only by qualified medical personnel
(Medical
Toxicology,

**** SECTION 5 - FIRE FIGHTING MEASURES ****

General Information:

As in any fire, wear a self-contained breathing apparatus in
pressure-demand, MSHA/NIOSH (approved or equivalent), and full
protective gear. During a fire, irritating and highly toxic
gases

may be generated by thermal decomposition or combustion.

Extinguishing Media:

In case of fire, use water, dry chemical, chemical foam, or
alcohol-resistant foam.

Autoignition Temperature: Not available.

Flash Point: Not available.

Explosion Limits, lower: Not available.

Explosion Limits, upper: Not available.

NFPA Rating: (estimated) Health: 1; Flammability: 0; Reactivity: 0

**** SECTION 6 - ACCIDENTAL RELEASE MEASURES ****

General Information: Use proper personal protective equipment as indicated

in Section 8.

Spills/Leaks:

Sweep up, then place into a suitable container for disposal.

Avoid

generating dusty conditions.

**** SECTION 7 - HANDLING and STORAGE ****

Handling:

Wash thoroughly after handling. Remove contaminated clothing

and

wash before reuse. Use with adequate ventilation. Minimize

dust

generation and accumulation. Avoid contact with skin and eyes.

Keep

container tightly closed. Avoid ingestion and inhalation.

Storage:

Store in a cool, dry, well-ventilated area away from

incompatible

substances.

**** SECTION 8 - EXPOSURE CONTROLS, PERSONAL PROTECTION ****

Engineering Controls:

Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Exposure Limits			
Chemical Name	ACGIH	NIOSH	OSHA -
Final PELs			
ACID RED 87	none listed	none listed	none
listed			

OSHA Vacated PELs:

ACID RED 87:

No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes:

Wear appropriate protective eyeglasses or

chemical

safety goggles as described by OSHA's eye and

face

protection regulations in 29 CFR 1910.133 or

European

Standard EN166.

Skin:
Wear appropriate protective gloves to prevent
skin exposure.

Clothing:
Wear appropriate protective clothing to minimize
contact with skin.

Respirators:
Follow the OSHA respirator regulations found in
29CFR 1910.134 or European Standard EN 149. Always use
a NIOSH or European Standard EN 149 approved
respirator when necessary.

**** SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES ****

Physical State: Solid
Appearance: red to brown
Odor: none reported
pH: Not available.
Vapor Pressure: Negligible.
Vapor Density: Not applicable.
Evaporation Rate: Negligible.
Viscosity: Not available.
Boiling Point: Not applicable.
Freezing/Melting Point: Not available.
Decomposition Temperature: Not available.
Solubility in water: Soluble in water.
Specific Gravity/Density: Not available.
Molecular Formula: C₂₀H₈Br₄O₅.2Na
Molecular Weight: 693.6486

**** SECTION 10 - STABILITY AND REACTIVITY ****

Chemical Stability:
Stable under normal temperatures and pressures.
Conditions to Avoid:
High temperatures, incompatible materials.
Incompatibilities with Other Materials:
Strong oxidizers.
Hazardous Decomposition Products:
Carbon monoxide, carbon dioxide, hydrogen bromide.
Hazardous Polymerization: Has not been reported.

**** SECTION 11 - TOXICOLOGICAL INFORMATION ****

RTECS#:
CAS# 17372-87-1: LM5850000
LD50/LC50:
CAS# 17372-87-1: Oral, mouse: LD50 = 2344 mg/kg.
Carcinogenicity:
ACID RED 87 -

Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology:
 No information available.
Teratogenicity:
 No information available.
Reproductive Effects:
 No information available.
Neurotoxicity:
 No information available.
Mutagenicity:
 Please refer to RTECS# LM5850000 for specific information.
Other Studies:
 None.

**** SECTION 12 - ECOLOGICAL INFORMATION ****

Other
 No information available.

**** SECTION 13 - DISPOSAL CONSIDERATIONS ****

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste.
US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

**** SECTION 14 - TRANSPORT INFORMATION ****

US DOT
 No information available
Canadian TDG
 No information available.

**** SECTION 15 - REGULATORY INFORMATION ****

US FEDERAL
 TSCA
 CAS# 17372-87-1 is listed on the TSCA inventory.
 Health & Safety Reporting List
 None of the chemicals are on the Health & Safety Reporting List.
 Chemical Test Rules
 None of the chemicals in this product are under a Chemical Test Rule.
 Section 12b
 None of the chemicals are listed under TSCA Section 12b.
 TSCA Significant New Use Rule
 None of the chemicals in this material have a SNUR under TSCA.
SARA
 Section 302 (RQ)
 None of the chemicals in this material have an RQ.

Section 302 (TPQ)

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 17372-87-1: acute.

Section 313

No chemicals are reportable under Section 313.

Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic

Pollutants

under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous

by OSHA.

STATE

ACID RED 87 is not present on state lists from CA, PA, MN, MA, FL, or

NJ.

California No Significant Risk Level:

None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols: Not available.

Risk Phrases:

Safety Phrases:

WGK (Water Danger/Protection)

CAS# 17372-87-1: 1

United Kingdom Occupational Exposure Limits

Canada

CAS# 17372-87-1 is listed on Canada's DSL List.

This product has a WHMIS classification of D2B.

CAS# 17372-87-1 is not listed on Canada's Ingredient

Disclosure List.

Exposure Limits

**** SECTION 16 - ADDITIONAL INFORMATION ****

MSDS Creation Date: 12/12/1997 Revision #2 Date: 8/02/2000

The information above is believed to be accurate and represents the best

information currently available to us. However, we make no warranty of

merchantability or any other warranty, express or implied, with respect to

such information, and we assume no liability resulting from its use. Users

should make their own investigations to determine the suitability of the information for their particular purposes. In no way shall the company be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if the company has been advised of the possibility of such damages.

MATERIAL SAFETY DATA SHEET

DATE: 2004 February 4

SECTION 1 MATERIAL IDENTIFICATION		For Internal Use Only HAZARD RATING LABEL
CHEMICAL NAME	Sodium Iodide Iodine 131 (I-131) Solution	
CHEMICAL SYNONYMS	Na ¹³¹ I in NaOH containing 0.02M Na ₂ SO ₄ pH-9-13	
CHEMICAL FAMILY	Base; Sodium Iodide in dilute sodium hydroxide solution	
MANUFACTURER /SUPPLIER NAME	MDS Nordion Inc. 447 March Road Kanata, Ontario K2K 1X8 Telephone: (613) 592-2790 - Radiation Safety	

SECTION 2 HAZARDOUS INGREDIENTS				
INGREDIENT	Activity or %	Radiation Category	%	TLV
High Radioactivity	200-10000 mCi/ml	High energy gamma and high energy beta Half-Life: 8.02 days		
Sodium Hydroxide	< 2.8 mg/ml (< 0.3% w/v)			
AECB Permitted Exposures: 50 mSv/y for Radiation Workers; 5 mSv/y for Public				

SECTION 3 PHYSICAL DATA			
BOILING POINT: 760 mm Hg (°C)	100-105°C	SOLUBILITY IN WATER, % by weight @ 25°C	100
VAPOUR PRESSURE: 20°C (mm Hg)	N/A	SPECIFIC GRAVITY (H ₂ O = 1)	1.003
VAPOUR DENSITY (air = 1)	> 1.0	EVAPORATION RATE (butylacetate = 1)	N/A
pH		MELTING POINT	
APPEARANCE AND ODOUR:	Product appears like water and is contained in a shielded and securely sealed package. No odour.		

SECTION 4 FIRE AND EXPLOSION HAZARD DATA				
FLASH POINT (°C); TEST METHOD:	None	FLAMMABLE LIMITS	LEL N/A	UEL N/A
AUTOIGNITION TEMPERATURE (°C)	None			
EXTINGUISHING MEDIA:	N/A			
SPECIAL FIREFIGHTING PROCEDURES: N/A				
UNUSUAL FIRE AND EXPLOSION HAZARDS: None				

SECTION 5 REACTIVITY DATA		
STABILITY:	STABLEX	CONDITIONS TO AVOID: None
	UNSTABLE <input type="checkbox"/>	
INCOMPATIBILITY:	N/A	
HAZARDOUS DECOMPOSITION PRODUCTS:		
HAZARDOUS POLYMERIZATION:	WILL NOT OCCURX	CONDITIONS TO AVOID: Not identified.
	MAY OCCUR <input type="checkbox"/>	

N/A - Not Applicable

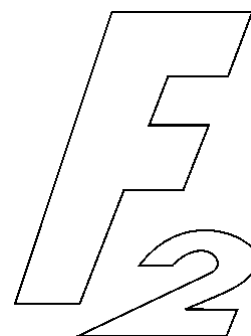
MATERIAL SAFETY DATA SHEET - Sodium Iodide Iodine 131 Solution (cont'd)

SECTION 6 HEALTH HAZARD DATA	
EFFECTS OF OVEREXPOSURE:	INHALATION: Will result in heavy thyroid radiation dose. No respiratory symptoms.
	INGESTION: Will result in heavy thyroid radiation dose. Sodium hydroxide concentration low, may cause throat irritation and burning sensation.
	EYES: Sodium hydroxide will have irritation effect; wash immediately.
	SKIN: Corrosive effect and high radiation on contact; wash immediately.
EMERGENCY FIRST AID PROCEDURES:	INHALATION: Remove to fresh air and stand upwind if outside. Ascertain if individual has allergies to iodine. If not, administer stable iodine (eg. Lugol's solution). Seek medical attention for radiation intake.
	INGESTION: Ascertain if individual has allergies to iodine. If not, administer stable iodine (eg. Lugol's solution). Do not induce vomiting, due to corrosive effect of solution. Remove from source. Seek medical aid for radiation intake.
	EYES: Flush open eye(s) continuously for 15 minutes with clean water. Remove from source. See Physician for external radiation or if irritation persists.
	SKIN: Wash well with soap and water to remove contamination. Remove contaminated clothing. Remove from source. See Physician for external radiation or if irritation persists.
	NOTE: IN ALL CASES, OBTAIN MEDICAL AID PROMPTLY.
SECTION 7 SPECIAL PROTECTION INFORMATION	
VENTILATION:	With I-131 local ventilation is very important, if I-131 gasses off. Wear respiratory protection, and stand upwind (if outside).
RESPIRATORY PROTECTION:	Air purifying respirator with combination radio-nuclide cartridge or SCBA where spill has occurred.
PROTECTIVE CLOTHING:	If package is damaged, wear lead-lined gloves before handling.
EYE PROTECTION:	<input type="checkbox"/> NOT NORMALLY NECESSARY <input type="checkbox"/> SAFETY GLASSES WITH SIDE SHIELDS <input type="checkbox"/> SAFETY GLASSES <input type="checkbox"/> GASTIGHT GOGGLES OR EQUIVALENT <input checked="" type="checkbox"/> CHEMICAL WORKERS GOGGLES <input type="checkbox"/> OTHER
SECTION 8 SPECIAL PRECAUTIONS	
PRECAUTIONS IN HANDLING AND STORAGE:	All shippers and consignees must possess radioisotope license and conform with all conditions of license.
OTHER PRECAUTIONS:	
SECTION 9 SPILL OR LEAK PROCEDURES	
STEPS TO BE TAKEN IF MATERIAL SPILLED OR LEAKED: Note also Section 7. If wet spill occurs, isolate contaminated area using vermiculite or charcoal. When acidified this material will release I-131. If in transport mode, call CANUTEC at (613) 996-6666 in Canada or National Response Centre at 1-800-424-8802 in USA.	
WASTE DISPOSAL METHOD: If on site, follow instructions on site license or as directed by local Radiation Control Officer.	

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Material Safety Data Sheet

FLUTEC-TG o-PDMCH

Last updated: 20th May 2002

1 – SUBSTANCE IDENTIFICATION

Trade Name:	FLUTEC-TG o-PDMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly perfluoro-1,2-dimethylcyclohexane
b) CAS Number	306-98-9

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure, rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halon Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise to toxic vapours; avoid inhalation of these vapours. Use approved self-contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	FLUTEC liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	<p>Do not smoke when handling.</p> <p>Avoid contact of vapour or liquid with red-hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride.</p> <p>Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable.</p> <p>Allow sufficient ullage when drum filling to allow for thermal expansion.</p>
b) Storage	<p>Store in original, tightly closed, labelled container.</p> <p>Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.</p>

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	102 °C
Pour Point:	-30 °C
Molecular Weight:	400
Density:	1.828 kg/l
Surface Tension:	16.6 mN/m
Vapour Pressure:	48 mbar
Specific Heat:	0.85* kJ/kg °C
Critical Temperature:	241* °C
Critical Temperature:	514* K
Critical Pressure:	19* bar
Critical Volume:	1.5* l/kg
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available
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13 – DISPOSAL CONSIDERATIONS

	<p>Contact manufacturer.</p> <p>Dispose of through an authorised contractor to a licensed landfill site.</p> <p>Do not discharge into drains or watercourses.</p> <p>Large quantities should be incinerated by a waste disposal organisation.</p>
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14 – TRANSPORT INFORMATION

	<p>Non-hazardous liquid not regulated for transport services.</p> <p>UN Number – not applicable</p> <p>IATA/ICAO – not regulated</p> <p>ADR – not regulated</p> <p>IMDG – not regulated</p> <p>Transport name – not applicable</p> <p>Hazchem code – not applicable.</p>
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15 – REGULATORY INFORMATION

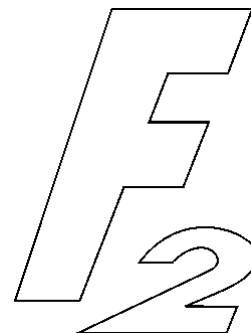
a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and/or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd. cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals Ltd. for advice.
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Material Safety Data Sheet

FLUTEC-TG PMCH

Last updated: 20th May 2002

1 – SUBSTANCE IDENTIFICATION

Trade Name:	FLUTEC-TG PMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly perfluoromethylcyclohexane
b) CAS Number	355-02-2

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure, rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise to toxic vapours; avoid inhalation of these vapours. Use approved self-contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	FLUTEC liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	<p>Do not smoke when handling.</p> <p>Avoid contact of vapour or liquid with red-hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride.</p> <p>Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable.</p> <p>Allow sufficient ullage when drum filling to allow for thermal expansion.</p>
b) Storage	<p>Store in original, tightly closed, labelled container.</p> <p>Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.</p>

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	76 °C
Pour Point:	-30 °C
Molecular Weight:	350
Density:	1.788 kg/l
Viscosity (kinematic):	0.873 mm ² /s
Viscosity (dynamic):	1.561 mPa s
Surface Tension:	15.4 mN/m
Vapour Pressure:	141 mbar
Heat of Vaporisation at b.p.:	85.9 kJ/kg
Specific Heat:	0.963 kJ/kg °C
Critical Temperature:	212.8 °C
Critical Temperature:	486.0 K
Critical Pressure:	20.19 bar
Critical Volume:	1.522 l/kg
Thermal Conductivity:	59.9 mW/m °C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available
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13 – DISPOSAL CONSIDERATIONS

	<p>Contact manufacturer.</p> <p>Dispose of through an authorised contractor to a licensed landfill site.</p> <p>Do not discharge into drains or watercourses.</p> <p>Large quantities should be incinerated by a waste disposal organisation.</p>
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14 – TRANSPORT INFORMATION

	<p>Non-hazardous liquid not regulated for transport services.</p> <p>UN Number – not applicable</p> <p>IATA/ICAO – not regulated</p> <p>ADR – not regulated</p> <p>IMDG – not regulated</p> <p>Transport name – not applicable</p> <p>Hazchem code – not applicable.</p>
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15 – REGULATORY INFORMATION

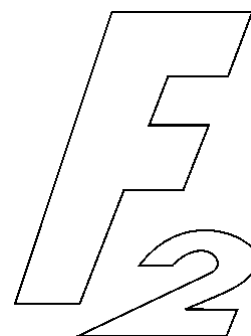
a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and/or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd. cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals Ltd. for advice.
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Material Safety Data Sheet

FLUTEC-TG PMCP

Last updated: 20th May 2002

1 – SUBSTANCE IDENTIFICATION

Trade Name:	FLUTEC-TG PMCP
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly perfluoromethylcyclopentane
b) CAS Number	1805-22-7

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure, rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise to toxic vapours; avoid inhalation of these vapours. Use approved self-contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	FLUTEC liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	<p>Do not smoke when handling.</p> <p>Avoid contact of vapour or liquid with red-hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride.</p> <p>Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable.</p> <p>Allow sufficient ullage when drum filling to allow for thermal expansion.</p>
b) Storage	<p>Store in original, tightly closed, labelled container.</p> <p>Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.</p>

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	48 °C
Pour Point:	-70 °C
Molecular Weight:	300
Density:	1.707 kg/l
Viscosity (kinematic):	0.58 mm ² /s
Viscosity (dynamic):	0.993 mPa s
Surface Tension:	12.4 mN/m
Vapour Pressure:	451 mbar
Heat of Vaporisation at b.p.:	90.5* kJ/kg
Specific Heat:	0.563 kJ/kg °C
Refractive index:	1.2650 N _D ²⁰
Oxygen Solubility:	45* ml per 100g
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available
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13 – DISPOSAL CONSIDERATIONS

	<p>Contact manufacturer.</p> <p>Dispose of through an authorised contractor to a licensed landfill site.</p> <p>Do not discharge into drains or watercourses.</p> <p>Large quantities should be incinerated by a waste disposal organisation.</p>
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14 – TRANSPORT INFORMATION

	<p>Non-hazardous liquid not regulated for transport services.</p> <p>UN Number – not applicable</p> <p>IATA/ICAO – not regulated</p> <p>ADR – not regulated</p> <p>IMDG – not regulated</p> <p>Transport name – not applicable</p> <p>Hazchem code – not applicable.</p>
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15 – REGULATORY INFORMATION

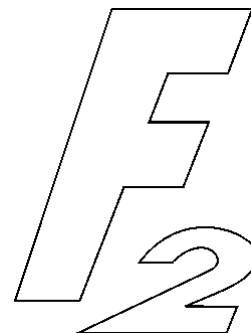
a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and/or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd. cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals Ltd. for advice.
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Material Safety Data Sheet

FLUTEC-TG PTMCH

Last updated: 20th May 2002

1 – SUBSTANCE IDENTIFICATION

Trade Name:	FLUTEC-TG PTMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly perfluoro-1,3,5-trimethylcyclohexane
b) CAS Number	374-76-5

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure, rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise to toxic vapours; avoid inhalation of these vapours. Use approved self-contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	FLUTEC liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	<p>Do not smoke when handling.</p> <p>Avoid contact of vapour or liquid with red-hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride.</p> <p>Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable.</p> <p>Allow sufficient ullage when drum filling to allow for thermal expansion.</p>
b) Storage	<p>Store in original, tightly closed, labelled container.</p> <p>Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.</p>

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	127.4 °C
Pour Point:	-70 °C
Molecular Weight:	450
Density:	1.888 kg/l
Viscosity (kinematic):	1.2 mm ² /s
Viscosity (dynamic):	2.28 mPa s
Surface Tension:	17.7 mN/m
Vapour Pressure:	13.1 mbar
Specific Heat:	0.96 kJ/kg °C
Critical Temperature:	269* °C
Critical Temperature:	542* K
Critical Pressure:	18* bar
Critical Volume:	1.5* l/kg
Thermal Conductivity:	61.1 mW/m °C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available
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13 – DISPOSAL CONSIDERATIONS

	<p>Contact manufacturer.</p> <p>Dispose of through an authorised contractor to a licensed landfill site.</p> <p>Do not discharge into drains or watercourses.</p> <p>Large quantities should be incinerated by a waste disposal organisation.</p>
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14 – TRANSPORT INFORMATION

	<p>Non-hazardous liquid not regulated for transport services.</p> <p>UN Number – not applicable</p> <p>IATA/ICAO – not regulated</p> <p>ADR – not regulated</p> <p>IMDG – not regulated</p> <p>Transport name – not applicable</p> <p>Hazchem code – not applicable.</p>
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15 – REGULATORY INFORMATION

a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and/or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd. cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals Ltd. for advice.
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**MATERIAL SAFETY DATA SHEET**

Distributed by: **MSDS:000085**
Machine & Welding Supply Co.
P.O. Box 1708 Phone: (910) 892-4016
Hwy 301 South Fax: (910) 892-3575
Dunn, NC 28335 Internet: www.mwsc.com

PRODUCT NAME: NEON**1. Chemical Product and Company Identification**

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (908) 464-8100
24-HOUR EMERGENCY TELEPHONE NUMBER:
CHEMTREC (800) 424-9300

TELEPHONE NUMBER: (905) 501-1700
24-HOUR EMERGENCY TELEPHONE NUMBER:
(905) 501-0802
EMERGENCY RESPONSE PLAN NO: 20101

PRODUCT NAME: NEON
CHEMICAL NAME: Neon
COMMON NAMES/SYNONYMS: Neon, compressed
TDG (Canada) CLASSIFICATION: 2.2
WHMIS CLASSIFICATION: A

PREPARED BY: Loss Control (908)464-8100/(905)501-1700
PREPARATION DATE: 6/1/95
REVIEW DATES: 6/7/96

2. Composition, Information on Ingredients

INGREDIENT	% VOLUME	PEL-OSHA ¹	TLV-ACGIH ²	LD ₅₀ or LC ₅₀ Route/Species
Neon FORMULA: Ne CAS: 7440-01-9 RTECS #: QP4450000	75.0 to 99.9999	Simple Asphyxiant	Simple Asphyxiant	Not Available
Helium FORMULA: He CAS: 7440-59-7 RTECS #: MH6520000	0 to 25.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

² As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents

3. Hazards Identification**EMERGENCY OVERVIEW**

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

ROUTE OF ENTRY:

Skin Contact No	Skin Absorption No	Eye Contact No	Inhalation Yes	Ingestion No
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PRODUCT NAME: NEON

HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No IARC: No OSHA: No

EYE EFFECTS:

None known.

SKIN EFFECTS:

None known.

INGESTION EFFECTS:

None known. Ingestion is unlikely as product is gas at room temperature.

INHALATION EFFECTS:

Product is a non-toxic simple asphyxiant. Effects of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

HMIS HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

RATINGS SYSTEM

0 = No Hazard
1 = Slight Hazard
2 = Moderate Hazard
3 = Serious Hazard
4 = Severe Hazard

4. First Aid Measures**EYES:**

None required.

SKIN:

None required.

INGESTION:

None required.

MSDS: G-59

Revised: 6/7/96

PRODUCT NAME: NEON

INHALATION:

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None	UEL(%): None	
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:

None. Nonflammable.

EXTINGUISHING MEDIA:

None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage**Electrical classification:**

Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125°F (52°C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

MSDS: G-59

Revised: 6/7/96

PRODUCT NAME: NEON

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS¹:

INGREDIENT	% VOLUME	PEL-OSHA ²	TLV-ACGIH ³	LD ₅₀ or LC ₅₀ Route/Species
Neon FORMULA: Ne CAS: 7440-01-9 RTECS #: QP4450000	75.0 to 99.9999	Simple Asphyxiant	Simple Asphyxiant	Not Available
Helium FORMULA: He CAS: 7440-59-7 RTECS #: MH6520000	0 to 25.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ Refer to individual state of provincial regulations, as applicable, for limits which may be more stringent than those listed here.

² As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

³ As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:

Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:

Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:

Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:

Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:

Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure	: Gas, above crit. temp.	
Vapor density at 70 °F, 1 atm (Air = 1).	: 0.70	
Evaporation point	: Not Available	
Boiling point	: -410.9	°F
	: -246.1	°C
Freezing point	: -415.5	°F
	: -248.6	°C
pH	: Not Applicable	
Specific gravity	: Not Available	
Oil/water partition coefficient	: Not Available	
Solubility (H2O)	: Negligible	
Odor threshold	: Not Applicable	
Odor and appearance	: Colorless, odorless gas	

10. Stability and Reactivity

STABILITY:

Stable

INCOMPATIBLE MATERIALS:

None

HAZARDOUS POLYMERIZATION:

Does not occur.

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

PRODUCT NAME: NEON

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Neon, compressed	Neon, compressed
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 1065	UN 1065
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:

Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

DISCLAIMER OF EXPRESSED AND IMPLIED WARRANTIES:

Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to the accuracy or completeness of the information contained herein, and assume no responsibility regarding the suitability of this information for the user's intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for their particular purpose(s).

Material Safety Data Sheet

acc. to OSHA and ANSI

Printing date 05/30/2000 Reviewed on 05/05/2000

1 Identification of substance:

Product details:

Trade name: Perfluorodimethylcyclobutane

Stock number: 43036

Manufacturer/Supplier:

Alfa Aesar, A Johnson Matthey Company

Johnson Matthey Catalog Company, Inc.

30 Bond Street

Ward Hill, MA 01835-8099

Emergency Phone: (978) 521-6300

CHEMTREC: (800) 424-9300

Web Site: www.alfa.com

Information department: Health, Safety and
Environmental Department

Emergency information:

During normal hours the Health, Safety and
Environmental Department. After normal hours
call Chemtrec at (800) 424-9300.

2 Composition/Data on components:

Chemical characterization:

Description: (CAS#)

Perfluorodimethylcyclobutane (CAS#
28677-00-1), 100%

Identification number(s):

EINECS Number: 249-145-3
3 Hazards identification

Hazard description: · Not applicable

Information pertaining to particular dangers for
man and environment

Not applicable

4 First aid measures

After inhalation

Supply fresh air. If required, provide
artificial respiration. Keep patient warm.
Seek immediate medical advice.

After skin contact

Immediately wash with water and soap and rinse
thoroughly.
Seek immediate medical advice.

After eye contact

Rinse opened eye for several minutes under
running water. Then consult a doctor.

After swallowing Seek medical treatment.

5 Fire fighting measures

Suitable extinguishing agents

Use carbon dioxide, extinguishing powder or
foam. Water may be ineffective but may be used
for cooling exposed containers.

Special hazards caused by the material, its
products of combustion or

resulting gases:

In case of fire, the following can be released:

Carbon monoxide (CO)

Hydrogen fluoride (HF)

Protective equipment:

Wear self-contained respirator.

Wear fully protective impervious suit.

6 Accidental release measures

Person-related safety precautions:

Wear protective equipment. Keep unprotected
persons away.

Ensure adequate ventilation

Measures for environmental protection:

Do not allow material to be released to the
environment without proper governmental permits.

Measures for cleaning/collecting:
Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust).

Additional information:
See Section 7 for information on safe handling
See Section 8 for information on personal protection equipment.
See Section 13 for disposal information.
7 Handling and storage

Handling

Information for safe handling:
Keep container tightly sealed.
Store in cool, dry place in tightly closed containers.
No special precautions are necessary if used correctly.

Information about protection against explosions and fires:
The product is not flammable

Storage

Requirements to be met by storerooms and receptacles:
No special requirements.

Information about storage in one common storage facility:
Store away from oxidizing agents.

Further information about storage conditions:
Refrigerate
Keep container tightly sealed.
Store in cool, dry conditions in well sealed containers.

8 Exposure controls and personal protection

Additional information about design of technical systems:
Properly operating chemical fume hood designed for hazardous chemicals and having an average face velocity of at least 100 feet per minute.

Components with limit values that require monitoring at the workplace:
Not required.

Additional information: No data

Personal protective equipment

General protective and hygienic measures

The usual precautionary measures for handling chemicals should be followed.

Keep away from foodstuffs, beverages and feed.

Remove all soiled and contaminated clothing immediately.

Wash hands before breaks and at the end of work.

Breathing equipment:

Use suitable respiratory protective device in case of insufficient ventilation.

Use suitable respirator when high concentrations are present.

Protection of hands: Impervious gloves

Eye protection: Safety glasses

Body protection: Protective work clothing.

9 Physical and chemical properties:

Form: Liquid

Color: Colorless

Odor: Nearly odorless

		Value/Range
Unit	Method	
Change in condition		
Melting point/Melting range:		Not determined
Boiling point/Boiling range:		
45 ° C		
Sublimation temperature / start:		Not determined
Flash point:		Not applicable
Ignition temperature:		Not determined

Decomposition temperature: Not
determined

Danger of explosion:
Product does not present an explosion hazard.

Explosion limits:

Lower: Not
determined

Upper: Not
determined

Vapor pressure: Not
determined

Density: at 20 ° C
1.62 g/cm³

Solubility in / Miscibility with

Water: Not miscible
or difficult to mix
10 Stability and reactivity

Thermal decomposition / conditions to be
avoided:
Decomposition will not occur if used and stored
according to specifications.

Materials to be avoided: Oxidizing agents

Dangerous reactions No dangerous reactions known

Dangerous products of decomposition:
Carbon monoxide and carbon dioxide
Hydrogen fluoride (HF)
11 Toxicological information

Acute toxicity:

Primary irritant effect:

on the skin: May cause irritation

on the eye: May cause irritation

Sensitization: No sensitizing effects known.

Subacute to chronic toxicity:

Other than potential irritation (see above), no information on illness or injury from acute or chronic exposure to this product is available.

Additional toxicological information:

To the best of our knowledge the acute and chronic toxicity of this substance is not fully known.

No classification data on carcinogenic properties of this material is available from the EPA, IARC, NTP, OSHA or ACGIH.

12 Ecological information:

General notes:

Do not allow material to be released to the environment without proper governmental permits.

13 Disposal considerations

Product:

Recommendation

Consult state, local or national regulations for proper disposal.

Uncleaned packagings:

Recommendation:

Disposal must be made according to official regulations.

14 Transport information

Not a hazardous material for transportation.

DOT regulations:

Hazard class: None

Land transport ADR/RID (cross-border)

ADR/RID class: None

Maritime transport IMDG:

IMDG Class: None

Air transport ICAO-TI and IATA-DGR:

ICAO/IATA Class: None

Transport/Additional information:
Not dangerous according to the above
specifications.
15 Regulations

Product related hazard informations:
Observe the general safety regulations when
handling chemicals

National regulations
This product is not listed in the U.S.
Environmental Protection Agency Toxic Substances
Control Act Chemical Substance Inventory. Use
of this product is restricted to research and
development only.

Information about limitation of use:
For use only by technically qualified
individuals.
16 Other information:

Employers should use this information only as a
supplement to other information gathered by
them, and should make independent judgement of
suitability of this information to ensure proper
use and protect the health and safety of
employees. This information is furnished
without warranty, and any use of the product not
in conformance with this Material Safety Data
Sheet, or in combination with any other product
or process, is the responsibility of the user.

Department issuing MSDS: Health, Safety and
Environmental Department.

Contact: Darrell R. Sanders

FLUTEC TG m-PDMCH™

Product Flutec TG m-PDMCH

8th December 1999

PAGE 1/4

1 – SUBSTANCE IDENTIFICATION	
Trade Name:	Flutec TG m-PDMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833
2 - COMPOSITION	
a) Substances	Predominantly Perfluoro-1,3-dimethylcyclohexane
b) CAS Number	335-27-3
3 – HAZARD IDENTIFICATION	
a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.
4 – FIRST AID MEASURES	
a) Inhalation:	In case of severe exposure; remove from exposure , rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES	
a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halon Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise of toxic vapours, avoid inhalation of these vapours. Use approved self contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.
6 – ACCIDENTAL RELEASE MEASURES	
a) Exposure Controls	Flutec liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE	
a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.
8 – EXPOSURE CONTROLS	
a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None
9 – PHYSICAL AND CHEMICAL PROPERTIES	
Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	102°C
Pour Point:	-70°C
Vapour Pressure:	48 mbar
Density:	1.828 kg/l @25°C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.
10 – STABILITY AND REACTIVITY	
a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.
11 – TOXICOLOGICAL INFORMATION	
a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION	
a) Ecotoxicity:	No specific data available
13 – DISPOSAL CONSIDERATIONS	
	Contact manufacturer. Dispose of through an authorised contractor to a licensed landfill site. Do not discharge into drains or watercourses. Large quantities should be incinerated by a waste disposal organisation.
14 – TRANSPORT INFORMATION	
	Non-hazardous liquid not regulated for transport services. UN Number – not applicable IATA/ICAO – not regulated ADR – not regulated IMDG – not regulated Transport name – not applicable Hazchem code – not applicable.
15 – REGULATORY INFORMATION	
a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and / or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.
16 – OTHER REGULATION	
a) Suitability for purpose:	F2 Chemicals Ltd cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals for advice.

FLUTEC TG-PECH™

Product Flutec TG-PECH

13th November 1999

PAGE 1/4

1 – SUBSTANCE IDENTIFICATION

Trade Name: Flutec TG-PECH
Material Type: Perfluorocarbon
Company: F2 Chemicals Ltd
Address: Lea Lane
Lea Town
Preston
Lancashire
PR4 0RZ
UK

Telephone: +44 (0) 1772 775804
Fax: +44 (0) 1772 775809
Emergency Telephone: +44 (0) 1772 775833

2 - COMPOSITION

a) Substances Predominantly Perfluoroethylcyclohexane
b) CAS Number 335-21-7

3 – HAZARD IDENTIFICATION

a) Hazard Symbols: Not applicable

b) Risk and Safety Keep container tightly closed.
Caution, avoid prolonged and repeated breathing of concentrated vapour.
Thermal decomposition may produce toxic products.
Small amounts of decomposition may occur above 400°C.
When using do not smoke.
Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation: In case of severe exposure; remove from exposure, rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.

b) Skin contact: Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.

c) Eye contact: Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.

d) Ingestion: Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

- a) Suitable Extinguishers: Carbon dioxide
Alcohol resistant foam
Powder
Halon
Water Fog
Water Jets
Inert material – Sand, earth, etc
Non-combustible material
- b) Unsuitable Extinguishers: Not applicable.
- c) Hazardous Decomposition: Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
- d) Special Procedures: Use water spray to cool containers.
Contact with flames gives rise of toxic vapours, avoid inhalation of these vapours.
Use approved self contained breathing apparatus.
Non-essential personnel should be evacuated from the area until any fumes have dispersed.
Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

- a) Exposure Controls Flutec liquid spillages produce very slippery surfaces which may be hazardous to personnel.
Evacuate area.
Do not allow spillage to enter drains and watercourse.
If water is contaminated inform relevant authority immediately.
- b) Personnel Protection: Wear laboratory coat.
Respiratory protection not normally required.
Wear impermeable gloves.
Wear chemical safety spectacles or goggles.
- c) Disposal Considerations: Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer.
Do not allow spillage to enter drains/sewers/water courses.
Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE	
a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.
8 – EXPOSURE CONTROLS	
a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None
9 – PHYSICAL AND CHEMICAL PROPERTIES	
Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	101.7°C
Melting Point:	-70°C
Vapour Pressure:	28.7 mbar
Density:	1.829 kg/l @25°C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.
10 – STABILITY AND REACTIVITY	
a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.
11 – TOXICOLOGICAL INFORMATION	
a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION	
a) Ecotoxicity:	No specific data available
13 – DISPOSAL CONSIDERATIONS	
	Contact manufacturer. Dispose of through an authorized contractor to a licensed landfill site. Do not discharge into drains or watercourses. Large quantities should be incinerated by a waste disposal organisation.
14 – TRANSPORT INFORMATION	
	Non-hazardous liquid not regulated for transport services. UN Number – not applicable IATA/ICAO – not regulated ADR – not regulated IMDG – not regulated Transport name – not applicable Hazchem code – not applicable.
15 – REGULATORY INFORMATION	
a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and / or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.
16 – OTHER REGULATION	
a) Suitability for purpose:	F2 Chemicals Ltd cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals for advice.

FLUTEC TG p-PDMCH™

Product Flutec TG p-PDMCH

17th November 1999

PAGE 1/4

1 – SUBSTANCE IDENTIFICATION	
Trade Name:	Flutec TG p-PDMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833
2 - COMPOSITION	
a) Substances	Predominantly Perfluoro-1,4-dimethylcyclohexane
b) CAS Number	374-77-6
3 – HAZARD IDENTIFICATION	
a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.
4 – FIRST AID MEASURES	
a) Inhalation:	In case of severe exposure; remove from exposure , rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES	
a) Suitable Extinguishers:	<p>Carbon dioxide Alcohol resistant foam Powder Halon Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material</p>
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	<p>Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.</p>
d) Special Procedures:	<p>Use water spray to cool containers. Contact with flames gives rise of toxic vapours, avoid inhalation of these vapours. Use approved self contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.</p>
6 – ACCIDENTAL RELEASE MEASURES	
a) Exposure Controls	<p>Flutec liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.</p>
b) Personnel Protection:	<p>Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.</p>
c) Disposal Considerations:	<p>Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.</p>

7 – HANDLING AND STORAGE	
a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.
8 – EXPOSURE CONTROLS	
a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None
9 – PHYSICAL AND CHEMICAL PROPERTIES	
Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	102°C
Pour Point:	-30°C
Vapour Pressure:	48 mbar
Density:	1.828 kg/l @25°C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.
10 – STABILITY AND REACTIVITY	
a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.
11 – TOXICOLOGICAL INFORMATION	
a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION	
a) Ecotoxicity:	No specific data available
13 – DISPOSAL CONSIDERATIONS	
	Contact manufacturer. Dispose of through an authorised contractor to a licensed landfill site. Do not discharge into drains or watercourses. Large quantities should be incinerated by a waste disposal organisation.
14 – TRANSPORT INFORMATION	
	Non-hazardous liquid not regulated for transport services. UN Number – not applicable IATA/ICAO – not regulated ADR – not regulated IMDG – not regulated Transport name – not applicable Hazchem code – not applicable.
15 – REGULATORY INFORMATION	
a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and / or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.
16 – OTHER REGULATION	
a) Suitability for purpose:	F2 Chemicals Ltd cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals for advice.



MATERIAL SAFETY DATA SHEET

PRODUCT NAME: XENON

1. Chemical Product and Company Identification

**BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974**

TELEPHONE NUMBER: (908) 464-8100
24-HOUR EMERGENCY TELEPHONE NUMBER:
CHEMTREC (800) 424-9300

**BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6**

TELEPHONE NUMBER: (905) 501-1700
24-HOUR EMERGENCY TELEPHONE NUMBER:
(905) 501-0802
EMERGENCY RESPONSE PLAN NO: 20101

PRODUCT NAME: XENON
CHEMICAL NAME: Xenon
COMMON NAMES/SYNONYMS: Xenon, compressed
TDG (Canada) CLASSIFICATION: 2.2
WHMIS CLASSIFICATION: A

PREPARED BY: Loss Control (908)464-8100/(905)501-1700
PREPARATION DATE: 6/1/95
REVIEW DATES: 6/7/96

2. Composition, Information on Ingredients

INGREDIENT	% VOLUME	PEL-OSHA ¹	TLV-ACGIH ²	LD ₅₀ or LC ₅₀ Route/Species
Xenon FORMULA: Xe CAS: 7440-63-3 RTECS #: ZE1280000	99.9 to 99.995	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

² As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents

3. Hazards Identification

EMERGENCY OVERVIEW

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

PRODUCT NAME: XENON

ROUTE OF ENTRY:

Skin Contact No	Skin Absorption No	Eye Contact No	Inhalation Yes	Ingestion No
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HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No IARC: No OSHA: No

EYE EFFECTS:

None known.

SKIN EFFECTS:

None known.

INGESTION EFFECTS:

None known. Ingestion is unlikely as product is gas at room temperature.

INHALATION EFFECTS:

Product is a non-toxic simple asphyxiant. High concentrations may exclude an adequate supply of oxygen to the lungs. Effects of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

HMIS HAZARD CODES

Health: 0
Flammability: 0
Reactivity: 0

RATINGS SYSTEM

0 = No Hazard
1 = Slight Hazard
2 = Moderate Hazard
3 = Serious Hazard
4 = Severe Hazard

4. First Aid Measures**EYES:**

None required.

SKIN:

None required.

INGESTION:

None required.

INHALATION:

MSDS: G-85

Revised: 6/7/96

PRODUCT NAME: XENON

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None		UEL(%): None
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:

None. Nonflammable.

EXTINGUISHING MEDIA:

None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical classification:

Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125 °F (52 °C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

MSDS: G-85

Revised: 6/7/96

PRODUCT NAME: XENON

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS¹:

INGREDIENT	% VOLUME	PEL-OSHA ²	TLV-ACGIH ³	LD ₅₀ or LC ₅₀ Route/Species
Xenon FORMULA: Xe CAS: 7440-63-3 RTECS #: ZE1280000	99.9 to 99.995	Simple Asphyxiant	Simple Asphyxiant	Not Available

¹ Refer to individual state or provincial regulations, as applicable, for limits which may be more stringent than those listed here.

² As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

³ As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:

Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:

Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:

Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:

Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:

Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure	: Above 61.9 °F (16.6 °C)	
Vapor density (Air = 1)	: Not Available	
Evaporation point	: Not Available	
Boiling point	: -162.6	°F
	: -108.1	°C
Freezing point	: -169.2	°F
	: -111.8	°C
pH	: Not Applicable	
Specific gravity at 70 °F, 1 atm.	: 4.56	
Oil/water partition coefficient	: Not Available	
Solubility (H2O)	: Slightly soluble	
Odor threshold	: Not Applicable	
Odor and appearance	: Odorless, colorless gas	

10. Stability and Reactivity

STABILITY:

Stable

INCOMPATIBLE MATERIALS:

None

HAZARDOUS POLYMERIZATION:

Does not occur.

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

PRODUCT NAME: XENON

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Xenon	Xenon
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 2036	UN 2036
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:

Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

DISCLAIMER OF EXPRESSED AND IMPLIED WARRANTIES:

Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to the accuracy or completeness of the information contained herein, and assume no responsibility regarding the suitability of this information for the user's intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for their particular purpose(s).



COLLEGE OF LIBERAL ARTS
THE UNIVERSITY OF TEXAS AT AUSTIN

*Texas Archeological Research Laboratory • J. J. Pickle Research Campus, Bldg. 5
Austin, Texas 78712-1100 • (512) 471-5960 • FAX (512) 471-5973*

October 7, 2002

Mr. Jeffrey G. Paine
Bureau of Economic Geology
University of Texas at Austin
University Station, Box X
Austin, TX 78713-8924

Re: South Liberty Oil Field
Liberty County, Texas

Dear Mr. Paine:

This letter is submitted in response to a file search, which was received by mail at this office on 04 October 2002, concerning the above-referenced project and the possible location of archeological or historical sites within its boundaries.

Please remember that information regarding site locations should not be made available to the general public, is not for publication or for use in public documents, and is for your company's use only. Site location information is protected by the National Historic Preservation Act of 1966 Title III, Section 304 and by Section 191.004 of the Antiquities Code of Texas. If you have questions regarding this policy please call Carolyn Spock, TARL Curator of Records at (512) 471-6006 or the Texas Historical Commission, Archeology Division at (512) 463-6096.

Our research has determined that within one kilometer of the proposed delineated project area, there are no recorded archeological or historical sites. No sites are registered as State Archeological Landmarks (SAL) or are listed in the National Register of Historic Places (NRHP).

Although no sites have been recorded in the immediate vicinity of this project, this does **not** mean sites are not present. The lack of recorded prehistoric or historic remains may indicate that the project is in an area not yet explored for sites or that the sites may not be visible on the modern ground surface.

For further guidelines concerning your project, you need to contact the Archeology Division of the Texas Historical Commission (512-463-6096) who handles regulatory and permitting details, provides comments, and makes decisions regarding archeological work.

I hope this response adequately fulfills your request for information. If you have any questions, please let us know.

Sincerely,

A handwritten signature in cursive script, appearing to read "Allegra Azulay".

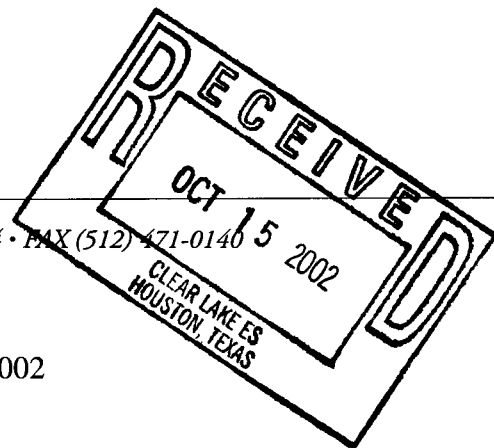
Allegra Azulay
Assistant Curator of Records

Enclosure
CC: Bill Martin, Archeology Division--THC



BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

University Station, Box X • Austin, Texas 78713-8924 • (512) 471-1534 • FAX (512) 471-0140
10100 Burnet Road, Bldg. 130 • Austin, Texas 78758-4497



October 9, 2002

Mr. Mike Morgan
Houston Ecological Services Field Office
U.S. Fish and Wildlife Service
17629 El Camino Real, Suite 211
Houston, TX 77058-3051

Dear Mr. Morgan:

As we discussed on the telephone yesterday, the Bureau of Economic Geology is conducting a study of geologic sequestration of carbon dioxide sponsored by the Department of Energy. One of our possible field experiment sites is in the South Liberty Oil Field in Liberty County, Texas. This field is located west of the Trinity River and southwest of the town of Liberty. We plan to drill a new well in this field, inject compressed carbon dioxide into the new well, and monitor an adjacent well to detect the underground carbon dioxide plume. The proposed well locations are within the box marked "experiment site" on the enclosed map of Liberty County, topographic maps of the northwest part of the Moss Bluff quadrangle, and the aerial photographic map of the site.

We are preparing an Environmental Assessment before the field experiment commences. As part of this assessment, we are required to determine whether the site falls within the geographic distribution of any endangered species. We request that your office prepare a letter for inclusion in the Environmental Assessment that lists the endangered species for these potential well sites. Thank you for your assistance in this matter and the helpful information you provided in our conversation yesterday.

A review of U.S. Fish and Wildlife Service files and your project information indicate that no federally listed or proposed threatened or endangered species are likely to occur at the project site. The project site is not located within officially designated critical habitat.

This review does not constitute our approval for wetlands, sensitive habitats, migratory birds or any other environmental requirements.

Sincerely,

Jeffrey G. Paine
Research Scientist

Approved JGP:ccu

Date

Enclosures

Clear Lake Ecological Services Field Office
U.S. Fish and Wildlife Service
17629 El Camino Real, Suite 211
Houston, Texas 77058-3051