UCID- 17523 Rev. 1

# Lawrence Livermore Laboratory

ENVIRONMENTAL IMPACT ASSESSMENT: CHEMICAL EXPLOSIVE FRACTURING PROJECT, PETROLEUM TECHNOLOGY CORPORATION/SUTTON COUNTY, TEXAS

Kathy A. Tonnessen

July 14, 1977



Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

## DISCLAIMER

# ENVIRONMENTAL IMPACT ASSESSMENT

# CHEMICAL EXPLOSIVE FRACTURING PROJECT

# PETROLEUM TECHNOLOGY CORPORATION

# SUTTON COUNTY, TEXAS



Kathy Tonnessen
June, 1977

"Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract number W-7405-ENG-48."

## PREFACE

This review of the plans for a gas stimulation program by chemical explosive fracturing (CEF) in the Canyon sands of the Val Verde-Kerr Basin in Sutton County, Texas also includes an assessment of the environmental effects of the proposed project. This document was prepared at the request of the Nevada Operations Office of the Energy Research and Development Administration, and is intended to provide the information and data required for an environmental assessment of the construction and testing program.

This report was compiled from material provided by the Petroleum Technology Corporation of Redmond, Washington and Union Oil Company of Midland, Texas during a site visit in October, 1976.

Kathy A. Tonnessen
Environmental Group
Earth Sciences Division

CONTENTS


I. Introduction ..... 1

II. Objectives of the PTC Chemical Explosive Fracturing Project ..... 5

III. Proposed Action ..... 6

IV. Description of the Environment ..... 13

V. Effects on the Environment of the Proposed Action ... 17

VI. Alternative to the Proposed Action ..... 22

VII. Mitigating Factors ..... 25

VIII. Irretrievable and Irreversible Commitment of Resources ..... 26

IX. Adverse Environmental Impacts Which Cannot be Avoided ..... 27

X. Cost Benefit Analysis ..... 29

XI. Potential Conflicts with State, Regional or Local Plans and Programs ..... 31

XII. Relationship of Short Term Use to Long Term Productivity ..... 34

References ..... 36

ENVIRONMENTAL IMPACT ASSESSMENT:

CHEMICAL EXPLOSIVE FRACTURING PROJECT, PETROLEUM TECHNOLOGY CORPORATION, SUTTY COUNTY, TEXAS

## ABSTRACT

The Nevada Operations Office of the Energy Research and Development Administration (ERDA) has contracted with Petroleum Technology Corporation (PTC) to perform a gas stimulation program by chemical explosive fracturing (CEF) in the Canyon sands of the Val Verde - Kerr Basin of Sutton County, Texas. This lenticular tight sand deposit, underlying much of southwestern Texas, contains large volumes of natural gas. To date this formation has yielded only marginal amounts of gas because of its low porosity and permeability.

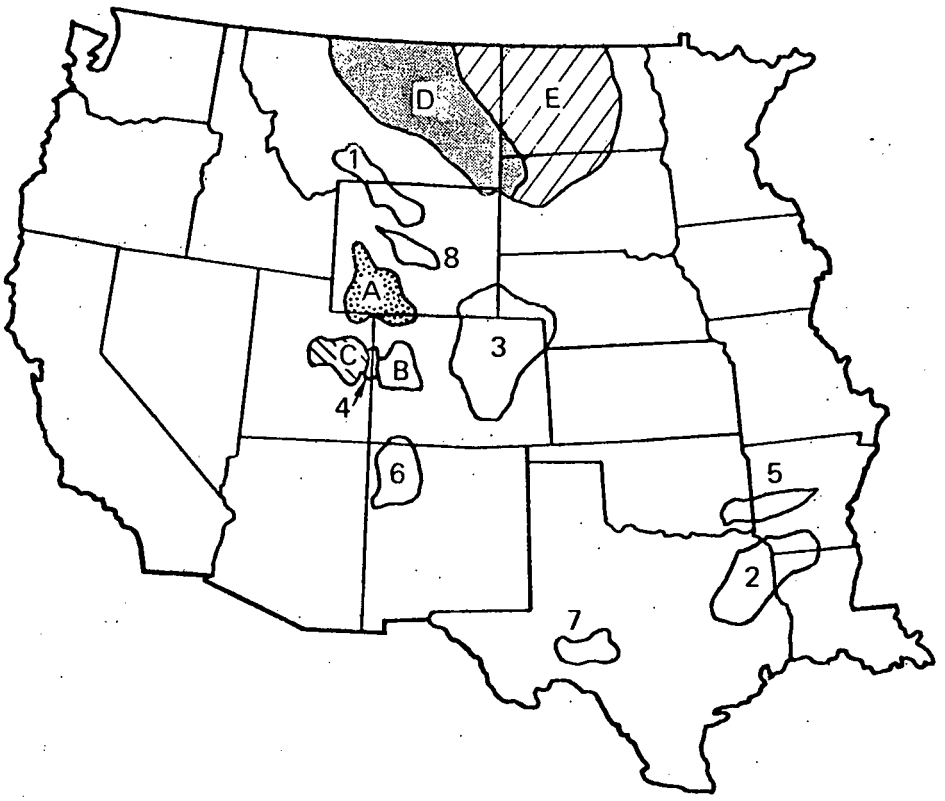
The semi-arid environment of the Aldwell/Sawyer field is characterized by dry arroyos and xeric vegetation. Population is sparse and sheep ranching is the primary occupation. Because of the existence of previously drilled oil and gas wells, road and pipeline construction will be minimal. Impacts from this two well project are expected to be minimal and be confined to temporary surface disruption and increased erosion at the well site.

## I. Introduction

Recent concern regarding the dwindling supply of our nation's natural gas would tend to justify any research, development and demonstration project which would increase those reserves. The Canyon sands tight gas formation of the southwestern Texas Sonora Basin is known to have as much as 5 TCF of gas in place over a six county area (Fig. 1). This gas can best be recovered by use of an optimized stimulation technology which will unlock the gas from the tight sands formation. Stimulation of the western gas sands has been attempted in other parts of the west (notably Utah and Colorado) using nuclear and massive hydraulic fracturing technologies.

This project, proposed by Petroleum Technology Corporation (PTC) of Redmond, Washington, is a two well test to be carried out in Sutton County, Texas. Work will be performed in the lenticular tight sand formation of the Val Verde-Kerr Basin to demonstrate the technical and economic feasibility of chemical explosive fracturing as a method of increasing gas deliverability in that formation. Technical details of the demonstration project are outlined in the PTC technical proposal "Canyon Gas Sand Explosive Fracturing Test Program, Response to RFP No. 261-76-6". This project will be funded in part by the Energy Research and Development Administration (ERDA) with authority granted by the Energy Reorganization Act of 1974. The actual execution of the project will be the responsibility of PTC, with assistance from the Union Oil Company. The entire program for the two well stimulation will be completed within a nine month period from well site selection to production testing and hook-up of the well to a pipeline system.

The site selected to evaluate the effectiveness of chemical explosive fracturing is the Val Verde-Kerr Basin, which underlies some 6500 square miles of southwest Texas (Fig. 2). Sands found at depths ranging from 2600'-9000' in the basin are likely candidates for explosive fracturing because: 1) their thickness can exceed 1200'; 2) they are sensitive to extraneous fluids: 3) they produce gas at uneconomical




| ERDA'S PRIMARY STUDY AREAS | | GEOLOGICAL AREA |
|---|---|---|
| A. | Greater Green River Basin | Tertiary and cretaceous |
| B. | Piceance Basin | Tertiary and cretaceous |
| C. | Uinta Basin | Tertiary and cretaceous |
| D. | Northern Great Plains Province | Cretaceous |
| E. | Williston Basin | Cretaceous |

| ADDITIONAL LOW-PERMEABILITY AREAS IN THE STUDY | | |
|---|---|---|
| 1. | Big Horn Basin | Tertiary and retaceous |
| 2. | Cotton Valley Trend | Jurrassic |
| 3. | Denver Basin | Cretaceous |
| 4. | Douglas Creek Arch | Cretaceous |
| 5. | Duachita Mountains Province | Mississippian |
| 6. | San Juan Basin | Cretaceous |
| 7. | Sonora Basin | Pennsylvanian |
| 8. | Wind River Basin | Tertiary and cretaceous |

Fig. 1. Locations of major western tight gas deposits. The Canyon sands are found in the Sonora Basin in Southwest Texas.

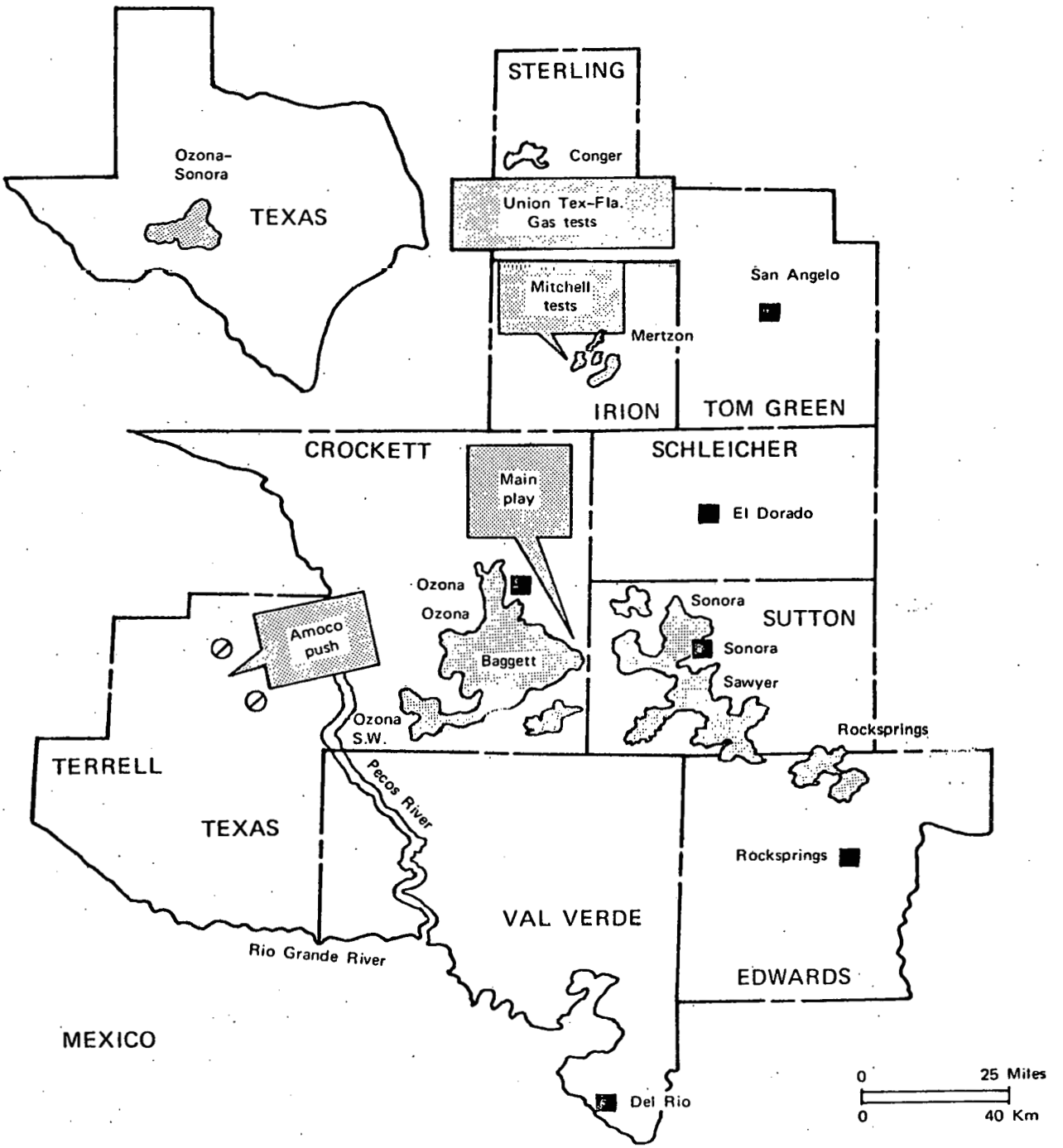



Fig. 2. The Ozona-Sonora gas field in southwestern Texas. The experimental well is located within the smaller Sawyer field of Sutton County.

to marginal rates; (4) they exhibit low ultimate gas recoveries; and (5) they contain large potential gas reserves and are known to be naturally fractured.

## II. Objectives of the PTC Chemical Explosive Fracturing Project

There has been increasing interest in the area of west Texas known as the Aldwell/Sawyer field. Since the rise in intrastate gas prices in Texas in 1971, there has been a tremendous increase in the number of wells drilled in the Canyon sands and the Strawn limes at 7,000'-10,000'. The focus of this PTC project is the Canyon sands deposits that occur in the Val Verde-Kerr Basin, a natural gas sandstone reservoir. These sands are distributed over an area of 6500 square miles and consist of a series of deltaic deposits of tight sands interbedded with shales. These sands are charterized as tight, dirty, lenticular, water sensitive sands, that are known to be naturally fractured. Although there have been considerable gas pay in this field, some of the drilled wells have failed to produce due to the "tight" nature of the deposits and the low permeability of the formation. It is proposed by PTC and Union Oil that such a deposit would be a suitable candidate for experimentation with the PTC chemical explosive fracturing technique to "liberate" the natural gas reserves.

The Energy Research and Development Administration's objectives in funding such a program include:

1) To determine which tight gas formations can be effectively stimulated using chemical explosives;
2) To experiment with fracture treatments which do not make use of proppant materials to keep induced fractures open and which do not require the use of large volumes of water, which might tend to further plug the reservoir;
3) To calculate the economic feasibility of performing such chemical explosive fracturing in the Canyon sands of Texas;
4) To determine the optimal method of explosively fracturing the formation in terms of the amount of explosives and the type of treatment; and

5) To further evaluate the safety factors associated with down-hole mixing of the PTC explosive as contrasted with the more traditional use of nitro-gel explosives in well completions.

The purpose of the project's experimental design, which calls for the testing of two separate wells using different techniques, would be to obtain the maximum amount of information relating to the most effective method of stimulating this particular reservoir. Results will permit the direct comparison of the different completion techniques. Also the testing of more than one well in a given area will allow for the collection of complementary data with regards to the characteristics of the reservoir and the experimental results from the explosive stimulation.

ERDA's objectives will be realized in the form of a series of deliverables which PTC will supply at the completion of the project. The Contractor shall supply:

1) a complete set of logs from the two tested wells;
2) monthly technical progress reports and financial management statements;
3) a complete summary report on the results of the experimental treatment, and
4) a final report which will include an economic evaluation of the project.

PTC will also be requested to present the results of their tests at an annual symposium sponsored by ERDA on the subject of enhanced gas recovery.

## III. Proposed Action

Petroleum Technology Corporation will carry out the proposed two well test program within a period of nine months in the Aldwell/ Sawyer field in Sutton County, Texas. The wells will be drilled and tested on acreage leased by the Union Oil Company within the formation known as the Canyon sands of the Val Verde-Kerr Basin. This area of southwest Texas is already the site of intense exploitation of the gas resources, with as many as 1500 gas wells being drilled and completed in this area since 1971.

The first phase of the demonstration project is designed to evaluate the effectiveness of a staged CEF shot (Fig. 3-5). The second well test is designed to compare the results of a simple borehole treatment, where all potential producing lenses are treated, to the results obtained in the two-stage job in the first phase:

Phase I: Open Hole Completion - Two stage Displacement CEF Test

a) The first well will be drilled to a depth of approximately 7,450' in the Canyon sands of the Aldwell/Sawyer field. Coring and logging and completion of the well will be performed; pre-stimulation production testing will be carried out.

b) This well will then be stimulated using a two-stage CEF test. Each stage will treat a section of approximately 500' of the tight sand formation. Each of these sections will be treated with 15,000 lbs. of PTC-4 explosive of which 10,000 lbs will be injected into the formation; that is, a total of 30,000 lbs. will be used, 20,000 lbs. of which will be injected into the formation.

c) The post-shot procedures will include pressure buildup and drawdown tests as well as short term and long term productivity tests to provide information for a technical and economic assessment of the stimulation process.

Phase II: Open-Hole Completion No. 2 - Single Stage Borehole CEF Test

a) In the same Aldwell/Sawyer field a second well of depth 7,450' will be drilled, cored, logged and completed.

b) This well will then be stimulated according to the program plan using 30,000 lbs. of PTC-4 explosive, following the usual pre-stimulation production tests.

c) Following stimulation,pressure build-up and drawdown tests, as well as short-term and long-term productivity tests will be performed to provide information for the economic and technical assessment of this particular technology.

Site selection will be performed jointly by Union Oil, PTC and

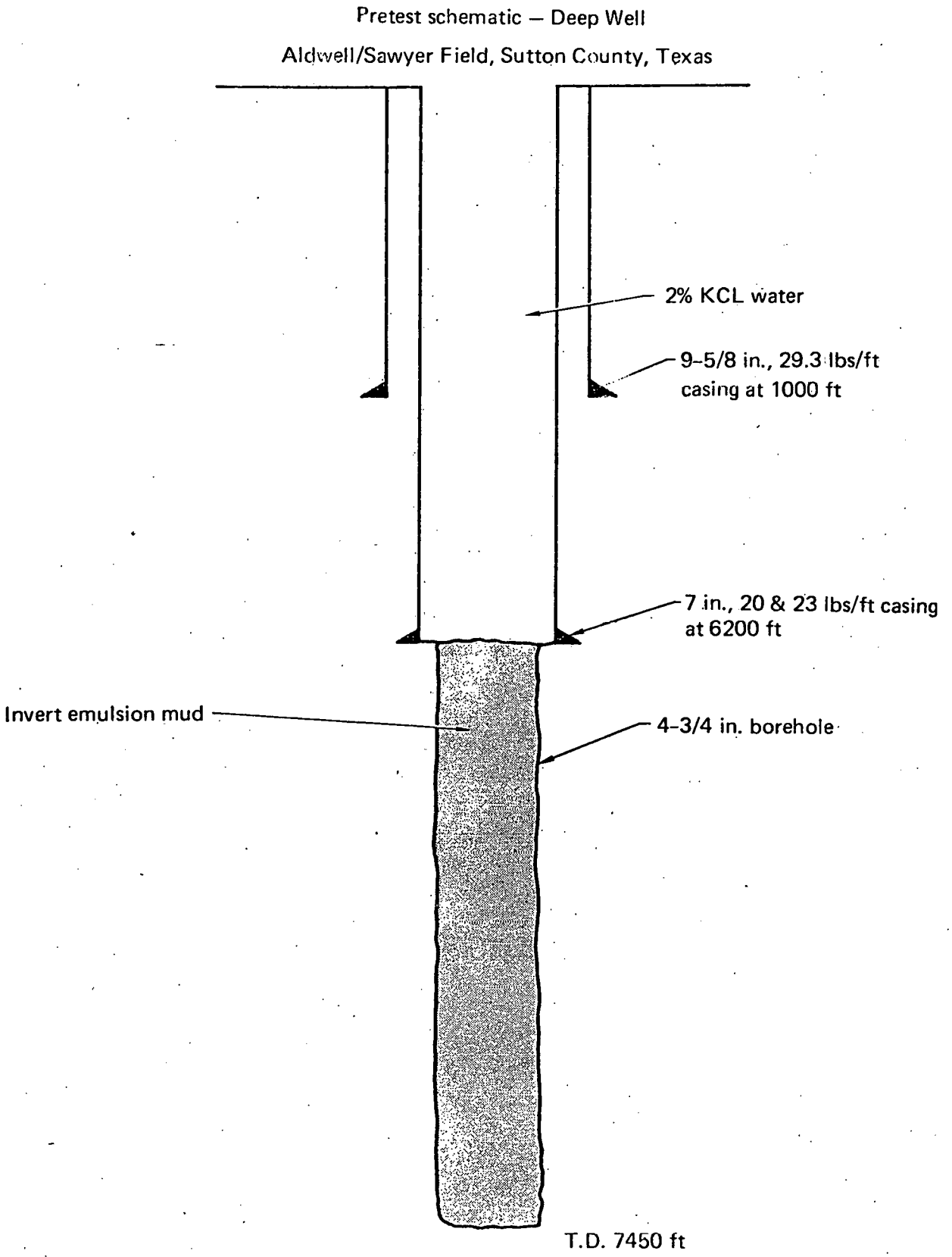



Fig. 3. Pre-test schematic, deep well to depth of 7450 ft.

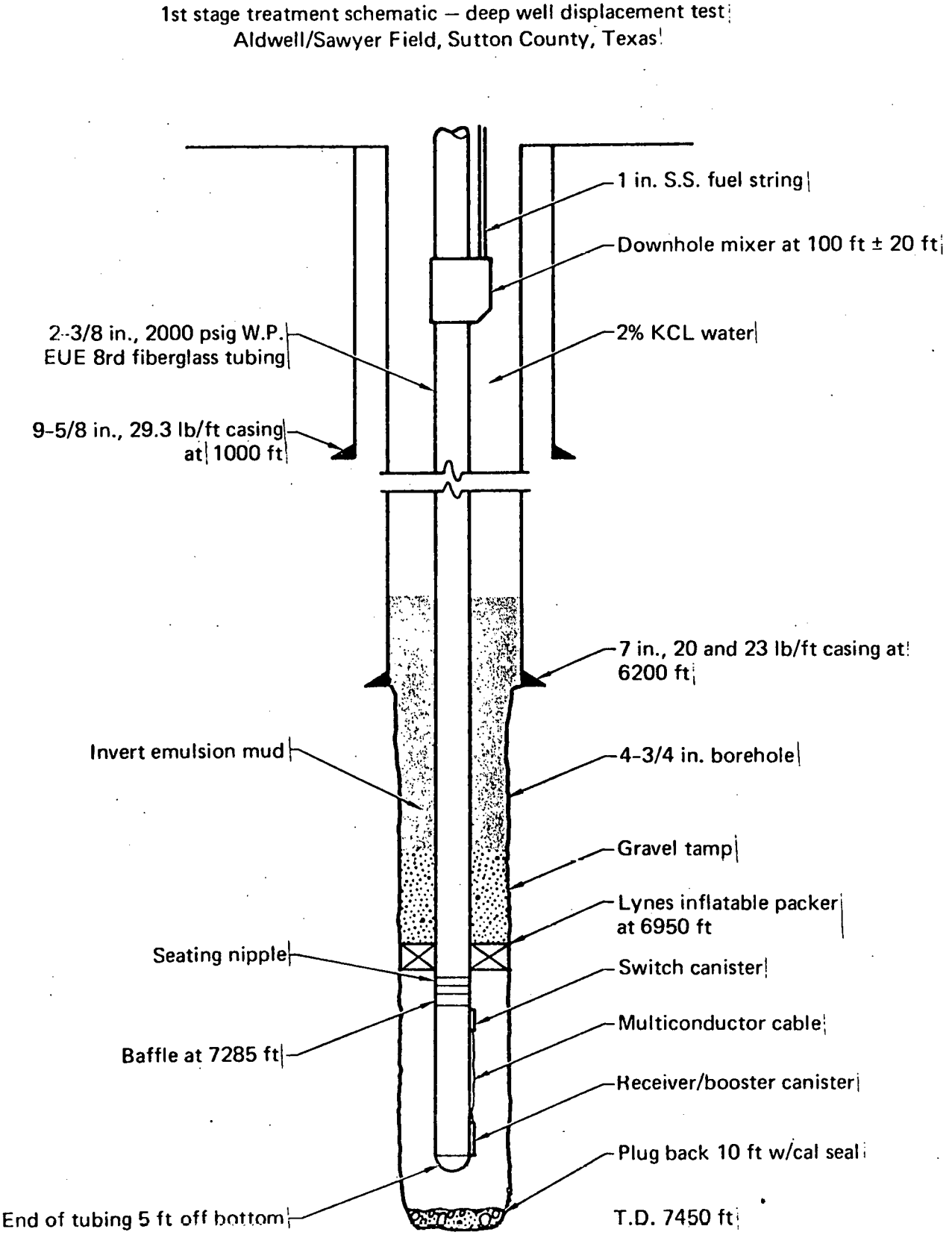



Fig. 4. First stage treatment schematic, deep wall displacement test.

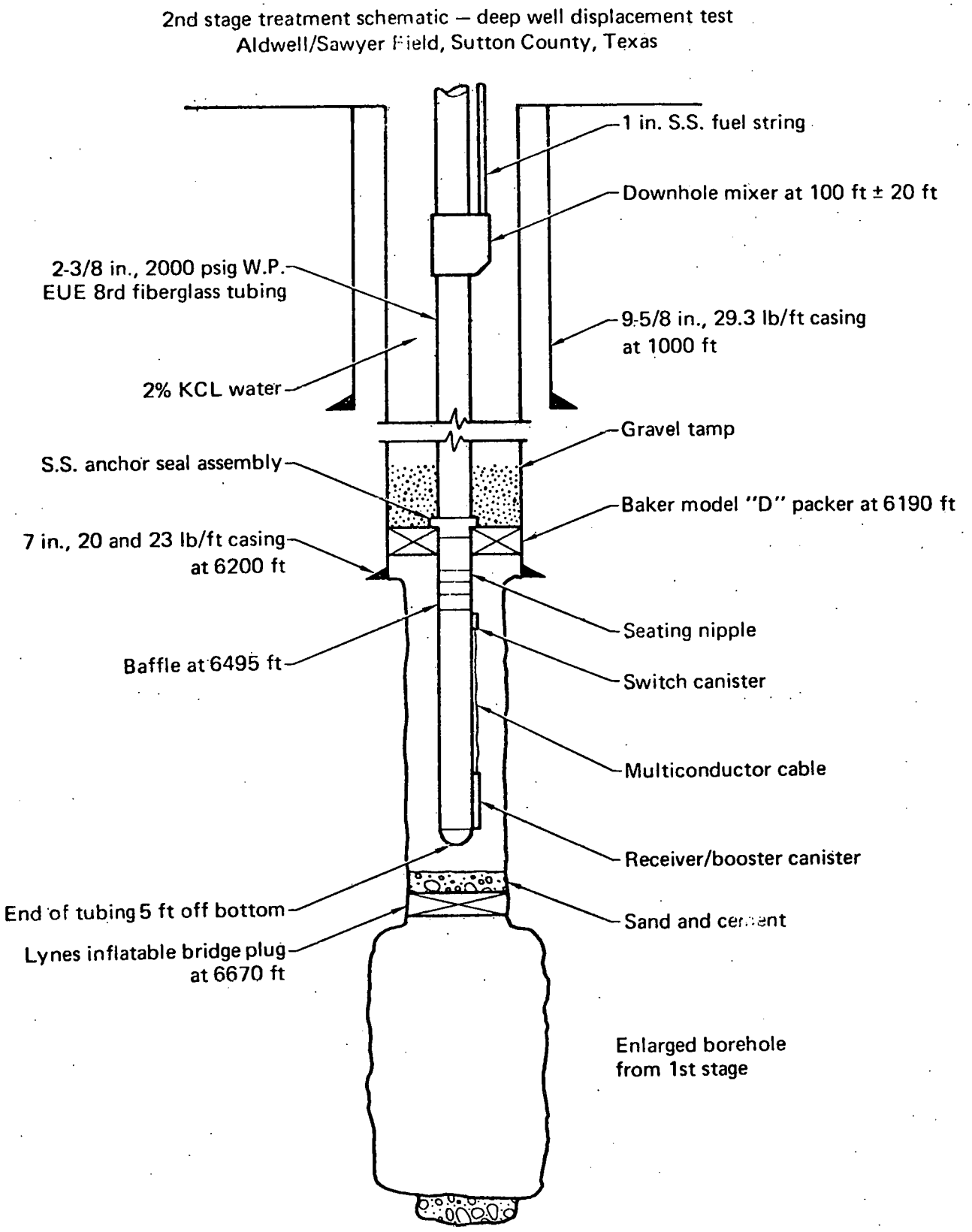



Fig. 5. Second stage treatment schematic, deep well displacement test.

the ERDA Nevada Operations office personnel. Probable sites will be located on sparsely wooded, relatively flat rangeland within the county of Sutton.

At the site of each of the two new wells, a drilling pad and experimental fracturing area will be cleared of vegetation and leveled to allow for the positioning of machinery. Necessary roads to the drilling site will be leveled and graveled. This will be of minor importance as there are numerous well-maintained company roads which allow ready access to the Aldwell/Sawyer field. Each of the cleared drilling pads will be less than one acre in area. This type of development and development related disturbance is common to this area of Texas, where oil and gas drilling has been going on for decades.

The actual drilling of the wells will entail a minimal impact on the surface environment. A pit for waste cuttings and drilling effluent will be present at each of the sites, but the size of that pit will be limited. Air drilling will be used at these sites, resulting in the production of little, if any, waste mud. The other obvious advantage of drilling with air is in terms of actual drilling time. Using air as the drilling medium, a well can be spudded at a rate of 500' - 800' per day; while with mud the rate is about 30' - 100' per day

The fracturing process will entail temporary disruption to the land surface because of the need to deliver the explosive components to the site in large tank trucks. Graded roads are necessary to allow access. During the actual pumping of the explosives into the formation there will be four trucks located at the site. Tubing and piping strings will be laid down from the trucks to the well-bore to deliver the chemicals. There will also be a control van present to monitor the operation and to record relevant data (Fig. 6). Seismic stations may be set up by representatives of Sandia Corporation to monitor the progress of the explosive treatments. This recording equipment will be removed at the close of the experiment.

Water requirements for the drilling and fracturing operations

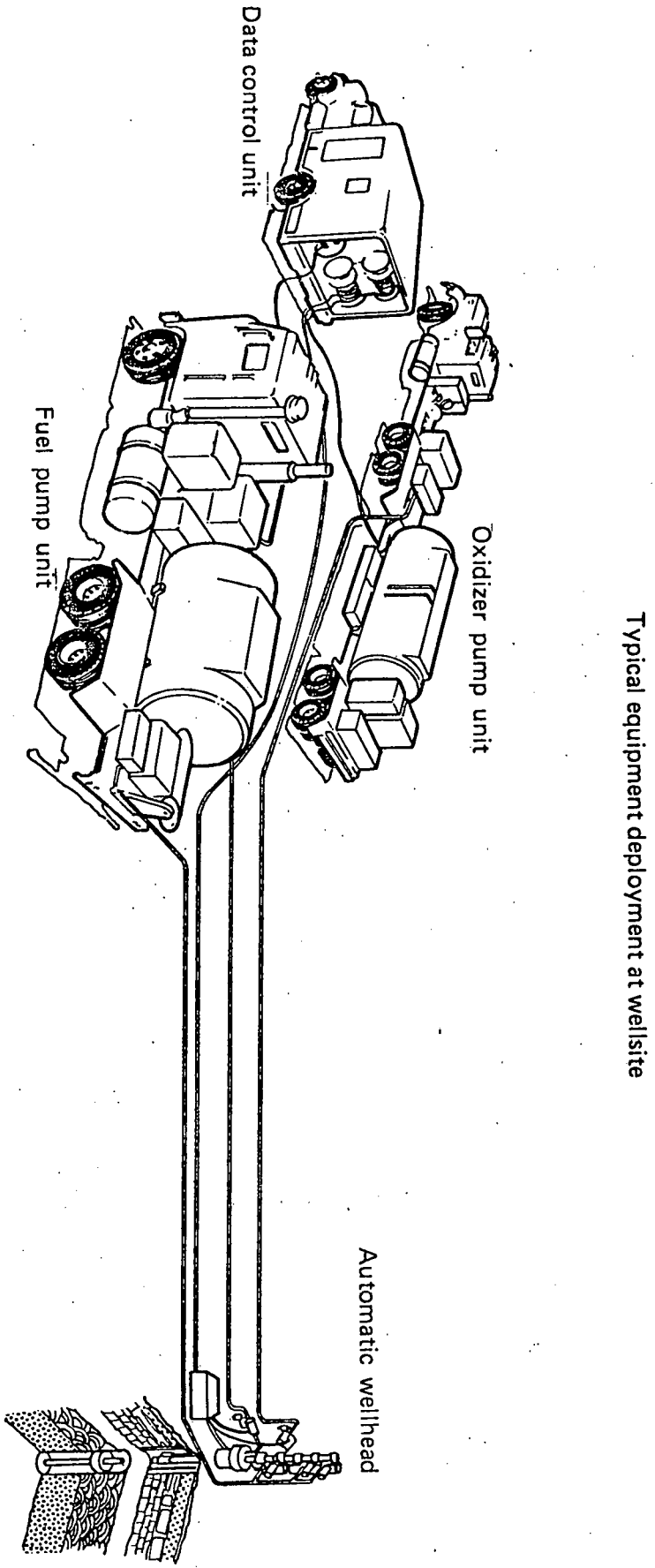



Fig. 6. Chemical explosive stimulation treatment surface apparatus. Explosive is mixed downhole.

will be minimal. Any water supplies which will be needed may be obtained by trucking supplies in or by tapping some of the well and spring water available in the Edwards limestone and Kea formations.

Following the detonation of the explosive, the hole will be cleaned out to the top of the rubble. Solid debris will be temporarily stored at the site until the completion of the operation and will then be trucked from the area and disposed of according to the laws of the state governing surface reclamation.

Pipeline gathering systems are already in existance in this area of Texas due to previous drilling of productive natural gas wells in the Basin. Less than a mile of new pipeline per well will be laid underground to allow for the collection of gas produced as a result of the explosive fracturing treatment. The proposed site of well #1 is actually located 1200' from a feeder pipeline.

In general, roads in the area are passable year round and are adequately maintained by gas companies in the area and by the ranchers who lease out the mineral rights to their land. Some of these roads were built to accommodate the heavy machinery and trucks which are needed for well drilling enterprises. It will probably be necessary to extend certain stretches of access road to the two sites.

## IV. Description of the Environment

This area of southwestern Texas (Fig. 7) is characteristic of central Texas vegetation and landform: rolling lands, interrupted by dry stream beds and arroyos, with dry, scrubby vegetation. Principal use of the land is for ranching and oil and gas drilling. The latter industry has been thriving in the Val Verde-Kerr Basin for several decades.

The wooded area of Sutton County consist of low growing juniper and scrub oak and willow. Plant cover is sparse and is characterized principally by certain xeric species, such as cacti and mesquite, and opportunistic weedy species, such as goldenrod and broombrush. The few trees are stunted in growth and are distributed widely. The soil is dry,

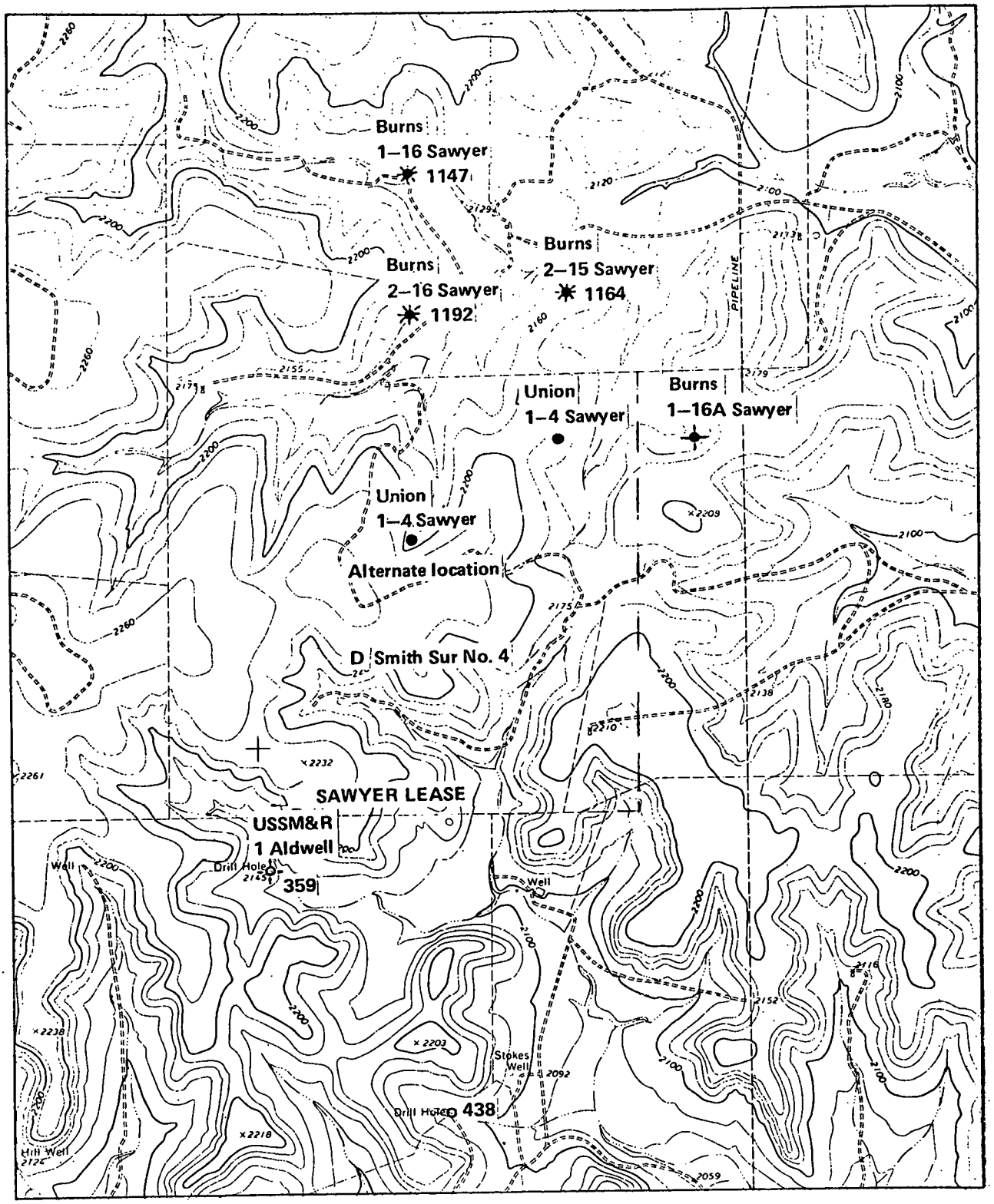



Fig. 7. Topographic relief of well site area in Sutton County, Texas. The Aldwell/Sawyer field is the site of previous gas development.

with numerous rocky outcrops.

Much of the range area has been cleared to allow for easier access to forage for the sheep, angora goats, and cattle which graze the area. These livestock have contributed to the patchy distribution of the vegetation. A number of native animal species have been identified in the area. These include: jackrabbit, mule deer, raccoon, ringtail, red-headed buzzard and wild turkey. These game animals are occasionaly hunted by the ranchers.

The weather for most of the year is hot and dry, although flash floods have been known to fill dusty draws during the heavy, seasonal rains. The land and climate do not support agriculture, thus the importance of ranching in the area. Average rainfall for most of the Basin is limited to 17" per year.

This region of Texas may be classified as semi-arid, with an extremely sparse population. The remoteness of the Aldwell/Sawyer field was considered to be an asset as a location for the CEF testing. The population of the county of Sutton is 3,175 or approximately 2 persons per square mile of county area. The nearest town to the proposed wells is Sonora, the county seat, located approximately 19 miles north of the Sawyer Ranch on route 277 (Fig. 2). This town is serviced by a branch of the Santa Fe railroad and may be the source of some of the labor required for the project.

The proposed site of the first experimental well is located on ranching land which has been leased from the owner. This location is situated approximately 800 feet from a lightly used paved road and about 1200 feet from a caliche ranch road. The nearest dwelling is the Reick ranch house, approximately 1 1/2 miles away. There are no surrounding structures, mines or nearby wells (the closest well being Burns #15, located 1/2 mile away). According to state law, well spacing must comply with the 160 acre limit. This limitation will be complied with. The other designated well will be located in an even more remote location within the field.

Other population centers in proximity to the experimental sites include San Angelo to the north (sheep capital of Texas) and Midland to the northwest headquarters for Union Oil Company). These towns will serve as the base of operations for the experimental program.

The Aldwell/Sawyer field is located on a comparatively undissected portion of the Edwards Plateau formation. This topographic province averages about 2200' above sea level and is cut by canyons and draws which may dip as far as 200' lower (Fig. 7). The surface is immediately underlain by a thick series of limestones of Glen Rose-Fredricksburg age. These limestones and deeper Cretaceous sands contain fresh water supplies which may extend as deep as 760' below the surface in the Kea and Edwards formations. The wells will be cased through these formations to prevent aquifer contamination. Numerous wells have been dug into these formations to a depth of 200' - 500' to obtain water for private use, livestock watering and irrigation. Most of the rivers in the area are dry for a large part of the year. The closest river to the experimental sites is Devil's River, located to the south of Sawyer's Ranch. The Pecos River and Rio Grande flow through counties which adjoin Sutton to the south and west.

The underlying Canyon sands of west Texas are deposits of tight sands interbedded with shales. The sands are known to reach a thickness of 1200', the average depth being 6000' below the surface. Good quality natural gas is present throughout this formation. Hundreds of wells have been completed, mostly in the last five years with production rates of between 1-2 MMCFD. However, a number of the wells drilled have failed to produce because of the microdarcy permeability of the sands. These are the target formations for the CEF program. An anomaly in the formation has been noted specifically. To the north of San Angelo the Canyon sands are known to produce oil at a depth which is characterized by 1 millidarcy permeability to the south.

Land use in the immediate vicinity of the experimental site is characterized by sheep grazing and well drilling. Most of the drilling near the West Sawyer ranch has been done by independents who receive farmouts from the larger companies and from the ranch owners. There are a

number of wells already located in proximity to the site of experimental well #1 (Fig. 7), with the closest being located 1/2 mile from that site. Because of the importance of gas production in this area, sites will be chosen so as to minimize the possibility of damaging existing wells during the CEF explosive test.

The natural gas pipeline system within this region of southwestern Texas is extremely well developed and extensive. No site within the Sawyer field is less than about 1/2 mile from a feeder line for one of the intrastate or interstate pipelines.

There are some recreational and archeological features of this region of Texas which should be noted. Approximately 30 miles north of the Aldwell/Sawyer field is located the Sonora Caverns, an underground, limestone cave with formations that are as much as 60 million years old. These caverns have been developed commercially as a tourist attraction and are viewed year round. Near the Pecos River certain archeological expeditions have uncovered Indian remains which have been recovered and preserved. Brachiopod fossils are also abundant in the area and a number of fossil beds have been located and preserved by a paleotological lab located in Midland, Texas. No such artifacts or fossils have been found within a 10-20 radius of the proposed experimental sites. However, to insure against possible intrusion on an archeological or paleontological site, all drillers are directed to consult with local officials and the appropriate labs prior to initiation of activity.

V. Effects on the Environment of the Proposed Action

There are currently more than 1500 wells drilled in the Ozono-Sonora play area, many of which are producing economic amounts of gas. Current drilling and completion procedures within this area of southwestern Texas is having no significant effect upon the environment of that area. The proposed two well program is expected to contribute little in the way of environmental degradation. The small scale of the program will result in only limited, site specific impacts.

This project will produce a limited environmental impact because of: the small scale of the operation, making use of 1-2 acres within Sutton County; the short duration of the project (9 months): the limited number of workers involved; the limited land use in that area; the scarcity of population; and the selection of a drilling and fracturing program which

will minimize disruption to the surface.

The actual drilling process that will take place at each of these well sites will disturb less than 1/4 of the one acre site area; approximately a 75' by 50' drilling pad will be used. The fracturing process will also be contained within that limited area, the only disturbance being the situation of tank trucks and pumping engines at the well site.

Construction at each of the selected well sites will include the grading and extension of the access roads, the construction of a small additional length of feeder pipeline and the actual leveling of the drilling pad. This activity will result in increased surface erosion, increased noise pollution, some additional air emissions, some disruption of animal and livestock habitat and inconvenience to the local ranchers who use the roads for transportation. However, as part of the leases granted to the contractors the ranchers are required to guarantee access rights as well.

Noise pollution will result from the air rotary drill rig operation over a period of about two weeks. To a limited extent there will be some impact resulting from the downhole detonation of 30,000 lbs. of explosives. Since the explosive will be pumped downhole under pressure, the noise from the pumping engines will produce a temporary disturbance.

Air pollution, over the limited time period included in the drilling and fracturing operation, will be produced from the operation of the drill rig, the pumping engines and the transport vehicles.

The use of air as the drilling medium for the experimental wells minimizes the need for water to be used in this process. Concurrently, it minimizes the area on the surface which must be reserved as a mud pit to receive waste drilling water and mud. The two chemical components which make up the explosive mixture for the CEF process will be consumed in the explosion and thus their disposal presents no problem. There will be no proppant added to the fracturing fluid; it is suggested that the rubbilization of the formation resulting from the explosive charge should serve to keep the newly created fractures open. The rubble which will be produced

in the wellbore as a result of the explosion may or may not be cleaned out, depending on the particular experiment in progress. Following the downhole detonation, the mixer will be removed, along with the tubing which had been used to transport the chemical components downhole. Any of the debris which is removed from the hole prior to post-fracturing tests may be stored on the site and then removed at the completion of the experiments.

The activity at the experimental site will result in some disturbance to the local population of animals due to temporary disruption of the rangeland and the general habitat. Given the fact that grazing has been going on in this area for a number of years, much of the plant cover has already been destroyed. This factor, along with the dry nature of the soil, has resulted in patchy ground cover over much of the area. The disturbance of an acre of surface will thus have minimal effect upon the amount and quality of native animal habitat. The vast, unpopulated range area can readily support any individuals which may be displaced as a result of this development.

Construction of additional access roads to the well sites and the improvement of already existing roads will result in some small amount of disruption to the surrounding land. Most of the area within the field being considered for development is located in proximity to either a ranch road or to one maintained by an oil or gas developer. The construction of a short span of additional access road would make use of very little additional land area. Use of these roads during the actual program may interfere to a limited extent with the activities of the local ranchers. However, the area is so large and the population so low in Sutton County that this interference is expected to be negligible. Increased vehicular traffic will result in an increase in the rate of erosive loss of soil along the access roads. Such traffic will increase the level of noise and air pollution over a period of time.

Little water, if any, will be necessary for either the drilling or the fracturing. The drilling medium is air and the fracturing fluid is

composed of two non-detonable chemical mixtures. A small mud pit constructed at the drilling site will be used to store the rock cuttings and debris resulting from the drilling process.

The subsurface aquifers in this area are located from the surface to 760' below the surface, although most well water is taken from supplies located between 200' - 500' in the Edwards limestone and Kea formations. These aquifers will be protected from contamination during the drilling and fracturing by casing through the specific zones.

Most of the explosive treatments of gas bearing formations result in the creation of vertical fractures. However, these fractures are propagated at such a depth, 6000' - 7000', that intrusion into a freshwater aquifer is highly unlikely. Also, fractures propagated in this way usually are attenuated once another formation or rock type is encountered.

There may be some concern regarding the detonation of this large amount of explosive below ground and the impact on surface structures and nearby wells. The closest gas well to the first experimental well is located 1/2 mile away. The 160 acre spacing should insure that no previously drilled gas well is located near enough to the experimental wells to sustain damage. The closest structure to the first experimental well is a ranch house, located at 1 1/2 miles away. The second well is expected to be developed in an area even more remote from human habitation. Precautions will be taken to avoid damage to any wells or structures which may be located near to the experimental wells.

The experimental stimulation treatment will make use of 30,000 lbs. of the PTC explosive, to be detonated at a depth of between 6000' and 7400' below the surface. The resulting ground velocity should not exceed 0.1 inch/sec. The U. S. Bureau of Mines has established criteria for threshold damage levels. This level has been set at a velocity of 2 inches/sec. To document that these levels are, in fact, not exceeded, Union Oil will install seismic monitoring equipment at the sites. Data obtained will be used to evaluate the performance of the chemical explosive mixture.

The present PTC system is definitely safer to personnel than the transporting, handling and loading techniques involved in 80% gel and liquid nitroglycerine. This is due to PTC's unique downhole, below ground lvel mixing and manufacturing process. Two non-detonable materials, a fuel and oxidizer are pumped from tank trucks to the well head and downhole some 100 or more feet to a mixer where they react and blend to form the explosive which is displaced down the tubing to the formation to be treated. Only 1/2 lb of explosive is handled at the surface during the brief time required to load the command fire and back up detonator systems. The detonators are loaded by 2 of PTC's skilled licensed blasters and during this operation all other personnel leaves the well site until the detonators are downhole, well below ground level. Further, an in-house analysis performed by Hercules, Inc., for PTC indicated that the risk to workmen involved in CEF is equivalent to or less than the risk involved in any typical non-hazardous work situation.

This region of southwestern Texas is not seismically active. Any concern that such explosive treatment might induce seismic events is not warranted. In many of the gas wells drilled in the Aldwell/Sawyer field various other methods of stimulation of the formation have been used with no evidence of subsurface movement.

Because of the small scale, experimental nature of this program, its impact on the socio-economic structure of the area will be minimal. Workers at the two wells will be employees of PTC, brought in from Washington, and local drilling crews supplied by contractors in Midland or San Angelo. Officials of Union Oil will come from the headquarters in Midland. No additional employment will result as a consequence of this project. There will be no requirement for additional support facilities due to the short time span of the project. The wells will be drilled consecutively, thus requiring a minimum number of employees to be present at the site at any one time. The only disruption from this project will be the increased traffic and noise which will result from the proposed development. Use of some grazing land might be pre-empted during the

experimental phase. However, following the explosive treatment and post-fracturing stages, the equipment will be removed and the drill pad leveled and reseeded.

Environmental impacts of the proposed project in Sutton County, Texas will be relatively minor and limited in duration. Increased noise pollution, air pollution and accelerated erosion will result from the drilling and fracturing of the two experimental wells. Present land use might be disrupted temporarily. However, these impacts will be mitigated by the short time span of the project and the limited area needed for the development.

## VI. Alternatives to the Proposed Action

As is the case with most developmental projects, there are a number of alternatives to the PTC program which may be considered in lieu of the proposed CEF project in southwest Texas. These include development of different types of stimulation technologies, experimentation with explosive fracturing under different conditions or in different locations, and the abandonment of the technology completely.

Possible alternative stimulation technologies include well completion using: conventional nitroglycerin gel explosives, hydraulic fracturing of the formation, massive hydraulic fracturing, methanol, cryogenic or foam fracturing or nuclear explosive fracturing. In addition to these alternatives, large volume chemical explosive fracturing (CEF) may be considered with reference to a different type of chemical mixture.

Massive hydraulic fracturing has been tested in a number of different formations from the Devonian shales of West Virginia to the Western gas sands of the Uintah Basin as a method of stimulation of tightly held natural gas. Conventional hydraulic fracturing was initially used in well stimulation in 1949. These two types of stimulation technologies are designed to bypass wellbore damage and to stimulate the specific zone of interest. The use of a proppant material (sand or glass

beads) is designed to permit the newly created fractures to remain open and to allow for the flow of gas through these artificially created fractures. One of the negative aspects of development of this technology would be the effects of fluid retention on the formation, which may be composed of a high proportion of hydrous clays. Additional water absorbed in the tight pore spaces might be extremely difficult to remove, thus impeding the flow of gas through the fractured formation. The consideration of cost effectiveness may also enter into the decision to hydraulically fracture a formation. MHF treatments make use of large volumes of fluid (500,000 gallons) and sand proppant (million pounds) and treatment chemicals, all of which are costly.

Experimental stimulation programs involving the use of methanol, gas and foam as the fracturing fluid have been carried out within the region of the Devonian shales. None of these experimental fracture treatments have been applied in the Canyon sands. However, there has been considerable experimentation with these various fracturing methods in other tight reservoirs in the Uintah and Piceance Basins and in the Devonian shales of the eastern U. S. These non-water fracturing treatments are particularly useful in formations which would tend to be damaged or plugged if a hydraulic fracture treatment were used.

The possibility of development of an alternate method of chemical explosive fracturing exists. Prior experience with conventional explosives has done much to point up the hazards associated with their use in such stimulation projects. Accidents have occurred in the past and the safety of workers is of concern. At the present time, the PTC Astro-Flow II explosive program has been proven safe in field and laboratory tests. The concept of downhole mixing of nonexplosive components to form a detonable material would appear to be the safest method of delivering the explosive to the formation. In surface handling and transportation such a method must be considered to be superior to conventional explosive methods.

Another explosive technology, natural gas stimulation using nuclear explosives, has been tested at Rio Blanco, Colorado. This technology

does not appear appropriate for use in the tight gas formations of Texas at the present time.

Alternate siting of the PTC experimental work might be considered for some other area within the Aldwell/Sawyer field in Texas. Although this alternative may appear to be acceptable, strong arguments might be made for development in the area specified in the technical submission presented by PTC. This area of Sutton County, Texas may be considered as a desirable location for development of the experimental wells for a number of reasons: proximity of the site to ranch roads and an extensive pipeline system; limited potential use of the land for other purposes; proximity of producing gas wells to allow for production comparisons; and scarcity of population thus limiting the potential for disturbance. Chemical explosive treatments of other tight formations are also being carried out in the Devonian shales of West Virginia and Kentucky. This type of program in a different, tight formation will permit evaluation of the general utility of this stimulation procedure in different types of reservoirs.

An argument against development of the potential gas reserves of the Canyon sands might be furthered by those who would prefer to see efforts directed towards development of some alternate source of energy, i. e., coal gasification, oil shale or geothermal resources. It is preferable that a number of alternate energy sources be developed simultaneously to allow for rapid accumulation of energy reserves in the United States. The environmental hazards associated with the CEF technology would appear to be less severe than those of many other energy development technologies. Also the clean burning characteristics of natural gas make it an acceptable energy source in terms of the environmental consequences of energy use.

A final objection to the increased recovery of natural gas resources using this type of stimulation technology might be made by conservationists who argue that the remaining fossil fuel reserves in the U. S. should be conserved for future generations. Such a philosophy would leave untapped an estimated 5 TCF of gas resources that are estimated to be contained in this region of the Canyon sands alone. The extension of this

technology to other reservoirs in Texas would unlock significantly more of this resource. The need for increased energy supplies in the very near future by the U. S. and the undesirable alternative of reliance upon foreign supplies of fossil fuels would argue strongly against this alternative.

VII. Mitigating Factors

Because of the limited scale of this experimental project, (2 gas wells developed within Sutton County, Texas) impacts to the environment are expected to be minimal. It is also important to note that this area of southwest Texas has been the site of resource exploitation for a number of years. Oil and gas drilling is common in the area, with as many as 525 wells per year being drilled within the 10,500 square mile Ozona-Sonora play area. Thus, this program, as outlined by PTC, will not represent a novel enterprise in this area.

Surface impacts are expected to be the only ones which will require some sort of mitigating measures to guard against possible environmental degradation. In this dry, sparsely vegetated area, erosion of the soil might present a problem due to increased vehicular activity. To minimize the impact of the drilling and fracturing operations on the land, PTC and its contractors will take a number of precautions. Sites will be selected in locations which will be readily accessible from existing ranch roads. The first designated site is known to be located adjacent to an asphalt road on Sawyer ranch property. Sites removed from dwellings will be favored. One selected site is within 1 1/2 miles of the nearest ranch house; the second site will be more remote. In each of the test locations, roads leading to the wellhead area will be cordoned off during the experimental detonation. All dwellings within a 200 feet radius of the wells will be evaculated prior to the explosion. If required, additional reinforcement of nearby structures will insure against damage resulting from the underground explosion. The 160 acre well spacing requirement will insure against siting of the two project wells unacceptably close to other producing wells in the area. Thus no damage will result from the detonation of the

30,000 lbs. of explosives.

The actual drilling and fracturing process will result in the surface disturbance to a total of less than 1 acre (probably less than 1/4 acre per well). This area will be reclaimed and reseeded following the fracturing process and post-fracture monitoring in accordance with regulations of the State Department of Natural Resources.

Any disruption of the plant or animal life which may result from this development will be limited in duration and extent. Following the drilling, explosive and clean-up phases of the experiment, the sites will be leveled, reseeded and the debris removed. Most of the vegetation in this area is composed of a low concentration of bushes (mesquite) and weeds. Since these plants were originally invading species on the disturbed rangeland, they will readily repopulate the well area once the project is completed.

The use of air drilling virtually eliminates the need for mud pits. The absence of waste water to be recovered from the wells and disposed of on the site make this method of stimulation preferable to a hydraulic treatment.

From a socio-economic viewpoint, impacts should be minimal, if not altogether absent. No new personnel will be relocated in the area on a permanent basis. There will be no additional burden placed on existing community facilities as a result of this experimental program.

Oil and gas production is one of the principal uses of land in this part of Texas. Current drilling and completion activity in this area has to date had no significant effect upon the environment of Sutton County. It is reasonable to expect that the addition of two more such wells will not contribute to environmental degradation in this area.

## VIII. Irretrievable and Irreversible Commitment of Resources

Certain of the materials and chemicals which will be used in this chemical explosive fracturing project will be irretrievably lost during the course of the experiment. These include: 30,000 lbs. of PTC explosives per

well (PTC-4: hydrazine, ammonium perchlorate/ammonium nitrate), command and timed detonators, 200-800 feet of tubing below the packer, the packer, wiper plugs, baffle and seating nipple, which are positioned below the packer. In addition, any gas which is produced from the two test wells will be delivered into a nearby pipeline and will be consumed commercially. These are reserves which could conceivably be conserved for use by future consumers. That small amount of gas which will be flared during the clean-out of the wellbore will likewise be lost, as will be the fuel expended by the drilling rigs (air rotary), trucks and compressor engines which will be operating during the pumping and drilling stages of the operation.

During the period of operation the use of the land for its primary purpose of grazing by livestock will be sacrificed. This, however, is but a temporary loss of use of that small amount of land.

The efforts of ERDA personnel involved in this joint industry/ERDA project will also be committed to this project instead of to another type of energy development project.

IX. Adverse Environmental Impacts Which Cannot Be Avoided

Because of the nature of the land to be used during the PTC/Union Oil CEF project in Texas, the impacts associated with this development will be essentially nonexistent. The minor impacts which will accompany the development of the two planned wells must be tolerated over the limited period of time planned for the project (Fig. 8) in order to allow for testing and development of this type of stimulation technology. These impacts will be in terms of increased surface disruption within the limited area of well development, increased erosion of the land surface and heightened noise and activity levels during the actual period of testing. Surface disruption will be in the form of limited road grading into the two sites, use of the roads for vehicular traffic, and preparation of the drilling pad (approximately 1/4 acre per well). Minor increases in the level of air pollutants will result from this increased activity in the area,

1. Using available geological & imagery data, select well location. Finalize drilling, coring, logging, drill stem testing & casing programs. Review previous test results.
2. Move rotary rig on location, drill, core, DST, log and complete well. Finalize treatment design & procedures. Move out rotary.
3. Transport PTC personnel to base station in West Texas. Prepare & checkout equipment.
4. Using completion rig, run fiberglass & stainless tubing strings, mixer & packer. Install & test wellhead assembly.
5. Load units at base station to comply with Texas weight laws & move units on location. Complete necessary chemical loading at well. Manufacture, displace and detonate explosive in well.
6. Return PTC equipment to West Texas base station or Appalachian base station and personnel to Seattle.
7. Pull downhole equipment out of well, then cleanout wellbore as required.
8. Run short-term production tests. Gather & analyze data. Continue monitoring production after well is connected to pipeline.
9. Prepare & submit monthly and final reports.



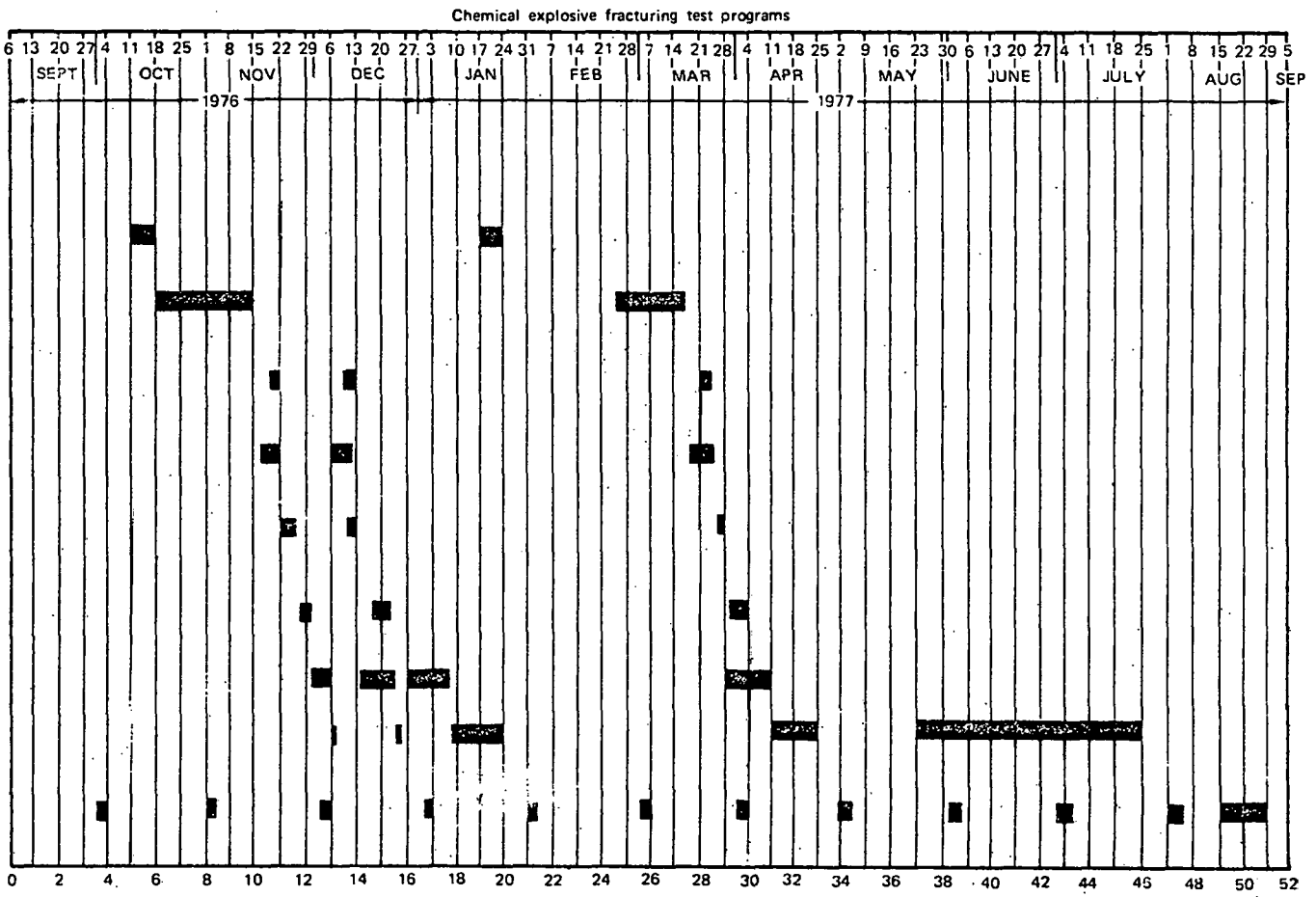



Fig. 8. Schedule for PTC Chemical Explosive Fracturing Program in Sutton County, Texas

from increased vehicle use and engine operation during drilling and pumping of the explosives mixture. Of necessity, some small amount of rangeland will be disrupted temporarily. Limited natural animal and plant habitat will be disturbed although much of the area is already devoid of vegetation.

The extremely limited ground cover (some low growing scrub oak and juniper, with associated weedy cover) will be disrupted during site preparation, drilling, road construction and pipeline extension (if necessary). This will also result in the interruption of current land use in terms of grazing for livestock. This impact will also be of limited duration and of negligible consequence.

X. Cost Benefit Analysis

The PTC project for the chemical explosive stimulation of natural gas deposits in the Canyon sands of Texas might result in the widespread use of the technology to "liberate" more of the tightly held gas in this formation and in other low permeability reservoirs. As of the present time, a number of wells in this formation are producing marketable quantities of gas (100 - 900 MCFD). The southern region of the Edwards Plateau formation is known for this tight, millidarcy permeability, while a similar formation to the north is known to contain oil and gas reserves. Thus the success of stimulation technology in this part of Texas could increase the reserves of natural gas by more than 5 TCF.

In view of this potential for development of the resource, it is important to consider the relative benefits which might accrue from such a project. These considerations must be weighed against the actual costs of the program in terms of land use, funds expended for the development and potential environmental degradation.

With reference to the costs of the two well program, ERDA has committed approximately 2/3 of the total cost or $751,806. The Petroleum Technology Corporation (PTC), contractor in this project,will provide the balance of the funds, subcontracting with Union Oil of California for min-

eral rights acquisition and site selection. In terms of expense of materials, the following will be expended during the process: 60,000 lbs. of PTC-4 explosive, detonators used to fire the explosives and well packers and associated equipment. The gas recovered from the two wells will be collected in nearby pipeline systems and transported to customers, either residential or commercial. This gas will be a cost of the program in terms of its being lost as future reserves.

The time, effort, funding and personnel reserved by ERDA for this project are being diverted from use in some other project which might be sponsored by the Division of Oil and Gas for the development of an alternate source of energy. Valuable rig time will be expended drilling the experimental wells, which may not be economically productive. This time might be better spent drilling in fields which are reliable in terms of consistent production.

The additional cost which must be included in this accounting would be concerned with the short-lived environmental disruption which will necessarily accompany this development. Surface use of the land for grazing would be pre-empted over a short period of time and over a limited area.

However, the proposed program can be assessed as beneficial in terms of the overall program to develop fossil fuel reserves within the United States. The positive benefit to this strategy would be to decrease our reliance on foreign sources of fuel (Canadian gas, Mideast oil and imported LNG). Potential benefits of the PTC program could ultimately include the collection of the gas trapped in the tight formations of Texas. The extension of this technology to other tight reservoirs in the U. S. would further enhance the worth of this program. This form of energy is valuable in terms of its clean burning characteristics, limited amount of refining necessary prior to use and the minimal amount of environmental disruption which accompanies drilling, collection and use of natural gas. The presence of established pipeline systems in this area of Texas make the project attractive in terms of transporting the produced gas to market easily and cheaply. The gas which is presently being collected in other

regions of the Sawyer field is particularly free of contaminants (Table I), having no $H_2S$ constituent. This will make the southwest Texas reserves particularly attractive to both producers and consumers.

Should the funds allocated for this project be diverted to programs designed to increase supplies of other energy sources (i. e., coal), environmental degradation would be of greater concern. The ultimate benefit of this program would be to increase reserves of natural gas and to give industry incentive to experiment with advanced technology to accomplish this end. An increased supply of natural gas would contribute to industrial energy supply stability and would reduce the necessity of curtailments in service to industrial and residential customers. The production of additional natural gas supplies in this area of the country could be viewed as the optimal method of spending limited government RD&D funds because of the already existing pipeline system as a method of transportation to areas of intensive energy use, the experience in this area with gas drilling and production, and the potential for application of the technology to other, nearby formations.

The PTC program could realistically provide information relating to the geology of the formation and the optimal fracturing technology to be applied to tight formations. This information, integrated with results from other enhanced gas recovery projects being carried out throughout the U. S., might well prove useful in selecting the optimal fracturing technology for use in the various low permeability formations.

Potential benefits of this project in terms of resource recovery may be considered to greatly outweigh the costs of the PTC program in terms of economics and environmental degradation. In view of these compelling arguments, there should be no reason for delaying or postponing the CEF testing in the Canyon sands of Texas.

## XI. Potential Conflicts with State, Regional or Local Plans and Programs

The possibility of a conflict arising as a result of the planned program in Sutton County, Texas has been virtually eliminated due to the drilling experience of a local subcontrator, Union Oil, whose headquarters

Table I: Gas analysis/Sawyer 15-2

| Constituent | Mole/% |
|---|---|
| $H_2S$ | nil |
| $CO_2$ | 6.08 |
| $N_2$ | 1.33 |
| Methane | 82.79 |
| Ethane | 5.85 |
| Propane | 2.34 |
| Isobutane | 0.34 |
| N-butane | 0.57 |
| Iso-pentane | 0.19 |
| N-pentane | 0.13 |
| Hexanes | 0.11 |
| Heptones + | 0.27 |
| | 100% |

is located in Midland, Texas. Agencies of the state of Texas which are empowered to regulate gas and oil development have been consulted regarding necessary permits and regulations with reference to this experimental program. In general, the widespread drilling of gas and oil wells in the state of Texas had made the procedures for obtaining the necessary permits particularly efficient.

Field testing using high explosives is regulated by Texas state law regarding use and handling of such dangerous materials. The integrity and quality of the subsurface and surface water supplies of the area is the responsibility of the State Public Health Service and water resource board. The state and local governing bodies and regulatory agencies are accustomed to dealing with the environmental consequences of development of mineral resources and are well organized to supervise such development.

Federal regulations have now established stringent limits on possible contamination of subsurface aquifers or mineral bearing formations. Casing down to 1600' in both of the test wells will insure against this sort of contamination during the drilling and fracturing.

The area which will be developed under the PTC program is currently being used by private owners as rangeland for livestock. However, it is common practice for private landowners to lease the mineral rights to this land to oil and gas developers. There are several gas wells already drilled within the 1/2 mile of the proposed site of the PTC development. The disturbance of less than an acre during the nine month period will have virtually no effect on the grazing activity currently going on in this area.

At this time there are no known plans or proposals by private owners or state and local agencies for use of the acreage under consideration. The lack of paved roads, inadequate surface water supplies and the scarcity of population in this area of Sutton County make the land ill suited for most other activities. Use of this limited acreage for gas development would appear to be the optimal use of the land.

## XII. Relationship of Short Term Use to Long Term Productivity

Should the proposed PTC/Union Oil project prove successful in stimulating additional gas production in the tight, lenticular Canyon sands of southwestern Texas, the potential for increasing the natural gas reserves of the United States will be considerably enhanced. The application of the CEF technology could be extended to other tight reservoirs, including the tight gas sands of the Rocky Mountain Basins and the tight shales which characterize the Devonian formations of the eastern U. S. Additions to the supply of domestic natural gas reserves would be particularly important during this period of acute shortage and curtailments to industry and homes. Also, the clean burning characteristics of natural gas increase the importance of that source of energy, particularly with respect to compliance with environmental standards regulating air quality.

It has been estimated that there may be more than 5 TCF of gas within the six county area of Texas which make up the Canyon sands region. The estimates of potential reserves in the other tight formations throughout the United States range even higher; 285 TCF for the Devonian Shales and 600 TCF for the tight, western gas sands. Any technology which would allow producers to economically exploit this resource would contribute to the stabilization of the U. S. resource base.

Also, the ability of industry to plan future production schedules would be improved should this additional supply of gas become available.

This short term use of the rangeland of Sutton County, Texas for the drilling and stimulating of two gas wells will have only slight impact in an area where gas wells have been drilled for several decades. In the short run some potentially important data regarding the geology of the formation and the applicability of CEF to well stimulation in that formation may be recorded. Such information might provide the basis for determining an optimal fracturing technology in the Canyon sands. This, in turn, would increase the total reserves of natural gas. In conjunction with two additional CEF test programs being carried out by PTC in West Virginia and Ken-

tucky, this project might serve to demonstrate the applicability of this technology in different types of reservoirs. However, this experimental program might demonstrate the ineffectiveness of the CEF stimulation method in the tight sands of Texas. In that case a limited amount of time and money will have been expended.

## REFERENCES


Energy Research and Development Administration. *Contract No. EY-76-C-08-0687 with Petroleum Technology Corporation.* September 8, 1976.

M. Hanson et al., *Quarterly Report: The LLL Massive Hydraulic Fracturing Program for Gas Stimulation,* April-June, 1976, Lawrence Livermore Laboratory UCRL-50036-76-2 (1976).

M. Hanson et al., *Massive Hydraulic Fracturing: Identification of Critical Technical Issues for Application in Increasing Natural Gas Production in the Western United States,* Lawrence Livermore Laboratory UCRL-51751 (1975).

Hercules Incorporated, *Final Report: Hazards Analysis of Petroleum Technology Corporation's Chemical Explosive Fracturing System and Field Operation,* May 1975.

Petroleum Technology Corporation. *Canyon Gas Sand Explosive Fracturing Test Program, Volume 1, Technical Submission in Response to RFP 261-76-6,* March 29, 1976.

"Hot Ozona-Sonora Play Still Expanding." Oil and Gas Journal, June 14, 1976, pp. 29-32.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $ ; Microfiche **$3.00**

| Page Range | Domestic Price | Page Range | Domestic Price |
|---|---|---|---|
| 001–025 | $ 4.00 | 326–350 | $12.00 |
| 026–050 | 4.50 | 351–375 | 12.50 |
| 051–075 | 5.25 | 376–400 | 13.00 |
| 076–100 | 6.00 | 401–425 | 13.25 |
| 101–125 | 6.50 | 426–450 | 14.00 |
| 126–150 | 7.25 | 451–475 | 14.50 |
| 151–175 | 8.00 | 476–500 | 15.00 |
| 176–200 | 9.00 | 501–525 | 15.25 |
| 201–225 | 9.25 | 526–550 | 15.50 |
| 226–250 | 9.50 | 551–575 | 16.25 |
| 251–275 | 10.75 | 576–600 | 16.50 |
| 276–300 | 11.00 | 601–up | —[1] |
| 301–325 | 11.75 | | |

[1] Add $2.50 for each additional 100 page increment from 601 pages up.

*Technical Information Department*
LAWRENCE LIVERMORE LABORATORY
University of California | Livermore, California | 94550