Potential Chemical Hazards Associated with the Well SS-25 Well-Control Materials at the Aliso Canyon Natural Gas Storage Facility Near Porter Ranch, California

Office of Environmental Health Hazard Assessment
California Environmental Protection Agency
May 22, 2018

Synopsis

The Office of Environmental Health Hazard Assessment (OEHHA) evaluated the potential health hazards to nearby residents arising from well-control materials used at Well SS-25 at the Aliso Canyon Natural Gas Storage Facility, between October 2015 and February 2016. OEHHA used information from the California Public Utilities Commission (CPUC), the Division of Oil, Gas and Geothermal Resources (DOGGR), and the Los Angeles County Department of Public Health (LADPH), pertaining to the substances used in the control activities and the possible air pollutant release mechanisms. The Office also reviewed onsite environmental sampling data to further understand the potential for exposure from site-related air emissions of these materials.

Aside from water, a large fraction of the substances used in the control operations consisted of non-volatile minerals such as barite (barium sulfate), bentonite clay, and diatomaceous earth, as well as, chlorides of calcium and potassium, cellulose (nut shells), and xanthan gum. Smaller quantities of crystalline silica, caustic substances (e.g., sodium hydroxide), glutaraldehyde, and a tannin derivative were also used. Trace amounts of toxic metal and organic impurities may also have been present in several of the well-control products.

Air emissions of well-control substances could have occurred on a sporadic basis during the period in which the Well SS-25 gas leak was brought under control and the well was sealed. Based upon the nature of the operations performed and the likely mechanisms of air pollutant release, OEHHA believes that potential exposures to residents would have been at low levels and only for short time periods. As such, these exposures may have contributed to the respiratory symptoms reported by residents during the incident (e.g., wheezing, sore throat, nose-bleeds, etc.). Nonetheless, these respiratory effects were more likely caused by the malodorous, sulfur-containing chemicals[1] that were emitted along with the natural gas plume. Because the potential exposures to well-control substances would have been short-term and at low concentrations, long-term health impacts would not be expected to occur from the well-control materials.

Introduction

The Aliso Canyon Natural Gas Storage Facility, owned and operated by Southern California Gas Company (SoCalGas), is the state's largest natural gas storage facility with a gas-storage capacity of 86 billion cubic feet. It is located in the hills above the northwest end of the San Fernando Valley, Los Angeles County, on land that has been a site of significant oil production (the Aliso Canyon Oil Field). Neighboring residential areas include Porter Ranch and Granada Hills.

On October 23, 2015, a large sub-surface natural gas leak was discovered emanating from gas well SS-25 at the facility. Subsequently, SoCalGas hired specialty contractors to carry out a

---

[1] Includes mercaptans, added to natural gas for safety reasons.

series of well-control operations to stop the leak and close down the well. Eight well-control operations were carried out between October 24, 2015 and February 11, 2016, including one on a relief well developed as part of the remedial action. Well SS-25 and its relief well were then permanently sealed by February 18, 2016.

OEHHA has provided assistance to the state and local agencies responsible for regulatory oversight of the incident and protection of public health and worker safety. In this capacity, OEHHA helped evaluate the potential public health impacts from exposure to the natural gas plume and its organic trace constituents including benzene, mercaptans,[2] and residual petroleum hydrocarbons.

This report provides information on the potential health hazards posed by short-term, low-level inhalation and oral exposures to chemicals used in the well-control process.

Background on SS-25 Well-Control Activities

Controlling a natural gas well involves stopping the associated gas reservoir from flowing into the well bore. To accomplish this, a well-control fluid with sufficient density to overcome the pressure of the formation gas is pumped into the well. The control procedures for Aliso Canyon well SS-25 used aqueous inorganic salt solutions and well-drilling muds.

According to information provided by SoCalGas, each of the well-control operations involved pumping from 70 to 1166 barrels (2,940 to 48,972 gallons) of water-based well-control fluids into the well-bore. Table 1 provides the well-control dates and fluid volumes used.

DOGGR inspectors who were on-site during the remedial action noted that in some of the control attempts, injected fluids migrated back to the surface through a vent that formed near the well bore and were ejected into the air. In one case, fluids were ejected approximately 70 to 80 feet into the air for several minutes, followed by a sporadic and less energetic venting of gas and fluid for several hours through a surface layer of emitted fluids. In this latter process fluids were ejected less than 10 feet into the air. DOGGR staff estimated that the quantity of emitted well-control fluids was on the order of 10 percent of the volume injected (about 100 barrels in total) for those control attempts in which well-control fluids came to the surface.[3]

According to the LADPH, Porter Ranch residents reported finding oily brown spots on outdoor surfaces around their homes in December 2015.[4] These oil spots were attributed to an oily mist emanating from the leaking well, and transported by wind to Porter Ranch. In response, SoCalGas collected six surface-wipe samples from affected cars and tested them for hydrocarbons and BTEX substances.[5]

---

[2] Mercaptans are sulfur-containing organic chemicals. Certain mercaptans are added to natural gas for safety to make it easier to detect leaks from household appliances, industrial equipment, and pipelines.

[3] The information in this paragraph is based upon a telephone conversation between OEHHA and DOGGR staff in July 2017.

[4] Los Angeles County Department of Public Health. Update on the Aliso Canyon Storage Facility Gas Leak, Chemical Exposures and Health Impacts in the Porter Ranch Community, January 19, 2016.

[5] BTEX: Benzene, toluene, ethylbenzene, and xylenes.

Table 1: Well-Control Dates and Fluid Quantities Used *		
Date	**Barrels Pumped**	**Gallons Pumped**
10/24/2015	70	2,940
11/13/2015	716	30,072
11/15/2015	239	10,038
11/18/2015	220	9,240
11/24/2015	1,091	45,822
11/25/2015	1,166	48,972
12/22/2015	325	13,650
02/11/2016	1,120	47,040
* Based on information reported in data sheet AC_PUC_0130169 (See Attachment 1)		

The samples indicated the presence of heavier-end petroleum hydrocarbons consistent with crude oil. BTEX substances were not detected in any of the samples. LADPH also stated:

> "[SoCalGas] reported these drops are likely resulting from an oily mist emanating from the leaking well during strong wind events. To further investigate the occurrence of the oily mist, [SoCalGas] has placed horizontal and vertical plexi-glass plates along the facility fence-line, immediately adjacent to the community. The highest concentration of spots was found north of the Highlands neighborhood, and [SoCalGas] has since installed screens over the leaking well, which are designed to capture any new oily mists that may occur. Between January 2 and 10, no further accumulation of spots on the plexi-glass plates occurred, and [LADPH] has not received additional reports of new spots in the community." [LADPH, 2016]

Based upon the above information, it appears that site-generated aerosols were sporadically transported by the prevailing winds to Porter Ranch during the period of the SS-25 gas leak and remedial action. Aerosols could have been produced by entrainment of sub-surface fluids into the leaking natural gas plume, or by pressurized ejection of fluids following a well-control operation. Since a portion of the residual well-control fluids from multiple control attempts may have mixed with naturally-occurring oily liquids present in the geologic formation, well-control constituents may have also become aerosolized by these release mechanisms. It is further possible that some air emissions were produced during the on-site preparation of the well-control fluid mixtures (e.g., dusts may have been generated in preparing the drilling mud).

Chemicals Used in Well-Control Operations

OEHHA reviewed several data files submitted by SoCalGas that contain information on the identity and quantity of chemicals or commercial product mixtures used in the well-control operations. Table 2 lists these substances. Approximately 96% of the mass of injected materials (not including water) consisted of barite, bentonite, diatomaceous earth, calcium chloride, and potassium chloride. Smaller quantities of natural organic polymers (e.g., cellulose, xanthan polymer gums, nut shells, sawdust), pH adjusters (e.g., caustic soda), glutaraldehyde (a biocide), and a tannin derivative were also used in the well-control fluids.

In addition to providing the relative amounts of different materials used to make the well-control fluids, the SoCalGas files contain laboratory reports for four samples of waste fluids (and one solid sample) obtained from on-site storage tanks. The sampling strategy and methods were not described, so it is unclear whether the samples were representative of fluids used in the various well-control attempts. The fluids were analyzed for metals and a number of organic compounds unrelated to the well-control fluid constituents. The detected metals may have been initially present in the well-control fluids but may also have been picked up from the geologic matrix when the fluids were pumped into the well or otherwise came in contact with the geologic matrix. DOGGR staff noted that the well-control operations significantly eroded the well casing, which could be another source of metals. OEHHA did not identify waste-fluid sample data for other chemical components of the well-control fluids.

Table 3 lists the maximum concentration of selected metals that were detected in the fluids from the on-site storage tanks. The major metal constituent was barium at 11 mg/L with six additional metals at concentrations of about 0.1 to 0.2 mg/L: zinc, copper, cadmium, arsenic, nickel, and vanadium. Smaller amounts of other metals such as molybdenum and chromium were also detected.

Table 2: Substances Used in the SS-25 Well-Control Operations *			
Product	**Total Pounds Used**	**Primary Chemical or Substance**	**Secondary Chemicals and Impurities**
Barite	122,000	Barium sulfate (80-84%)	Crystalline silica (10-12%); Mica/Illite (< 6%) Calcite (calcium carbonate; <2%)
Calcium chloride	80,098	Calcium chloride (28-40%)	Water, NA (†)
PolyTek+	37,000	NA (a water-based mud product)	Crystalline silica (<= 9%); Mica/Illite (< 2%) Titanium oxide (Rutile) (<0.5%) Acetic acid (<0.02%); Ethylene oxide (<0.002%)
Potassium chloride	11,978	Potassium chloride (18-24%)	Water (76-82%)
DiaSeal-M	6,250	Diatomaceous earth (80%)	Calcium hydroxide (8%); Cellulose (5-15%) Crystalline silica (<1%)
Nut Shells	3,870	Cellulose (99-100%)	Crystalline silica (0.5-1.5%)
Bentonite (GEO GEL)*	3,000	Montmorillonite clay (>80%)	Water (8-12%); Crystalline silica (0-7%) Feldspar; Calcite
Geo Zan	2,575	Clarified xanthan polymer	Xanthan gum (>=99%) Glyoxal (<1%)
DrisPac SL	2,240	Sodium carboxymethylcellulose (95-99%)	Calcium stearate (1-5%)
Caustic Soda	1,270	Sodium hydroxide (>98%)	NA
Amber Guard	600	Glutaraldehyde (15%)	Water (85%)
Desco	200	Methyl ester of sulfonated tannin (40-55%)	Ferrous sulfate (5-9%) Crystalline silica (0.1-0.4%)
Saw Dust	60	Wood dust (84-89%)	None reported
Water Based Mud (WBM)	See above	Barite (10-30%) Bentonite (10-30%)	Crystalline silica (1-6%) Sodium chloride (5-10%) Sodium hydroxide (1%); Water

* Based primarily on product information reported in data sheet AC_PUC_0130169 (See Attachment 1, below) and additional Safety Data Sheets (SDSs) provided by SoCalGas. GEO GEL is listed as "Gel" in Attachment 1.

(†) NA: Not available based on the information contained in the SDS.

Table 3: Maximum Concentrations of Selected Metals in Well-Control Waste Fluids (mg/L) (SoCalGas, December 2015)	
Barium	11.0
Zinc	0.23
Copper	0.22
Nickel	0.21
Antimony	< 0.17
Cadmium	0.11
Arsenic	0.10
Vanadium	0.10
Molybdenum	0.075
Cobalt	0.016
Chromium	0.013
Lead	0.006
Mercury	0.0002

Hazardous Properties of Well-Control Chemicals

The potential toxic hazards from inhalation and oral exposure to the well-control substances are briefly discussed below. Most of the identified fluid additives are non-volatile substances. The exceptions are glutaraldehyde, glyoxal, acetic acid, and ethylene oxide. Acetic acid and ethylene oxide are trace impurities in “PolyTek+” and glyoxal is a minor component of “GeoZan,” according to the Safety Data Sheets (SDS) provided to OEHHA by the California Public Utilities Commission (CPUC). Given the low percentages in which these substances were likely to be present (see Table 2), they are not expected to have been a significant exposure hazard to downwind residential areas. Glutaraldehyde, which is a main component of “Amber Guard,” is further addressed below.

OEHHA assumed that if well-control fluid chemicals were emitted from the site, they would have been associated with brine or oil aerosols, or with process-generated dusts. To be respirable, and thus capable of depositing in the lung, these particles would generally need to be 10 microns or smaller in aerodynamic diameter (also called PM_{10}). Hazard information for particulate matter, in general, and for specific well-control fluid additives (or groups of additives) is provided below.

1. Particulate Matter (PM_{10})

   PM_{10} is a ubiquitous air pollutant and can be made up of a mixture of smoke, soot, dust, salt, acids, a number of combustion-related pollutants, and metals, especially in urban environments. Motor vehicles, many industrial operations, and agricultural activities are common sources of PM_{10}. The health effects of exposure to PM_{10} include increases in asthma attacks and worsening of bronchitis and other lung diseases. In addition, heart disease can be exacerbated by PM_{10}. Well-control related aerosol particles could have contributed to short-term atmospheric PM_{10} levels and PM-related health impacts. Particles larger than PM_{10} could also have been emitted. Larger particles are also inhalable, but deposit mostly in the upper airways where they may cause nasal and throat irritation and other health effects, depending upon their specific chemical composition.

2. Substances with Low Toxicity

Several of the well-control chemicals are not expected to raise toxicity concerns from short-term low-level exposure: sodium chloride, potassium chloride, calcium chloride, calcium carbonate (calcite), calcium stearate, ferrous sulfate, cellulose, sodium carboxymethylcellulose, and xanthan polymer. These substances are considered to be of low toxicity by ingestion, and are either present naturally in foods or are widely used as food additives or nutritional supplements. Low levels of oral exposure, as might occur from contact with precipitated SS-25 aerosols, are unlikely to be hazardous. Similarly, low levels of exposure by the inhalation route would also be unlikely to be hazardous (unless there was a significantly large short-term increase in PM_{10} above the ambient background). These substances also appear on US Food and Drug Administration's list of food additives that are Generally Regarded as Safe (GRAS).[6]

3. Mineral Substances

The mineral additives used in the well-control operations included: barite, montmorillonite, mica, illite, feldspar, diatomaceous earth and rutile (Additional details provided in Table 2).

Barite is largely composed of insoluble barium sulfate with smaller amounts of other minerals. Montmorillonite, mica, illite, and feldspar are aluminum silicate minerals containing varying amounts of metallic ions such as sodium, potassium, calcium, magnesium, and iron. Diatomaceous earth is composed mainly (> 80%) of non-crystalline silica with smaller amounts of alumina and iron oxide. Rutile is a mineral form of titanium dioxide, typically containing a few percent of iron and zirconium oxides, and silica.

As shown in Table 2, several of these minerals likely contain small percentages of crystalline silica, which represents a potential inhalation hazard from use of these substances.[7] Inhalation exposure to crystalline silica over long periods (years) as seen in occupationally-exposed workers can result in silicosis, chronic obstructive pulmonary disease, and lung cancer. OEHHA has established a Reference Exposure Level (REL) for long-term inhalation exposure to crystalline silica of 3 micrograms per cubic meter. In addition, long-term exposure to mica dust, such as occurs in an occupational scenario, may cause pneumoconiosis.[8]

The LADPH collected residential air samples in Porter Ranch homes in March and April of 2016, after well-control activities ended and the well leak was sealed, and did not find detectable levels of crystalline silica at or above detection limits of 2 micrograms per

[6] GRAS (Generally Recognized as Safe): Under the Federal Food, Drug, and Cosmetic Act, a food additive is considered safe for use in foods if it is generally recognized, among qualified experts, as having been adequately shown to be safe under the conditions of its intended use.

[7] Table 2 also indicates that nut shells contain a small amount of crystalline silica.

[8] Pneumoconiosis is a chronic lung disease characterized by inflammation and fibrosis, and caused by over-exposure of the lung to mineral or metal particles; silicosis is a specific form of pneumoconiosis.

cubic meter (for quartz and cristobalite).[9] Whether crystalline silica levels were elevated temporarily as a result of the well-control operations is not known since crystalline silica was not analyzed in air samples taken prior to the well closure.

For mineral components other than crystalline silica, to the extent that they were present as respirable particles, they could contribute to ambient PM_{10} pollution and PM-related health impacts.

The low levels of oral exposure to the mineral substances in the well-control fluids that could have occurred in neighboring communities are unlikely to represent a health hazard to exposed residents. Regarding the potential hazard of ingesting barium sulfate, although soluble barium compounds can be toxic by ingestion,[10] barium sulfate is a very insoluble mineral and not appreciably absorbed in the gut. Unlike soluble barium, it is considered to be of low toxicity by ingestion.

4. Trace Metal Impurities

The data provided by SoCalGas on the chemical composition of the well-control fluids did not include information on trace metal impurities in the additives used. However, it is likely that some of fluid additives contained small amounts of toxic metal elements. For example, barite derived from base-metal deposits may contain low levels of heavy metals such as cadmium and mercury.[11] In addition, the waste-fluid analyses discussed above suggest that some additives may have contained trace-metal contaminants.

Short-term inhalation of aerosols containing metals such as barium, zinc, nickel, and vanadium could produce eye, nose, and throat irritation. If present as respirable particulates, these metals could add to PM_{10}-related, lower lung symptoms such as wheezing and cough, and possibly exacerbate asthmatic conditions.

At higher levels of inhalation or oral exposure, and over longer periods of time, heavy metals can produce a wide range of more serious toxic responses in the lung and various other organs. However, these types of long-term exposure hazards are unlikely to be present as a result of the well-control additives used to stop the well leak.

5. Caustic Substances

Sodium and calcium hydroxides were also listed as well-control fluid constituents. These highly alkaline substances are strong eye irritants, as well as respiratory and skin irritants, and can cause chemical burns upon ingestion. However, in this particular use, they are expected to react with other more acidic components of the process fluids and be neutralized.

Nonetheless, if excess quantities of these substances were present in the fluids, they could add to the irritating character of airborne particulate emanating from the site. If

---

[9] County of Los Angeles, Department of Public Health. Aliso Canyon Gas Leak, Public Health Assessment, Environmental Conditions and Health Concerns in Proximity to Aliso Canyon Following Permanent Closure of Well SS-25, May 13, 2016.

[10] For example, a California Public Health Goal (PHG) for drinking water of 2 mg/L has been defined for soluble barium. The PHG is based upon cardiovascular effects and an increased risk of hypertension in adults.

[11] U.S. Geological Survey, 2015 Minerals Yearbook, Barite [Advance Release], May 2017.

present in aerosols, these hydroxides would be expected to be neutralized by carbon dioxide in the air, as well as by reacting with contacted surfaces, and thus would not pose a long-term hazard to residents.

6. Allergens

Some of the well-control fluid additives are natural polymers or derivatives of natural polymers (e.g., xanthan gum, carboxymethylcellulose, ground nut shells, and wood dust), for which repeated inhalation exposure could produce allergic responses, including asthmatic responses in sensitized individuals.[12] In this case, particles containing allergens would be a potential hazard. This health hazard would be mitigated by the fact that potential inhalation exposures, if they occurred, were likely to be sporadic and short-term.

7. Other Substances

Other substances that were reported by SoCalGas to have been used in the well-control fluids included glutaraldehyde (contained in “Amber Guard”) and a tannin-derivative (the main ingredient in “CF Desco II” deflocculant).[13]

Glutaraldehyde is a reactive, semi-volatile, biocidal chemical used in a variety of applications, for example to sterilize medical devices and in food handling and storage. Short-term inhalation exposure of humans to the vapor (at 0.2 to 0.3 ppm) or to glutaraldehyde mist causes eye, nose, and respiratory tract irritation.[14] Headaches have been reported at 0.4 ppm, and air concentrations of 0.5 ppm glutaraldehyde are highly irritating (*ibid*). The Agency for Toxic Substances and Disease Registry has defined a minimal risk level (MRL) of 1 ppb in air for short-term exposures of one to 14 days.

Fifty pounds of glutaraldehyde (as a 15% aqueous solution) were reportedly used in the November 13, 2015, well-control operation, and 550 pounds were used in the February 11, 2016, operation. Given its strong irritant properties, if glutaraldehyde was present in air emissions from the well-control operations, and if it was transported to neighborhoods downwind of the site, it may have contributed to respiratory and other symptoms reported by some of the residents. Since glutaraldehyde is reactive and readily biodegradable, it is not expected to persist in surface-deposited aerosols and would not represent an ongoing oral exposure hazard.

According to its Safety Data Sheet (SDS), “CF Desco II” is composed mainly of a methyl ester of sulfonated tannin. An initial literature search by OEHHA did not identify any studies on the inhalation toxicity of sulfonated tannin esters. The SDS indicates that the

[12] Inhalation of wood dust has been shown to cause nasal and paranasal tumors in wood workers and furniture makers, who were exposed to relatively high air concentrations over extended time periods. The use of 60 pounds of saw dust in one of the well-kill attempts (See Attachment 1) would not have created a significant inhalation exposure or cancer risk to Porter Ranch residents.

[13] According to the information provided to OEHHA, Desco (specifically, “CF Desco II”) was used in preparing the barite pills. Barite plugs can alternatively be prepared with chrome containing compounds or sodium acid pyrophosphate. OEHHA assumed that only CF Desco II was used in preparing the barite pills.

[14] National Library of Medicine, Hazardous Substances Databank, (http://toxnet.nlm.nih.gov), September 26, 2017.

short-term oral toxicity of this substance is likely to be low (based on limited animal studies). Given the sparse toxicity information available for this additive, OEHHA was unable to fully judge its hazard potential to humans exposed by inhalation.

Conclusions

In the period when Well SS-25 was leaking, LADPH collected information on health complaints made by Porter Ranch residents.[15] The health issues that were reported include: eye, nose, and throat irritation, respiratory problems such as cough, wheezing, worsening of asthma, nosebleed, headache, dizziness, nausea, and skin rash. Many of these symptoms are consistent with low-level exposure to malodorous substances (e.g., sulfur compounds).[16]

However, it is also possible that well-control chemicals were present in the SS-25 aerosols that were transported to the Porter Ranch neighborhood. If there were increases in particulate matter concentrations possibly containing small amounts of well-control fluid constituents (for example, if residents were exposed to aerosols containing glutaraldehyde) these could have worsened air quality, possibly contributing to symptoms. No long-term health consequences would be expected. While it cannot be ruled out that well-control chemicals contributed to the health effects reported by residents, the sustained release of odorants with methane during the leak event appears to be a more likely cause of the respiratory issues experienced by residents.

[15] Los Angeles County Department of Public Health. Aliso Canyon Gas Leak, Community Assessment for Public Health Emergency Response (CASPER), May 13, 2016.

[16] See OEHHA's earlier gas-leak hazard assessment, which addressed the natural gas plume and trace organic chemicals, including odiferous sulfur compounds: https://oehha.ca.gov/air/general-info/aliso-canyon-underground-storage-field-los-angeles-county.

Attachment 1

SoCalGas Data Table

"SS-25 and Porter 39A Relief Well Fluids and Fluid Additives"

(Data sheet number: AC_PUC_0130169)

SS-25 and Porter 39A Relief Well Fluids and Fluid Additives

Date	Fluid Type	BBLS Pumped	Additive	Amount Added (lbs)	Additive	Amount Added (lbs)	Additive	Amount Added (lbs)	Additive	Amount Added (lbs)
10/24/2015	HEC Polymer Pill	60	GeoZan	360						
	KCL 3%	10	Kcl	106						
	Total BBLS	70								
11/13/2015	Polymer Pill	20	GeoZan	150	Amber Guard	50	CaCl 9.4	1,160		
	CaCl 9.4 ppg	696	CaCl	40,368						
	Total BBLS	716								
11/15/2015	Barite Pill 18 ppg	19	Barite	11,500	Desco	50	Caustic Soda	50	CaCl	1,102
	CaCl 9.4	220	CaCl	12,760						
	Total BBLS	239								
11/18/2015	Barite Pill 18 ppg	35	Barite	17,600	Desco	100	Caustic Soda	50	CaCl	2,030
	CaCl 9.4	185	Cacl	10730						
	Total BBLS	220								
11/24/2015	Polymer Pill	50	GeoZan	325						
	Barite Pill	35	Barite	17,600	Desco	50	Caustic Soda	50		
	Fresh Water	1006								
	Total BBLS	1091								
11/25/2015	Polymer Pill w/ LCM	150	GeoZan	900	Cacl	8,700	Nut Shell Fine	60	Nut Shell Med	60
			Saw Dust	60						
	CaCl 9.4	56	CaCl	3,248						
	Fresh Water	960								
	Total BBLS	1166								
12/22/2015	WBM 15 ppg	200	Gel	3,000	Barite	75,300				
	WBM 15 ppg /w LCM	125	Nut Shell	3750	DiaSeal-M	6,250				
	Total	325								
2/11/2016	Poly Tek+	1120	Kcl	11,872	GeoZan	840	DrisPac SL	2,240	Caustic Soda	1120
			PolyTek+	37,000	Amber Guard	550				
	Total BBLS	1120								

These are not exact volumes or materials used. This was calculated from all the Halliburton daily logs from all the pump jobs. Product and fluid discriptions are in the folder Product and fluid info