ROCKY MOUNTAIN OILFIELD TESTING CENTER

PROJECT TEST RESULTS


# AUTOMATED THREE-PHASE CENTRIFUGE PROJECT

MARCH 30, 1998

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# RMOTC TEST REPORT

AUTOMATED THREE-PHASE CENTRIFUGE PROJECT
**Centech, Inc.**

**Prepared for:**

## INDUSTRY PUBLICATION

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## ABSTRACT

The Rocky Mountain Oilfield Testing Center (RMOTC) conducted a test of an Automated ThreePhase Centrifuge at the Department of Energy's Naval Petroleum Reserve No. 3 (NPR-3).

Centech, Inc. has manufactured a three-phase centrifuge which has been retrofitted with a PCbased, fuzzy-logic, automated control system, by Los Alamos National Laboratory. The equipment is designed to automatically process tank-bottom wastes within operator-prescribed limits of Basic Sediment & Water (BS&W) values. This report documents the equipment performance and the results of the Centech test.

The project encompasses the testing of Centech's trailer-mounted, automated three-phase centrifuge, which is designed to produce salable oil from tank-bottom waste. Performance of the technology was evaluated in four areas:

1. The equipment and modifications operate reliably.
2. The process breaks tank bottom emulsions.
3. Salable oil is produced.
4. The system operates in a hands-off mode.

The demonstration proved successful in all four areas.

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**INTRODUCTION:**

Tank bottoms are a byproduct waste of crude-oil production. There may be 39,000,000 barrels (bbl) of oil-field tank-bottom waste in storage throughout the United States, and the material is accumulating at a rate of 2,000,000 bbl per year.' Tank bottoms are comprised of oil, water, drilling mud, chemicals, sand, silt, wax, asphaltenes, and other precipitated solids that form tight emulsions that are difficult to economically break down into salable oil. Resolution of this environmental-waste problem lies in disposal and treatment operations.

The Wyoming Oil & Gas Conservation Commission (WOGCC) and the Wyoming Department of Environmental Quality (DEQ) both consider petroleum sludge an exempt waste under the Resource Conservation Recovery Act (RCRA). Wyoming tank bottoms can be disposed of by the following methods:

1. Road application through a Wyoming DEQ permit .
2. Incineration in an out-of-state permitted Environmental Protection Agency (EPA) facility.
3. Land farming at a RCRA-permitted site, if below 5% hydrocarbons.
4. Underground injection in a Class 11 well under the Safe Drinking Water Act (SDWA).

Note: Burial in a Subtitle D, RCRA-permitted landfill will only be approved for materials that pass the paint-filter test (non-liquids).

Tank bottoms at NPR-3 are typically utilized for road maintenance through a Wyoming DEQ permit. The emulsions are spread over designated roads and worked in with a motor grader, in compliance with the permit.

There are currently two viable tank-bottom treatment options:

1. A thermal process that provides water removal through flash, oil recovery through distillation, and benign solids through pyrolysis.
2. A mechanical three-phase centrifuge process.

Centech's Three-Phase Centrifuge is a continuous-flow waste-treating machine that mechanically separates feed stock into its individual phases of water, oil, and solids. Feed material is introduced along the centerline of a spinning bowl, which centrifugally forces the feed material to the bowl wall, where it is phase separated by density. The liquid levels of the water and oil are controlled by weirs, and a rotating auger transports the solids through the unit.

The solid-effluent material from the centrifuge's processed tank-bottoms may be disposed of by the following methods:

1 . Land farming at a RCRA-permitted site, if below 5% hydrocarbons.
2. Road application of the centrifuge solids may be permitted through a Wyoming DEQ permit.
3. Burial in a Subtitle D, RCRA-permitted landfill will only be approved for materials that pass the paint-filter test (non-liquids).

If the centrifuge processes pit-bottoms, the WOGCC may approve the return of the solid-effluent material to the original pit, provided only water is added for slurrying.

The Centech Three-Phase Centrifuge system, which is mounted on a 40' "low-boy" trailer, is comprised of the three-phase centrifuge (with solids trough), an electric process heater, a vapor recovery unit, a control cab (with a personal-computer-based automation system), feed & oil & water tanks, and various piping, pumps, motors, and electrical panels. Centech also utilizes a 28' trailer for decontamination, laboratory, and office functions.

The oil-production potential of tank bottoms is difficult to ascertain, due to the high degree of stratification that often exists. Emulsions may not homogenize to allow evaluation of the potential, even after the tanks are "rolled" by a vacuum / pump truck. The value of oil that is locked in the emulsions is often significant. If a treatment process is successful, then revenues for the recovered oil may offset process costs.

**PROCEDURE:**

Testing was performed at the B-3-2 production facility at NPR-3 on several different feed streams, including both tank and pit bottoms. The facility includes two 2,000-bbl tanks in which NPR-3's production tank bottoms are stored, a production pit from which soil was excavated, and rented 400-bbl tanks for centrifuge-processed water and oil, as shown in Figure 1.

To challenge the process equipment, testing was first conducted on the west 2,000-bbl tank (No. 7587) for 8 days, then the east 2,000-bbl tank (No. 7588) for 5.5 days, then the west tank for .5 days, then pit bottoms for 2 days, and then the final test was conducted on 10/31/96 using the fluids in the west tank. The oil saturation of the pit soil was too low to adequately test the centrifuge's control system, so the feed stock was changed to the west 2,000-bbl tank for the final day of testing.

For the tank-bottom processing, the 2,000 bbl tanks were connected to Centech's equipment with 4" piping and hoses, as shown in Figure 2. The solid phase of the processed material was discharged into a welded steel trough that was installed below ground level to the side of the centrifuge trailer. Centech's front-end loader was used to scoop the material from the trough and place it in a dump truck for temporary storage and transport to the land farm.

For the pit-bottom processing, a 100-bbl open tank was set near the back of the unit, and a portable air compressor was installed to permit an operator to pneumatically "roll" the tank with a hand-held wand. The soil was removed from the B-3-2 pit using a rented backhoe and transported to the 100-bbl tank, in which it was mixed with hot produced-Tensleep-Formation water. The effluent solids that were produced by the process were then returned to the pit, in compliance with the WOGCC pit-closure permit.

**CONTROL SYSTEM:**

The Los Alamos National Laboratory control system utilized a personal computer (PC) and displayed real-time data. Variances in the feed streams, which were commingled from all the NPR-3 production facilities, required different process flow rates and temperatures. The control program provided flexibility for operator input of process parameters such as flow rate, basic sediment and water (BS&W) heater temperature, etc.

Adequate retention time of the feed-stock material in the centrifuge (which is determined by flow rate) is needed for efficient separation of the fluid and solid constituents. The primary controlling instrument for the process was the BS&W meter which was incorporated in the centrifuge's processed-oil shipping tank. The meter was interrogated by the PC at preset intervals, and the system evaluated operations based on operator-input BS&W values obtained from manual grindouts. Control was achieved through feedback to a variable frequency drive on the feed pump and to a three-phase 480-VAC process heater.

Tests were conducted to evaluate the response of the control program. Sample rates were changed to determine the optimum rate which allowed the system to smoothly respond to variations in feed stock, as opposed to radically altering system performance. Ultra clean oil was also simulated (BS&W=O) by introducing air into the BS&W meter. The system responded by increasing feed flow rate and reducing heater temperature. When the next sample setpoint was reached, the system evaluated the actual effluent and corrected the controls back to "normal" operating parameters.

**TEST RESULTS:**

After 24 days of "fine tuning" equipment and testing (9/30-10/31/96), the system did show promise of hands-off operation. The upper and lower limits for BS&W were specified, and the system effectively tracked variations in feed stock to maintain the desired effluent quality. The upper limit for salable pipeline oil at NPR-3 is 0.3% BS&W, and the processed-oil grindouts consistently measured BS&W below that limit (as per API Publication 2542), during the final six-hours of the test, on 10/31/96.

Sample analyses were run on composite samples taken during the processing of the west 2,000 bbl tank over a ten-day period (10/9-18/96). The feed material was comprised of 59.7% oil, 38.7% water, and 1.6% solids. The water analysis indicated .3% total petroleum hydrocarbons (TPH), while the "solid"-effluent analysis indicated 6.7% TPH and 51.1% moisture.

The fluidal characteristic of the "solid" material made it difficult to handle. Centech's front-end loader was used to scoop the fluidized material from the trough and place it in a dump truck, for temporary storage and eventual transport to the land farm. The high TPH of the "solid" also made land farming difficult for a motor grader, because the material had to be worked in with clean dirt to facilitate spreading. A tractor with disks was then used for tilling the mixed soil. Costs for land farming the "solids" would be higher than for road applying the tank bottoms, due to higher labor requirements.

The testing of pit bottoms was conducted over a two day period (10/29-30/96). Handling and processing of the pit bottoms required considerably more labor than the tank bottoms. The soil was excavated and transported by a rental backhoe to a 100-bbI open slurry tank, where it was pneumatically mixed with hot produced water using a hand-held wand. The slurry was then drawn into the centrifuge feed tank for processing. Pit-bottom processed solids were then returned to the pit, by Centech's front-end loader.

Control problems developed while processing the slurried pit material, because the oil content in the feed stock was below the calibration range of the BS&W meter. There were also problems with processing slurried pit material through the feed-stream flowmeter. The solids disrupted the flowmeter's accuracy and therefore the system's automation. The oil saturation of the pit soil was too low to adequately test the centrifuge's control system, so the feed stock was changed to the west 2,000 bbl tank for the final test day

The accuracy of the tank-gauging and effluent-solids data (provided by Centech) was not sufficient to facilitate a quantitative material balance. The total effluent volume was 7.5% higher than the processed-feed volume; therefore, the following test data reflects only qualitative process performance. Over a "semi-controlled-test period" (10/8-16/96), oil production averaged 38%, water production averaged 48%, and solids averaged 16% of the feed stream per day. Over the same period, the average volume of feed material that was processed was 60 bbl / day, and the maximum rate was 82 bbl / day. (See Project Data Sheet.)

An energy test was also performed (using a Dranetz Energy Analyzer) on the centrifuge's process equipment, which operated on three-phase 480-VAC service. Average demand during normal operation (most motors & 98% heater output) was 107 kW Normal-operation electricalconsumption costs, at $.03 per kWH, would be $32 per ten-hour day. Average demand for motor operation (all motors & no heater) was 11 M.

Line losses between the 34.5-kV / 480-V transformer and the test site resulted in supplied voltage of approximately 460 VAC and reduced heater output. A constant 480-VAC source would have helped to optimize heater performance.

**CONCLUSIONS:**

The Centech Automated Three-Phase Centrifuge test demonstrated that:

1. The system did operate reliably while processing the tank bottoms; however, problems developed with the BS&W meter and the feed-stream flowmeter, while processing the slurried pit material.

2. The Centech centrifuge process broke emulsions that could not be economically produced by typical oilfield production technology, that utilized heat and chemicals. The oil that was produced during the test had been processed from tank bottoms that had previously been treated by NPR-3 production facilities.

3. The upper limit for salable pipeline oil at NPR-3 is 0.3% BS&W. Grindouts of the processed centrifuge oil consistently measured BS&W below that limit, during the final six hours of the test.

4. The automated-control system appeared to be tracking BS&W for a specific production feed stock over the final six hours of a 24-day test. The brevity of this success suggests that a much longer run over a much broader range of operating parameters should be performed for the system to be considered commercially viable.

## ECONOMIC CONSIDERATIONS:

The evaluation of disposal / treatment methods should include the costs for facility upgrades and material handling, treating, shipping, and processing. The following are considerations that were identified for this test.

1 Electrical equipment modifications were required to facilitate Centech's 120-kW process heater, including 167-kVA transformers, an enhanced overhead-distribution system, and a 400-amp service center.

2. A paraffin inhibitor / crystal modifier was used in the effluent oil to prevent paraffin from dropping out of solution in the 400-bbl tanks. The cost of a 4,000-ppm treatment that was recommended for 38 degree F protection was in excess of $2 per bbl of processed oil.

3. Outside of Centech's normal operations (which averaged 60 bbl per day of processed feed material), there were other requirements: Mobilization - 1 day, Setup - 2 days, Rig down - 4 days, and Demobilization - 1 day.

4. The excavation and transport of the pit bottoms caused minor damage to the rental backhoe, which resulted in repair and cleaning costs.

## ACKNOWILEDGEMENTS:

This report was prepared by the Rocky Mountain Oilfield Testing Center (RMOTC) based on field testing conducted at the Naval Petroleum Reserve No. 3 (NPR-3), located 35 miles north of Casper in Natrona County, Wyoming, in cooperation with the U.S. Department of Energy (DOE). Testing was funded jointly by the State of Wyoming, Los Alamos National Laboratory, and RMOTC.

RMOTC is operated by Fluor Daniel (NPOSR), Inc., the Management and Operating Contractor for the DOE's Naval Petroleum and Oil Shale Reserves in Colorado, Utah, and Wyoming. Project work was directed by Project Manager, Michael J. Taylor, and project support was provided primarily by Engineering Technician, Brian Meidinger.

RMOTC's goal is to partner with the oil and gas industry to improve productivity, by field testing new petroleum technology, evaluating new equipment and techniques, disseminating information to industry, and conducting training. For more information, contact the Rocky Mountain Oilfield Testing Center, 907 North Poplar, Suite 100, Casper, Wyoming 82601; phone (888) 599-2200.

For information about Centech, Inc., contact Neal Miller, President, 920 Lakeview Lane, Casper, Wyoming 82604; phone (307) 265-7621 / 473-8040.

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1 Satchwell, R.M. and Johnson Jr., L.A.: "Process Development for Treatment of Tank Bottom Wastes", Western Research Institute, Laramie, Wyoming, September 1993.

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3. Parkinson, W.J., Smith, R.E., and Miller, N.: "A Fuzzy-Controlled Three-Phase Centrifuge for Waste Separation", Los Alamos National Laboratory, Los Alamos, New Mexico, November 1997.

# Centech Site Layout @ B-3-2

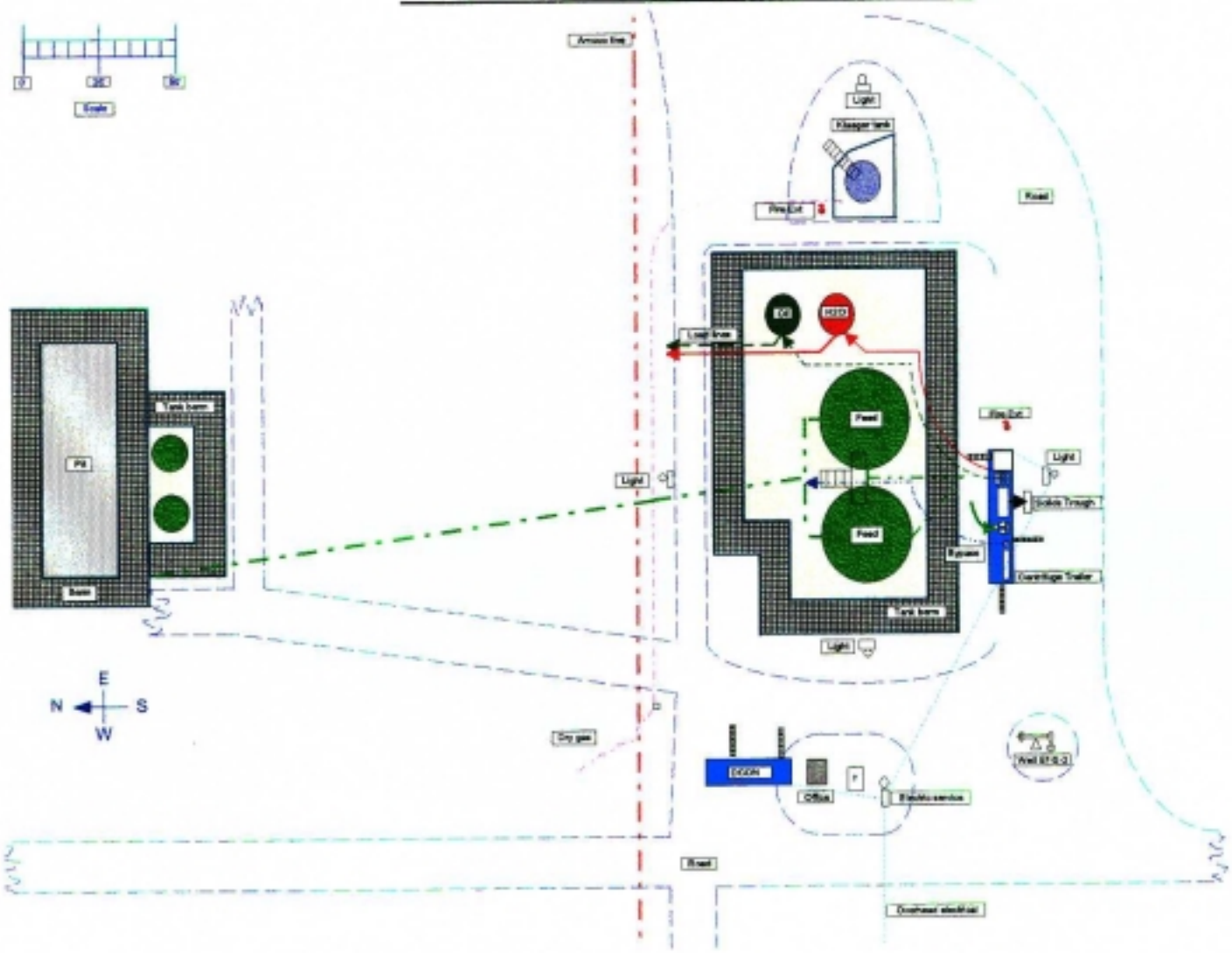


**Figure 1**

# Centech Site Layout @ B-3-2

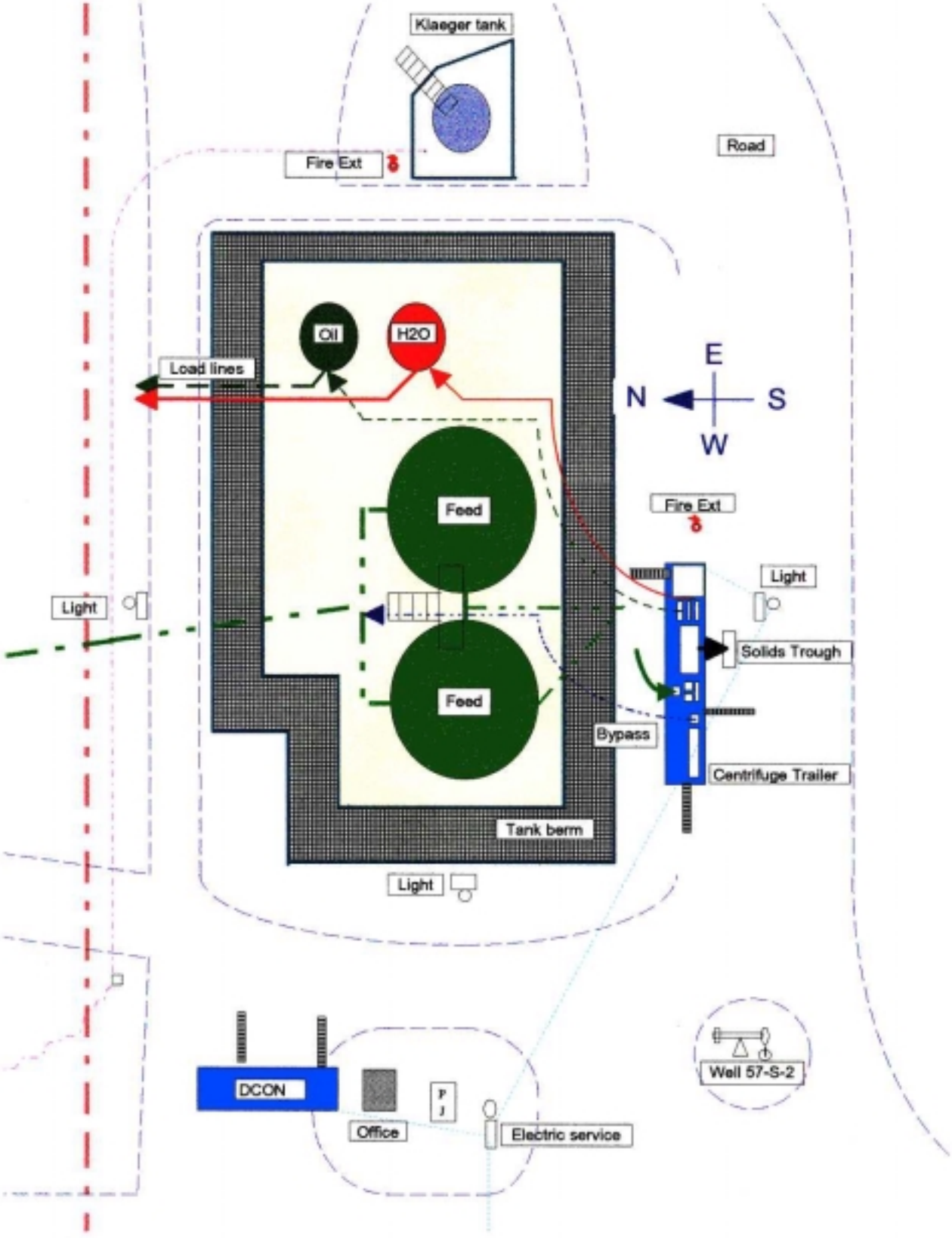


**Figure 2**

# CENTECH THREE-PHASE CENTRIFUGE PROJECT DATA SHEET

| DATE | COMMENTS | FEED PROCESSED (BBL) | WATER PRODUCED (BBL) | OIL PRODUCED (BBL) | SOLIDS PRODUCED (CU YD) | TOTAL PRODUCED (BBL) |
|---|---|---|---|---|---|---|
| 10/1/96 | LANL on site | "ASSUME" | QUESTIONABLE | QUESTIONABLE | QUESTIONABLE | QUESTIONABLE |
| 10/2/96 | Fine tuning equipment | "GOOD" | DATA | DATA | DATA | DATA |
| 10/3/96 | Fine tuning equipment | Strap gauge | Float gauge | Float gauge | Estimated | Calculated |
| 10/4/96 | Fine tuning equipment | | | | | |
| 10/5/96 | No processing | | | | | |
| 10/6/96 | No processing | | | | | |
| 10/7/96 | Process West tank | | | | | |
| 10/8/96 | Process West tank | 72.12 | 36.00 | 20.00 | 2 | 84.62 |
| 10/9/96 | Process West tank | 30.87 | 20.00 | 18.34 | 2 | 47.96 |
| 10/10/96 | Process West tank | 41.12 | 20.00 | 11.66 | 2 | 41.28 |
| 10/11/96 | Process West tank | 61.75 | 31.66 | 26.34 | 2 | 69.62 |
| 10/12/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/13/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/14/96 | Process West tank | 61.75 | 28.66 | 23.32 | 4 | 68.24 |
| 10/15/96 | Process West tank | 82.37 | 36.66 | 26.68 | 0 | 63.34 |
| 10/16/96 | Process West tank | 71.99 | 33.34 | 31.66 | 2 | 74.62 |
| 10/17/96 | Equipment frozen | 71.99 | 26.66 | 25.02 | 6 | 51.68 |
| 10/18/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/19/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/20/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/21/96 | Process East tank | 61.75 | 30.00 | 28.32 | 4 | 77.56 |
| 10/22/96 | Process East tank | 61.75 | 61.66 | 0.00 | 0 | 61.66 |
| 10/23/96 | Process East tank | 82.37 | 88.34 | 0.00 | 0 | 88.34 |
| 10/24/96 | Process East tank | 20.13 | 36.00 | 10.02 | 2 | 58.24 |
| 10/25/96 | Process East tank | 61.75 | -0.20 | 12.40 | 2 | 22.82 |
| 10/26/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/27/96 | No processing | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/28/96 | Process East/West tank | 41.99 | 28.60 | 11.60 | 2 | 47.62 |
| 10/29/96 | Process pit bottoms | 10.74 | 23.40 | 5.00 | 2 | 38.02 |
| 10/30/96 | Process pit bottoms | 0.00 | 0.00 | 0.00 | 0 | 0.00 |
| 10/31/96 | Process West tank | 0.00 | 98.00 | 0.00 | 3 | 100.43 |
| 11/1/96 | No further testing | 61.50 | 28.40 | 1.61 | | |
| 11/7/96 | Drain 400 bbl tanks | | | 69.99 | | |
| | Totals | 915.83 | 610.80 | 324.96 | 31.00 | 984.87 |
| | % of Produced Feed | 100.0% | 66.7% | 35.5% | 16.3% | 107.5% |
| | % Error (produced : processed) | | | | | 7.5% |
| | Semi-Controlled-Test Process Volumes | (BBL) | (BBL) | (BBL) | (CU YD) | |
| | Semi-Controlled-Test Total West tank (10/8-16/96) | 421.97 | 203.34 | 160.00 | 16.00 | |
| | Semi-Controlled-Test Daily Averages (10/8-16/96) | 60.28 | 29.05 | 22.86 | 2.00 | |
| | % of Daily-Average Feed Total (10/8-16/96) | 100.00% | 48% | 38% | 16% | |
| | | | | | (4.81 BBL/YD) | |