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IN THE PEATGAS™ PILOT-PLANT PROGRAM

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Introduction

Peat gasification research began at IGT in 1974 under the sponsorship of the Minnesota Gas Company (Minnegasco). Sponsorship has since grown to include the U.S. Department of Energy (DOE), the Gas Research Institute (GRI) and Internorth (a parent company of Northern Natural Gas Co). In 1980 the program was expanded to pilot plant scale to further develop peat gasification technology. A large coal conversion pilot plant facility (formerly the HYGAS pilot plant) located at IGT's Energy Development Center was modified in 1981 to test IGT's PEATGAS process. A 1-year operating program was just recently completed.[1]

In a pilot plant program, the measurement and control of major process variables such as flow, temperature, pressure, density and level are essential to develop accurate material balance and reliable scale-up data.[2] Of these, solids mass flow metering and control usually present the most difficult application. Problems are encountered because of a) solids characteristics, which can cause erosion and plugging; b) measurement requirements, which are often at elevated pressures and temperatures; and c) changes in stream characteristics, such as density, viscosity and solids concentration.

This paper reviews the approaches used to measure and control solid-liquid and solid-gas mixtures and elaborates on the design, installation and operating experiences of a lockhopper dry feed system commissioned to control solids feed to the gasifier.

PEATGAS Process

Peat is classified a geologically young coal and is currently used in Europe as a source of fuel, electric power and chemicals. In the United States, peat is found in all 50 states. Of these, Minnesota has the second largest peat reserves totaling about 16 billion tons. In some states, peat represents the only significant energy resource available.

The PEATGAS process is an alternative means for the production of substitute natural gas (SNG) using a peat feedstock. The process uses a three-zone, fluidized-bed reactor to convert the carbon and volatile matter in the peat to methane and liquid fuels by hydrogasification at operating temperatures up to 1700°F and pressures of 500 psig. Figure 1 is a flow diagram of the process.

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Solids Measurement and Control

The main area of experimental study is the PEATGAS reactor. To close the balance around the gasifier a number of process streams must be measured.[2,3] Three streams, composed of solids-liquid and solids-gases mixtures, entering and leaving the gasifier are particularly important and are shown in Figure 2. Methods used in measuring and controlling these multi-component streams are presented. Information describing other instrumentation applications has been published in papers pertaining to the HYGAS pilot plant.[2,3,4]

Solids-Liquid Measurement and Control

The PEATGAS reactor has two solids discharge streams. Both streams exit as a solid-liquid slurry that must be let down in pressure to dispose of the solids residue.

The reactor off-gas contains entrained solids that are removed by a cyclone. Solids exit the cyclone and flow by gravity into a tank where they are cooled by mixing with water to form a slurry. The slurry level in the tank is controlled by throttling a high-pressure letdown valve. (This valve made by the Willis Oil Tool Co., is known as a Willis choke.) The choke is an M1 model and consists of two tungsten-carbide circular discs and a pair of 1/4-inch diameter orifices. With one disc fixed in the valve body, the other can be rotated 90 degrees to open or block the flow. IGT's improvements to the choke's trim design increased the valve's operating life and reduced its maintenance.[4]

The slurry stream consists of fine solids (95% -100 US Sieve size). Solids loading varies between 2 and 10 wt % in the slurry. The flow is measured after the pressure is reduced by a 1-inch magnetic flow meter. Since this device gives volumetric output, solids concentration and composition are obtained by automatic sampling at pre-set, timed intervals.

The second reactor outlet stream contains ash discharge from the bottom of the gasifier. Ash is automatically dropped out of the char gasifier by regulating a solids control valve. The ash is conveyed with steam into a tank where the steam is condensed and the solids cooled by mixing with water to form a slurry. Once again the slurry level is automatically controlled with a Willis choke valve. A pair of 1/2-inch diameter orifices are used for flow control in the tungsten-carbide discs.

Solids loading varies between 5 and 20 wt %. Flow is measured by a high-pressure venturi. The venturi pressure taps require water purges to prevent plugging. Solids concentration is obtained using the method previously described. In addition, a continuous, on-line gamma-radiation density detector is attached to the 1-1/2-inch Schedule 160 slurry pipe. This meter uses a Cesium 137, 100-millicurie source and is calibrated for a 0.9 to 1.1 S.G.U. span. Satisfactory results have been obtained, however, sporadic operation has been observed and is believed to be caused by trapped gas bubbles flowing in the pipeline.

Solids-Gas Measurement and Control

Measurement and control of solids entering a high-pressure system are essential to pilot plant and future commercial operations. In the PEATGAS pilot plant program IGT installed, started-up and demonstrated operation of one such technique — a lockhopper dry feed system.

In the coal gasification program, a slurry technique was used to feed solids into the high-pressure reactor.[3] However, a dry feed method was preferred in the peat program because of favorable economics. Design criteria were developed for the system (Table 1).

Table 1. Design Criteria for Dry Feed Material

- Provide a continuous solids weight-rate measurement.
- Accurately measure the batch weight of solids to within ±1% (of batch weight).
- Compensate weight-rate measurement for accurate and reliable operation over a range of process parameters.
- Feed solids at controlled rates between 1 and 4 tons/hr at operating pressures to 500 psig.
- Prevent bridging, ratholing or segregation in feed equipment due to variable feedstock characteristics.
- Scale-up to commercial-size plants.

After carefully evaluating state-of-the-art, dry feed systems, IGT chose Petrocarb,Inc., to manufacture the system for the pilot plant because of their experience in similar applications.[5]

Lockhopper Dry Feed System Description

The lockhopper dry feed system, referred to as a solids injection system by the manufacturer (Petrocarb,Inc.), automatically feeds peat at controlled weight-rates against pressures up to 500 psig. A simplified equipment diagram for the peat lockhopper feed system is shown in Figure 3. It consists of two specially designed vessels, the primary and storage injectors, that have nominal capacities of 5000 and 2500 pounds of peat, respectively. The storage injector, used to pressurize the peat from atmospheric to gasifier pressure, is filled from a 16-ton live-bottom bin with a scalping screen that removes the oversize. Peat in the storage injector is automatically transferred to the primary injector whenever the primary injector can accept a 2500-pound storage injector batch.

The primary injector is the system feeder and delivers a continuous flow of peat to the gasifier through a pneumatic conveying line. Peat is discharged from the primary injector under weight-rate control. Solids flow control is achieved without the use of a mechanical rate controlling device.

Dry Feed System Instrumentation

Filling the storage injector and the transfer of material between the storage and primary injectors are automatically sequenced by hard-wired electromechanical relays. The relay logic incorporates all safety and process interlocks to ensure reliable and continuous lockhopper operation. Interfacing with the relay logic are Foxboro Spec 200 electronic analog controls, which handle all analog signals, computational requirements and automatic control functions for the feed system. Figure 4 shows a simplified schematic of the weight measurement and control portion of the system.

The storage and primary injectors are independently weighed on A.H. Emery Company hydraulic load cells. An expansion joint between the two vessels provides the freedom of movement necessary for independent weighing. All auxiliary piping and electrical tie-ins to both vessels are arranged to provide sufficient flexibility for accurate weighing. The weight signal from each injector is compensated for the pressure and spring thrust generated by the expansion joint and also for the weight of the injector and the weight of gas in the injector. The storage injector weigh instruments record the weight of each batch of peat and the total weight of peat fed during a test run. The primary injector weigh instruments control and measure the feed rate of peat to the gasifier through cascade control of the pressure differential between the primary injector and the gasifier.

The feed system uses Kamyr ball valves for peat lockhoppering in the storage injector. Most other feed system valves in on-off service are Kamyr valves. These valves have stainless-steel balls and seats and were tested at the factory for gas-tight sealing capability.

The injectors are enclosed in a sided structure to prevent wind loads from affecting the weight readings. The injectors are supported on a second smaller structure within but remain independent of the sided structure to prevent vibration and side loads from affecting the weight readings.

Operating Experience

IGT began commissioning of the dry feed system in November 1981 with the shakedown of the lockhopper logic sequence. Although the electromechanical relay logic had been shop assembled and shop tested, interface problems arose when the control logic was tied into field sensors, field actuators and Foxboro controls. The problems were systematically identified and corrected.

With the logic sequence debugged, a calibration of the weighing system was attempted. Several problems became apparent. Process piping, control wiring and instrument air tie-ins to both injectors had to be reworked to increase their flexibility and minimize weighing errors. The expansion joint between both injectors was reworked to eliminate mechanical drag, which caused weighing system hysteresis. The expansion joint spring rate compensation instrumentation was reworked because the actual spring rate of the expansion joint was higher than originally specified by the manufacturer. After solving these problems, the weigh system was calibrated.

Several additions were made to the feeding system during system start-up. Drexelbrook radio frequency level probes were added to both injectors to allow the lockhopper sequencing logic to operate under weight control or under level control. This modification increased the system's flexibility. Computerized data logging of feed system pressures, temperatures, weights and flows was added to facilitate data collection. Finally, a valve positioner was added to the pneumatic transport line differential pressure control loop to increase its response speed and provide more accurate valve positioning.

Two successful gasification tests were completed with the new dry feed system. The first test was made in December 1981 and the second in March 1982. Figure 5 shows the weight of peat versus time tracing in the primary injector for a 3-hour period during the March test. The weight of peat in the primary injector rises rapidly during solids transfer from the storage injector and falls off gradually during approximately a 1/2 hour of continued peat withdrawal. Approximately 2200 pounds of peat are added in each of these cycles giving a gasifier feed rate of approximately 2.2 tons/hr. Figure 6 shows the transport line pressure differential versus time for the same time period. The pressure differential is essentially constant. The system performance record to date is presented in Table 2.

Table 2. Dry Feed System Performance

Total Number of Cycles	335
Total Peat Fed, tons	365
Operating Pressure, psig	300-500
Feed Rate, tons/hr	1-2.5
Operating Time, hr	225
Peat Moisture Content*, wt %	10-30

* (wet basis)

Summary

Accurate and reliable solids flow measurement and control was achieved during the operation of the PEATGAS pilot plant. Standard instrumentation, modified to meet process requirements, was used to measure multi-component flows of solid-gas and solid-liquid mixtures. In addition, a lockhopper feed system using an innovative solids rate control and measurement technique was installed, commissioned and operated.

IGT as a process developer will continue to look for new or improved instrumentation that might be better suited to measure important process variables such as the solids mass flow applications discussed herein.

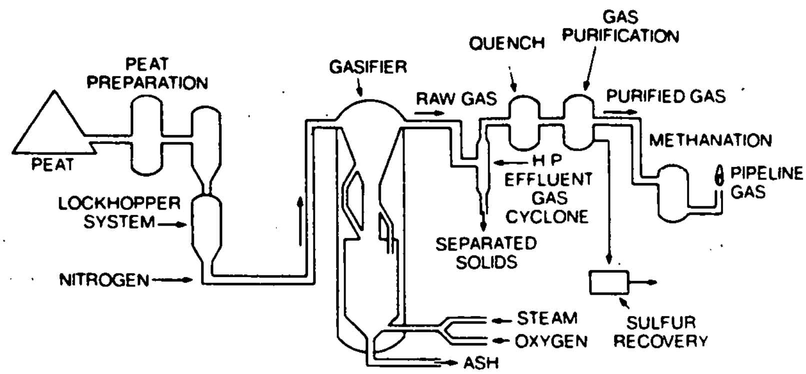

Figure 1. PEATGAS Pilot Plant Facility

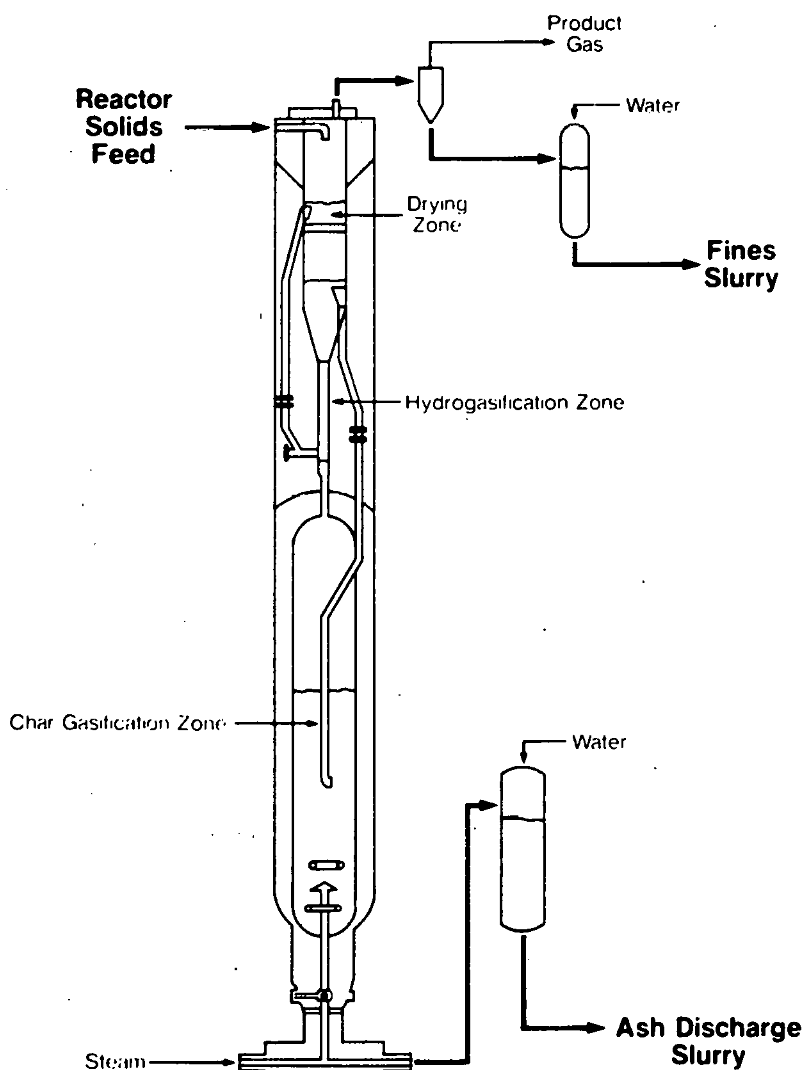

Figure 2. PEATGAS Reactor Solids Flow Measurement

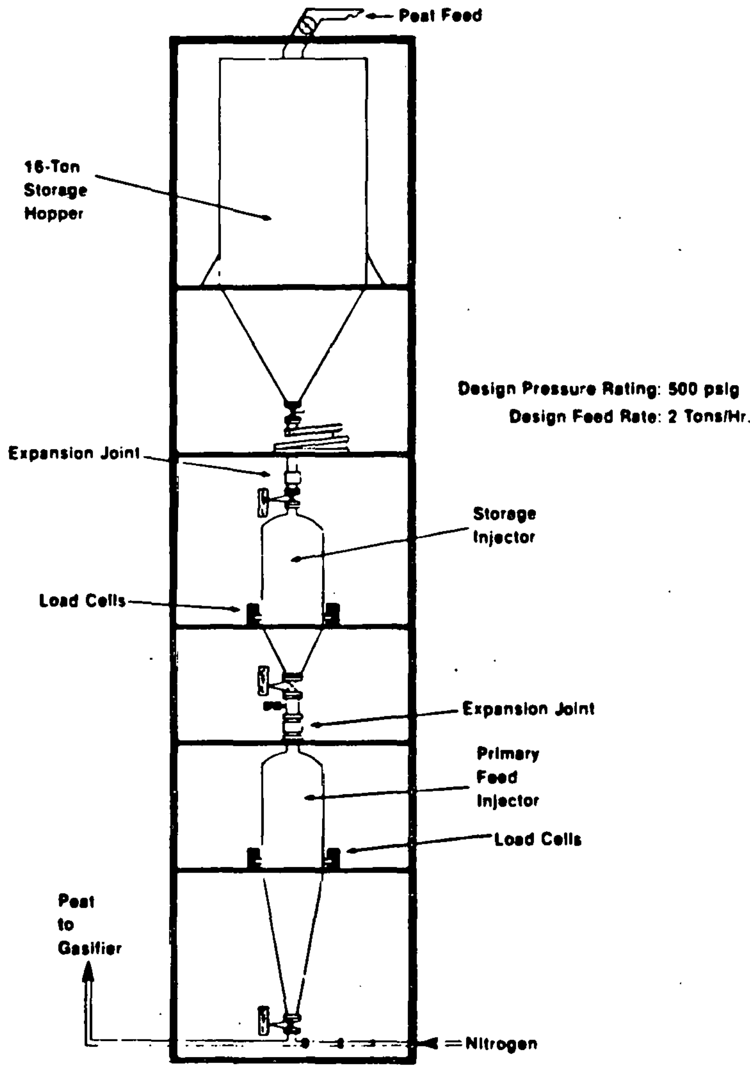

Figure 3. Lockhopper Feed System

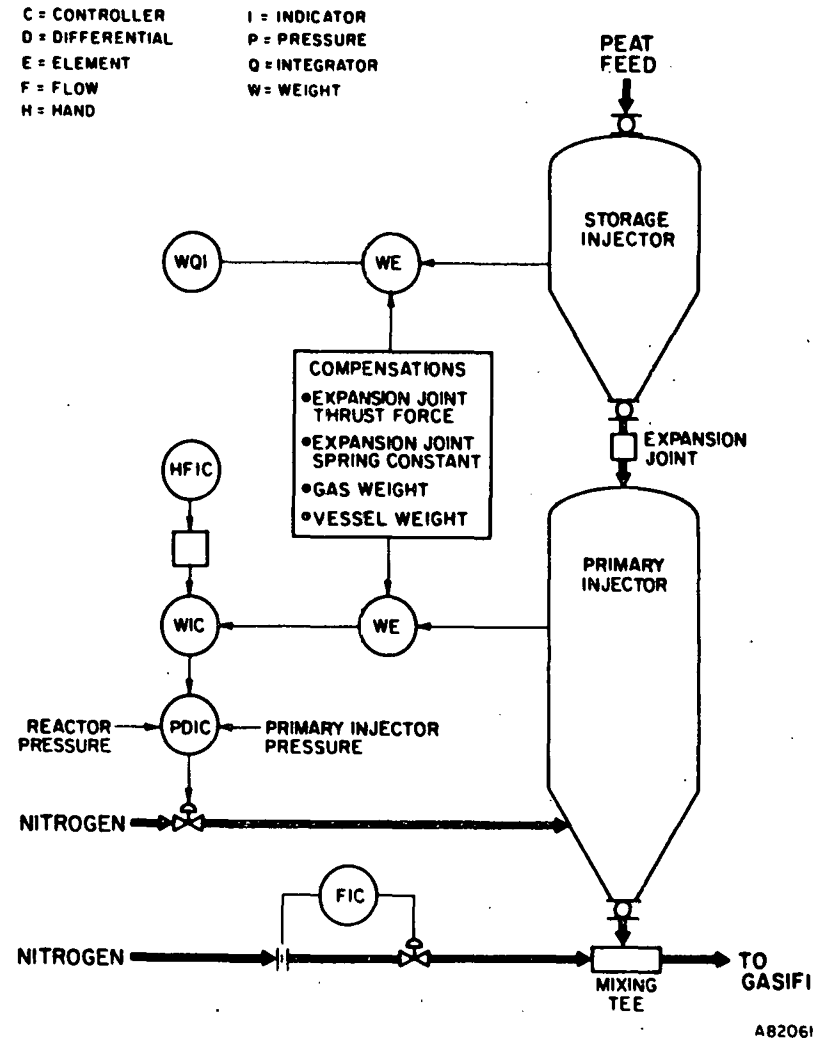

Figure 4. Peat Weight Measurement and Control Schematic

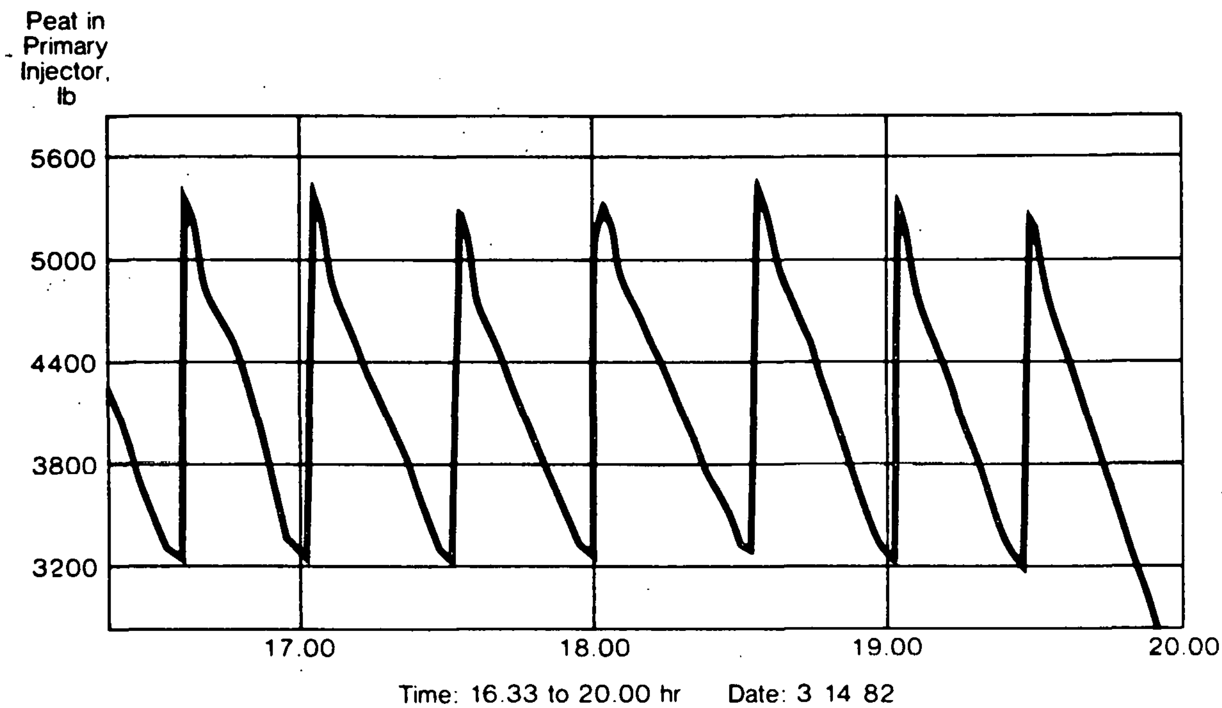

Figure 5. Peat Weight in Primary Injector Vs. Time

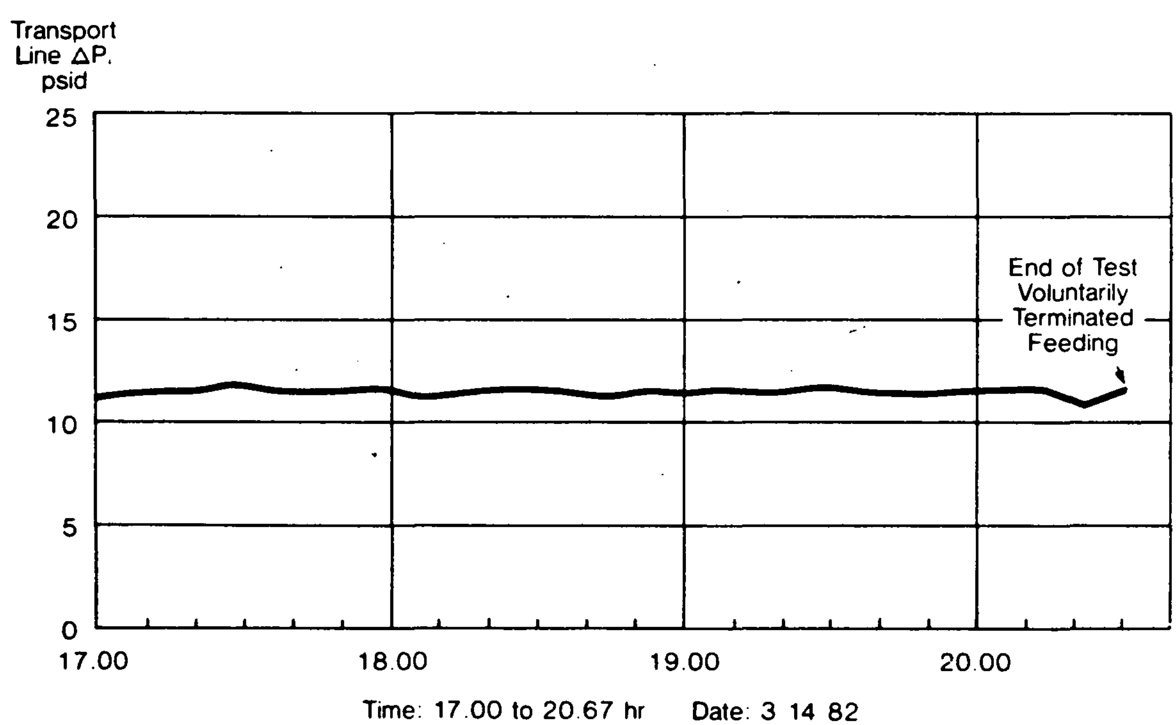

Figure 6. Peat Transport Line Pressure Differential Vs. Time

Acknowledgement

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