THIXOTROPIC CHEMICAL PACKER SYSTEM FOR HORIZONTAL, DEVIATED, AND GRAVEL-PACKED WELLS

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ABSTRACT

This technology utilizes a thixotropic in-situ polymerized gelation (TIPG) system. It is designed to prevent gravity slumping to form a chemical packer in horizontal and deviated wells. This system has a relatively low viscosity at surface temperature but develops its thixotropic properties in a time frame of 20 to 30 minutes as temperature increases while being pumped downhole. This thixotropic blend can be used in wells with bottomhole injection temperatures ranging from 100°F (38°C) to 200°F (93°C).

The TIPG system utilizes synthetic clays (SC) that impart the thixotropic properties to maintain a temporary chemical seal until secondary vinyl polymerization occurs to form the final packing seal. The vinyl polymerization system is a low viscosity monomer solution that uses temperature-activated initiators to induce a phase change from liquid to a ringing gel at predictable times.

INTRODUCTION

TIPG is a combination of synthetic clays and an in-situ polymerized gelation system. When reacted, it forms a chemical packer designed to shut off undesired water and gas flow within the wellbore. This chemical slurry exhibits thixotropic properties, which will prevent gravity slumping when treating horizontal and/or deviated wells. This system exhibits a relatively low viscosity at surface temperature, but quickly gains a very high viscosity when pumping is stopped. Once the TIPG is in place, the thixotropic nature of the synthetic clays in the system holds the slurry in place until the secondary reaction (an in-situ polymerization of a monomer) occurs, with the final product resulting in the forming of a chemical packer within the wellbore. The TIPG system is a combination of an in-situ polymerizing monomer system and synthetic clays. It can be used in wells with bottomhole injection temperatures from 100°F (38°C) up to 200°F (93°C).

The following requirements were identified for the development of the TIPG system and its associated placement as a chemical packer:

- Able to penetrate: (a) gravel pack, (b) wire-wrapped screen in an open hole, (c) wire-wrapped screen with gravel pack, (d) pre-packed screen in an open hole, and/or (e) pre-packed screen with gravel pack (20/40 sand)
- Applicable in high-angle/horizontal wells
- No gravity slumping
- Pumpable through coiled tubing
- Withstand differential pressures up to 1,000 psi
- Controllable setting times
- Permanent and/or reversible
- Able to shut-off water and/or gas

THIXOTROPIC IN-SITU POLYMERIZATION SYSTEM DESCRIPTION

The primary applications of the TIPG will be in gravel-packed, screened, and horizontal wellbore completions. **Figure 1** illustrates the treatment of a gravel-packed section of a horizontal well. In such wells, it is extremely difficult to isolate and treat water-producing zones. Even if a section of the wellbore is isolated with packers and a sealant is pumped into the zone, there is nothing to stop the sealant from running down the length of the gravel pack via gravity segregation or slumping back into the wellbore. The thixotropic properties of the TIPG treatment will aid in avoiding gravity slumping and lateral annular flow during and after placement.

The system is placed with an initial low viscosity (the viscosity will vary depending on the thixotropic clay concentration). As the solution is pumped downhole and the temperature increases, the thixotropic clay will start building strength. This is illustrated by **Figure 2**, which shows the physical appearance of the system as it develops viscosity and thixotropic properties. **Figure 3** shows the rheology data for a particular system formulation at 180°F (82°C) and illustrates again how the system develops viscosity over time at elevated temperature. A Chan 35 viscometer was used to measure viscosity as a function of time at 100 RPM (viscometer was allowed to run continuously).

IMPACT OF TEMPERATURE ON THIXOTROPIC PROPERTIES

The TIPG system exhibits low viscosity at room temperature. When the temperature is elevated, the system begins increasing in viscosity and exhibiting thixotropic properties. **Figure 4** shows the expected rheology numbers (viscosity vs. time) for the recommended formulations, depending on temperature. At a given temperature, the higher concentration of thixotropic clay will result in higher ultimate viscosity of the system. The following steps were performed to measure the rheology data of the TIPG systems:

1. A water bath or temperature cell was preheated to reach testing temperature.
2. A Fann 35 viscometer was set to 100 RPM.
3. Viscosity values were recorded as a function of time at 100 RPM (viscometer was kept running continuously). The temperature of the fluid was monitored as well.
4. Rheology data was collected for approximately 1 hour.

Shear rate has a significant impact on the viscosity of the system as illustrated in **Figure 5**. Duplicate samples of the TIPG were evaluated at 130°F at 100 and 300 RPM in a Fann 35 viscometer. Note a lower viscosity profile was observed at the higher shear rate.

EFFECT OF THIXOTROPIC CLAY ON GELATION TIME

As illustrated in **Figure 6,** the polymerization time of the in-situ polymer gel system is not significantly affected by the addition of the synthetic clays. Note that the sudden increase in the viscosity of the TIPG system is not due to early polymerization but rather to the development of the thixotropic properties as temperature starts increasing (this behavior matches the one observed in Figure 4).

EFFECT OF THIXOTROPIC CLAY ON HYDRATION TIME

Hydration time (mixing time) at room temperature of the TIPG system has an effect on the initial viscosity of the solution. The time required to develop thixotropic properties and the final viscosity at testing temperature are independent of the hydration time. **Figure 7** shows how a solution stirred for 8 hours develops more initial viscosity than one stirred for only 30 minutes. Both solutions reached approximately the same final viscosity and developed thixotropic properties in about the same time at 160°F.

LARGE-SCALE TESTING

The objectives for the large-scale tests were:

- To calculate friction pressures while TIPG was flowing at a given temperature in different pipe sizes.
- To calculate the yield pressure required to begin flow after TIPG has been static for 30 minutes.

Figures 8 and 9 illustrate the equipment used for these tests. The TIPG solution was evaluated in three tubing sizes: 5/8-, 3/4-, and 1-inch ID pipes. The equipment allowed monitoring pressure differentials and temperature while the solution was flowing through each pipe. A volume of 200 gallons of TIPG slurry was used for each test.

FRICTION PRESSURE TESTS

Figures 10, 11, and 12 show the friction pressure results for the 180°F, 130°F, and 100°F tests, respectively. The formulation for the 100°F test shows the worst-case scenario in terms of friction pressure due to higher concentrations of thixotropic clay, which translates into higher viscosity. According to the results, the formulations can be pumped without presenting pressure problems.

SHUT-IN TEST

Figure 13 is a schematic of the equipment used to measure the pressure to initiate flow in tubulars after the solution has been shut in for 30 minutes. **Table 1** summarizes the results, which show that TIPG will not present any pressure problem if shut-in is needed during the application. The 5/8-inch ID pipe might be a concern for TIPG formulations in which the thixotropic clay concentration is higher that 4%.

FILTRATION TEST

The purpose of this test was to investigate the ability of the system to be filtered and maintain thixotropic properties after passing through a 1.5-inch 20/40 sandpack and 125-micron screen. A pre-heated 60-mL syringe was filled with the pre-heated TIPG formulation and was shut in for 30 minutes at testing temperature (refer to **Figure 14**). Then, attempts were made to push the mixture out of the syringe. The solution was filtered out from the syringe without presenting pressure problems and showed good thixotropic properties after leaving the syringe.

CONCLUSIONS

- TIPG broadens the capabilities of the standard acrylate monomer solution to shut off water in challenging completions, such as gravel-packed, screened, and horizontal wellbores.
- The temperature range of applicability of the TIPG system is 100°F to 200°F.
- No compatibility problems were encountered when performing injection experiments with the following annular fluids: tap water, air, API brine, 2% KCl brine, a formation brine, and kerosene.
- When cured, a TIPG system placement experiment showed a complete annular fill with no evidence of trapped water.
- Using the acrylate monomer system as a gelant means that the temperature limit of the application is 200°F (95 °C).
- The friction pressures exhibited by the increase in viscosity of the TIPG system are within acceptable parameters during pumping of the treatment (refer to Figures 10 through 12).
- Based on large scale experiments, the pressure required to start flow after the TIPG system has been in static conditions for 30 minutes is within acceptable pressure limits (refer to Table 1).

REFERENCES

1. Halliburton, *Conformance Technology*, Halliburton Energy Services Publication, USA, 1996.
2. Dalrymple, D., Tarkington, J., and Hallock J.: “A Gelation System for Conformance Technology,” paper SPE 28503 presented at the 1994 SPE Annual Technical Conference and Exhibition in New Orleans, Louisiana, September 25-28.
3. Bergem, J., Fulleylove, R., Morgan, J., Stevens, D., Dahl, J., Eoff, L., and Enkababian, P.: “Successful Water Shutoff in a High-Temperature, High-Volume Producer–A Case History from the Ula Field, Offshore Norway,” paper SPE 38833 presented at the 1997 SPE Annual Technical Conference and Exhibition in San Antonio, Texas, October 5-8.

ACKNOWLEDGMENTS

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Table 1
Pressure to Initiate Flow after 30-min Shut-In Period for TIPG System

Temperature, °F	Pipe ID, in.	ΔP/ft to Initiate Flow after 30-min Shut-in
180	5/8	0.14 psi/ft
180	3/4	0.03 psi/ft
130	1	0.35 psi/ft
100	5/8	1.10 psi/ft
100	1	0.73 psi/ft

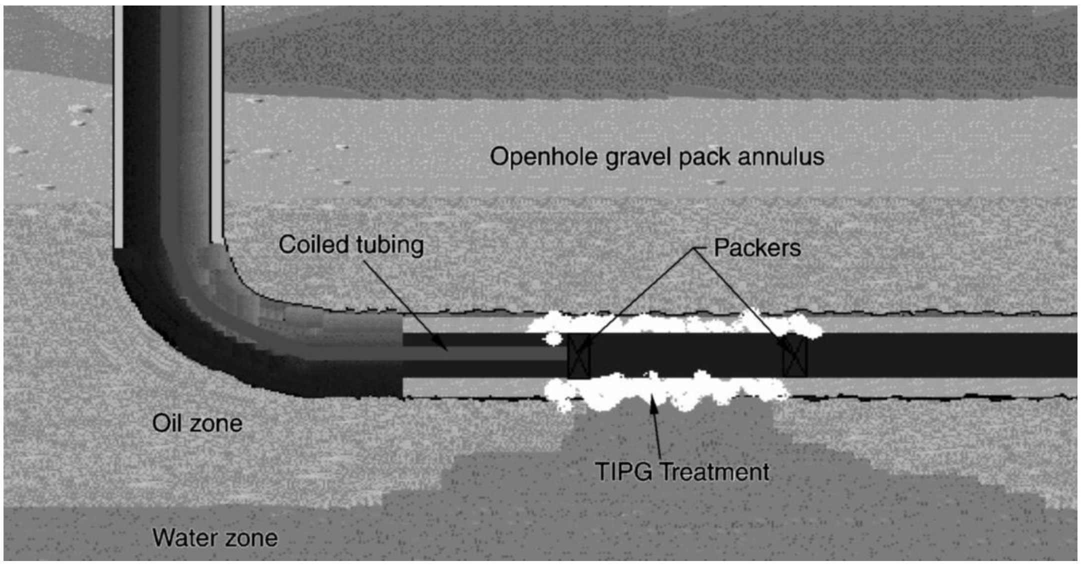

Figure 1 - TIPG Treatment of a Gravel-Packed Section in a Horizontal Well

(a) (b) (c)

Figure 2 - Physical appearance of TIPG: (a) system has not developed thixotropic properties yet; (b) system has started developing thixotropic properties but it still slumps; and (c) ideal state of TIPG system (no slumping when movement stops).

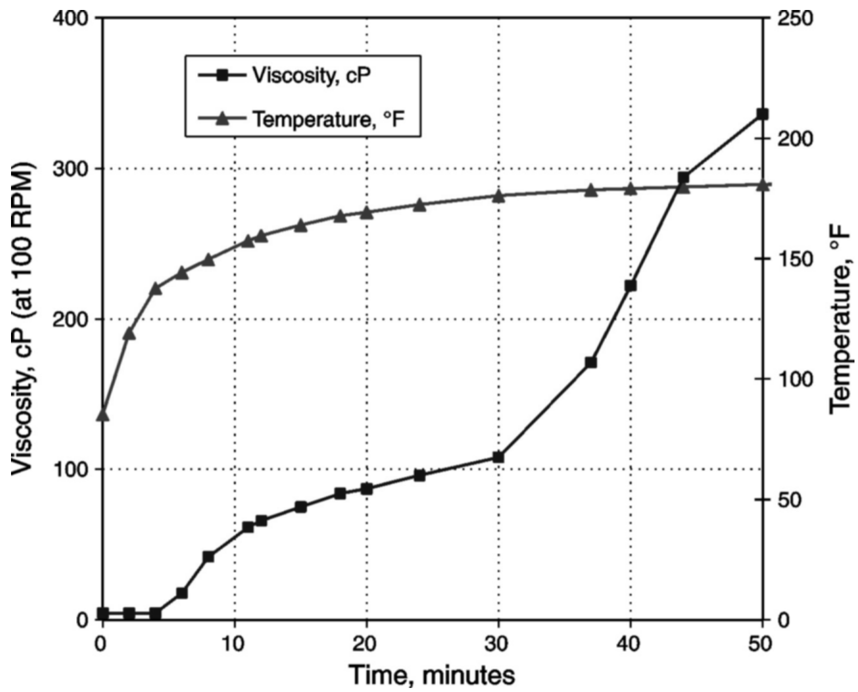

Figure 3 - TIPG Rheology
Data: Viscosity vs. Time at 180°F Using a Chan 35 Viscometer

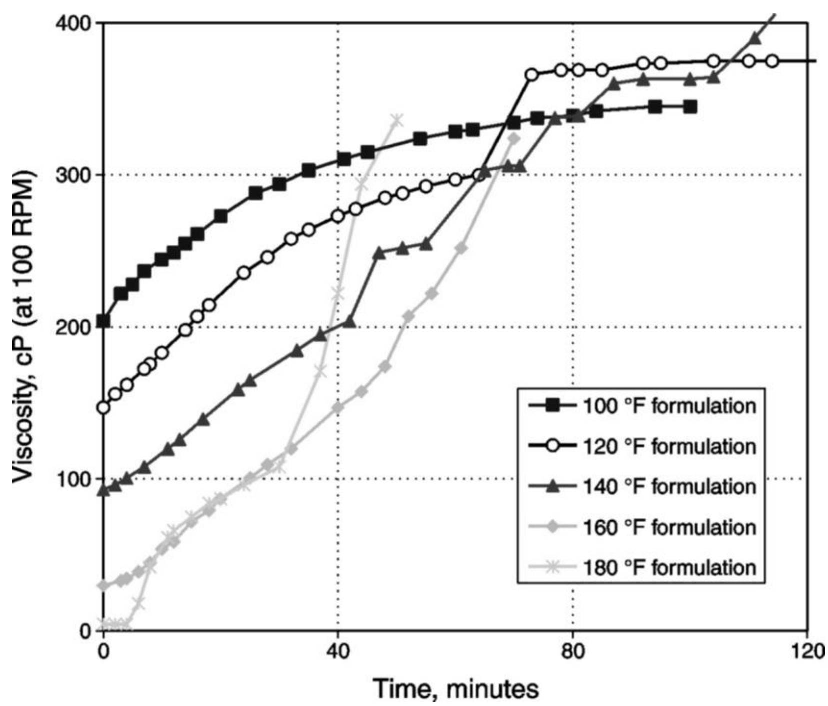

Figure 4 -TIPG Rheology Data for the Recommended Formulation at Various Temperatures:
Viscosity vs. Time

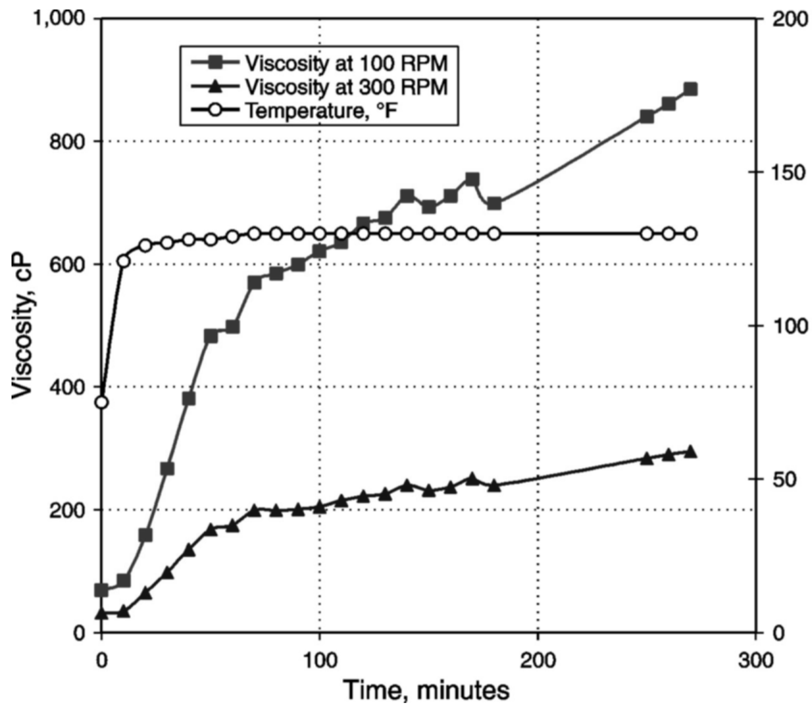

Figure 5 - Effect of Shear Rate on the TIPG System (Apparent Viscosity at a Function of Time as 130^{o}F)

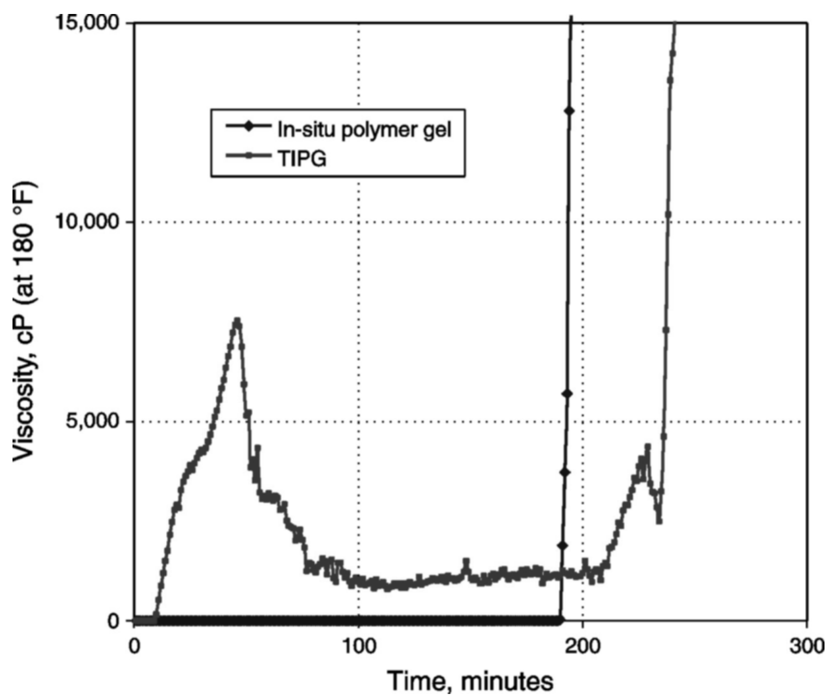

Figure 6 - Gelation Time Comparison for Different TIPG Formulations at 180^{o}F
Using a Brookfield Viscometer

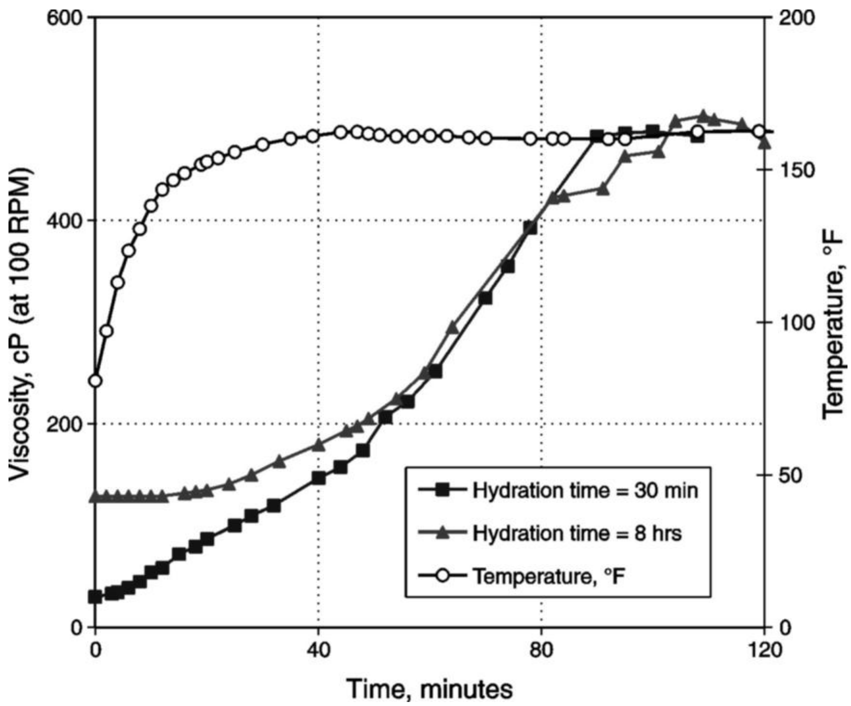

Figure 7 - Effect of Hydration Time for TIPG System at 160°F (Viscosity vs. Time)

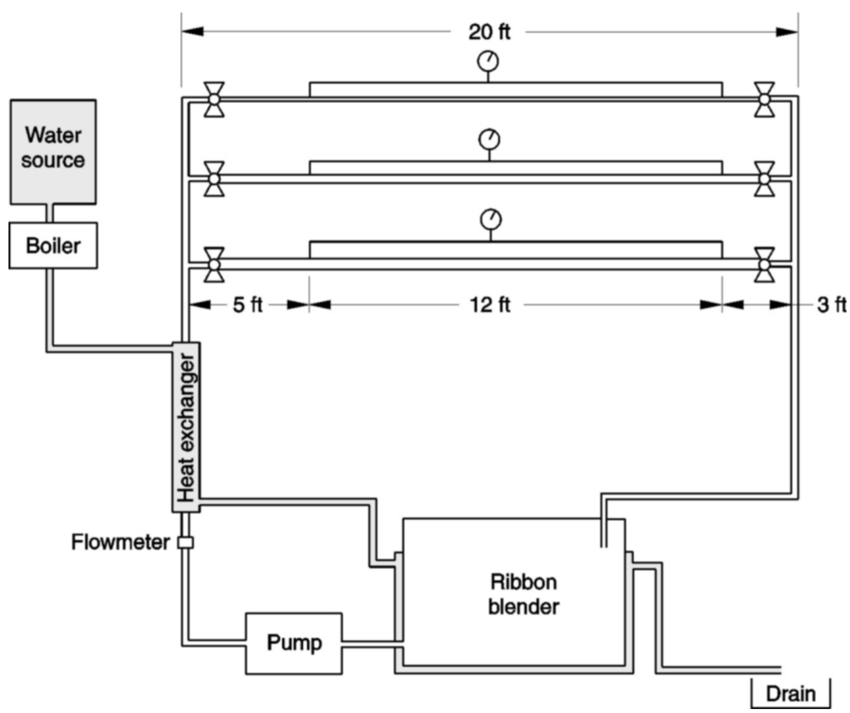

Figure 8 - Friction Pressure Test Equipment

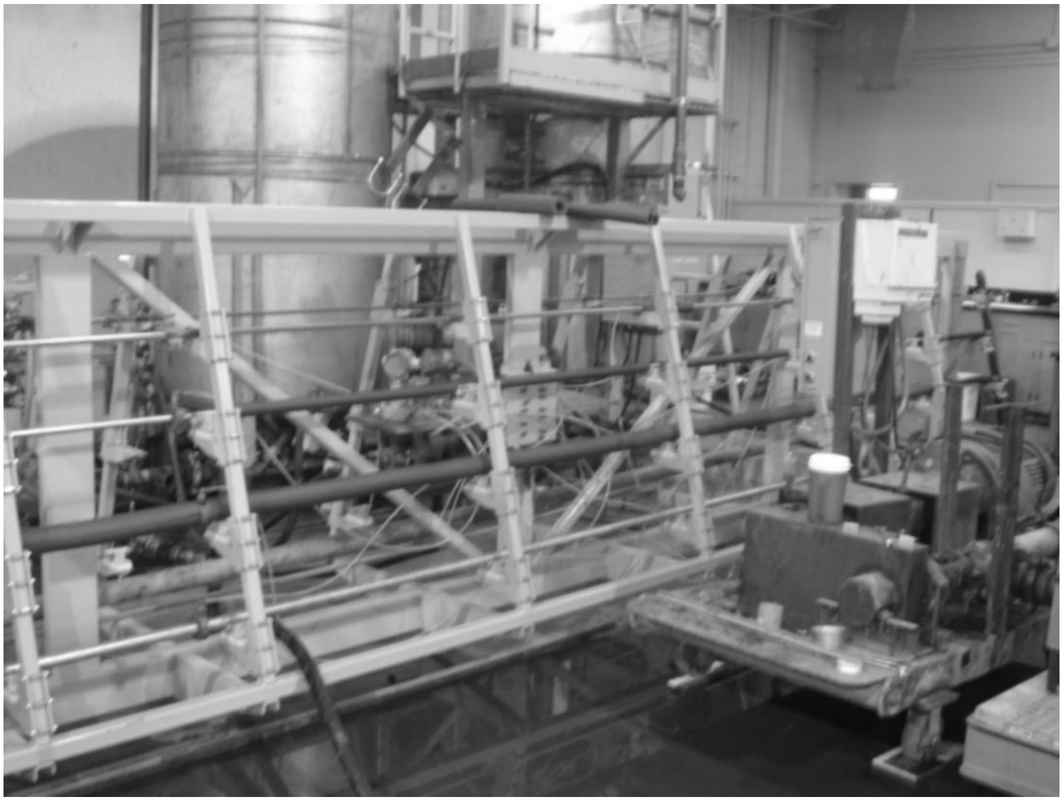

Figure 9 - Friction Pressure Test Equipment

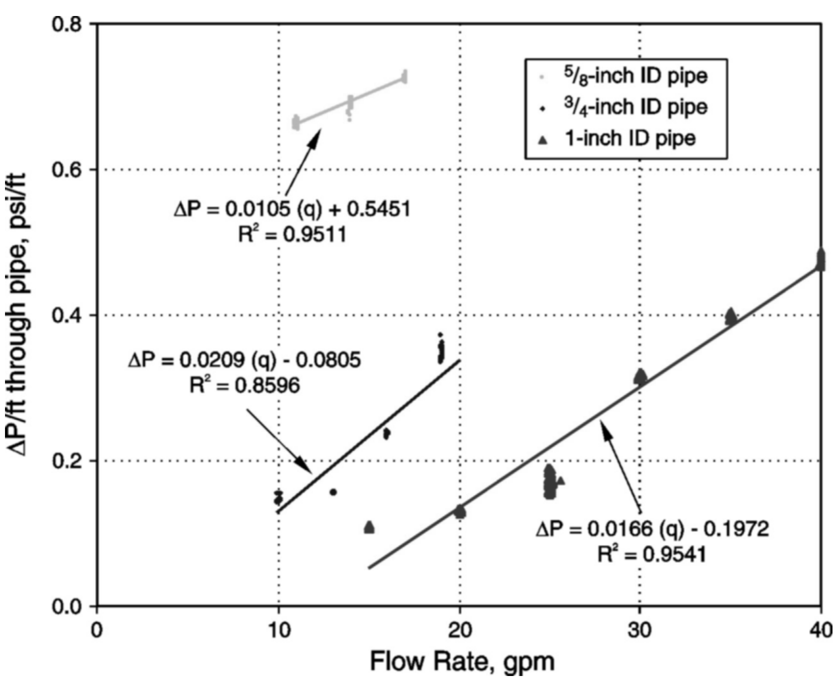

Figure 10 - Friction Pressure Test for TIPG at 180^{o}F

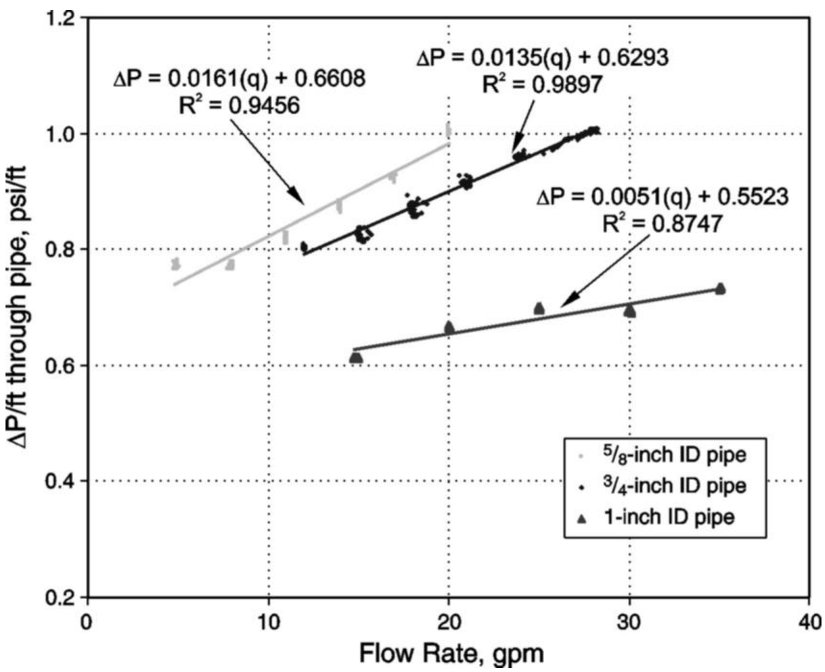

Figure 11 - Friction Pressure Test for TIPG at 130°F

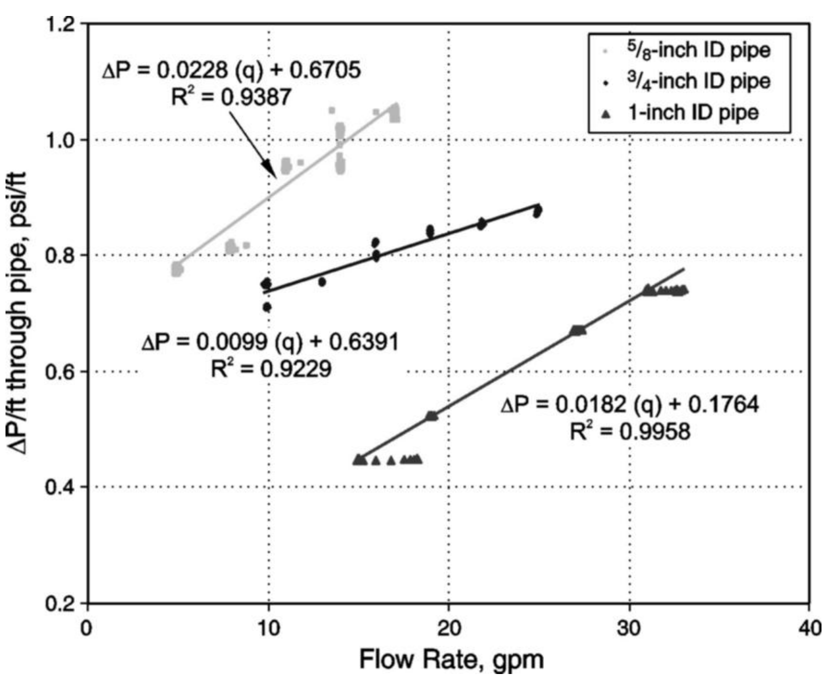

Figure 12 - Friction Pressure Test for TIPG at 100°F

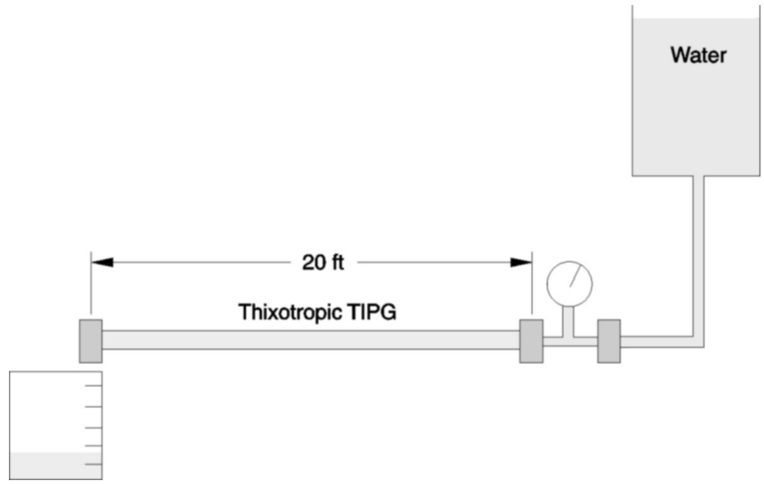

Figure 13 - Equipment to Determine Pressure to Begin Flow After Shut-in Period

Figure 14 - TIPG System Being Filtered Through a 1.5-in. 20/40 Sand and 125-Micron Screen at 180°F