4.2 Task B - Hydrodynamic Study

4.2.1 Introduction

The cold flow hydrodynamic test unit was designed to be a diverse, highly instrumented test facility. All components are to be selected based on proven performance in similar operating pilot plants. To provide the maximum in serviceable information, all process variables are to be monitored and controlled by industrial type, state-of-the-art instrumentation.

An ebullated bed consists of a reactor whose catalyst contents are fluidized by bulk upward liquid flow. The liquid velocity should only be sufficient to expand the catalyst bed to 1.5-2 times its settled height, but should not elutriate the smaller particles from the reactor. The feed gas is sparged into the fluidized catalyst mass where it diffuses through the liquid phase and reacts at the catalyst surface. The exothermic heat of reaction is absorbed by the flowing liquid, primarily as sensible heat. The product gas and liquid only, pass from the reactor to a vapor/liquid separator. The separated liquid is cooled by generating high pressure steam, prior to recycle back to the reactor inlet.

In contrast, for the entrained reactor, the bulk liquid phase contains a uniformly distributed fine catalyst particle ($< 100\,\mu$) suspension. The liquid flow rate must be set to maintain proper flow dynamics and temperature control.

These reactors fall into the general category of plug-flow reactors (as compared to CSTR or fully back-mixed reactors). Deviations from plug-flow ideality for these systems have been historically modelled by superimposing an axial dispersion (diffusion) mechanism over the plug-flow case. The obvious effect of back-mixing in such reaction systems is a reduction in overall reactor productivity due to a global lower average concentration of reacting species. In addition, for the ebullated bed case, the relative phase motions within the reactor affect the ability to establish a well defined solids level interface within the reactor. When this behavior becomes the dominent characteristic, the catalyst cannot be readily contained within the reactor. Further, the rates of catalyst attrition depend very heavily on the dynamics of phase mixing. Both these conditions were strongly evident during the pilot plant experimental program.

The key assumption in the axial dispersion model is that the reactants move under plug-flow conditions while simultaneously diffusing along the axis of flow. A mass balance on a differential element of the fluid (with no reaction term) results in Fick's second law of diffusion,

$$\frac{\partial c}{\partial t} = \mathcal{D}_L \frac{\partial^2 c}{\partial x^2}$$

In this equation $\mathcal{D}_L$ is the axial diffusivity, c is the reactant concentration, x is the distance along the axis of flow and t is time. The value of the axial diffusivity can be determined for a given system using any of several experimental techniques, e.g., tracer analysis.(19-22)

The effect of axial dispersion is quantified by the dimensionless Peclet number defined as:

$$Pe = \frac{u \cdot L}{\mathcal{D}_L}$$

where u is a relative or absolute velocity in the direction of flow, L is the length of the reactor in the direction of flow and $\mathcal{D}_L$ is the axial diffusivity.

For a true plug-flow reactor the axial diffusivity approaches zero while the Peclet number approaches infinity. For the other limiting case, a true backmixed reactor with infinite mixing, the axial diffusivity approaches infinity while the Peclet number approaches zero.

The performance of a chemical reactor with respect to conversion and selectivity depends on the intrinsic kinetics of the various chemical reactions, various physical rate processes such as interphase, and inter and intra particle heat and mass transfer. The effects of these physical rate processes on the reactor performance have been shown to depend on the dynamics of the various phases involved. While there are numerous publications about backmixing in liquid-gas bubble columns and in solid-fluid systems,[23-27] much less material has been published on three-phase ebullated bed/liquid entrained systems[28-30].

Experimental data on Peclet numbers due to axial dispersion in chemical reactors are also very limited. Most of the work has been limited to single phase packed bed reactors. Moreover, data on such systems are only reliable when applied to systems resembling those of the experimental studies[31].

At the present time an extensive effort is being directed toward the measurement and evaluation of backmixing in multiphase systems through residence time distribution (RTD) studies[32-33] (from which Peclet numbers can be calculated). One major problem encountered is that separate RTD measurements are required to evaluate the mixing characteristics of each phase. Although there are numerous methods available to obtain RTD data in complex multiphase systems, measurement problems have been encountered by all recent investigators. Flow maldistribution of the phases can especially impede evaluation of RTD data.

In most RTD models, radial mixing is assumed to be complete. Under many conditions this may not be correct. At the present time there are no applicable criteria that would define the set of reactor conditions under which the assumptions of complete radial mixing are valid. The establishment of any governing criteria would need to consider all phases and all possible flow regimes within the reactor.

Basic to the operation of a three-phase reactor system is the need to properly distribute the respective phases within the vessel. For small diameter columns the design of the gas distributor has been shown to have a significant effect on the Peclet number. Data on large diameter three-phase columns is presently unavailable. Liquid phase maldistribution also remains a problem. A liquid fluidized bed is known to have poor liquid redistribution. This could have a significant impact on the LPM reactor design.

Reactor modelling ultimately combines the RTD analysis with the reaction kinetics in conjunction with heat and mass transfer effects in order to describe a given chemical reactor system. Unless simplifying assumptions are made, the mathematics describing the performance of a three-phase system become very complex, even though the phase mixing phenomenon may be described by a simple axial diffusion model. Furthermore, the RTD data reported in available literature has generally been limited to small scale apparatus. Since the prevailing flow regimes in small and large equipment may differ, there is a real need for experimental data from large diameter reactor systems. At the present time experimental data for commercial reactors is generally confidential and unavailable in the open literature.

The cold flow hydrodynamic unit can be operated as either a liquid fluidized reactor or a liquid entrained (slurry) reactor. In the liquid fluidized mode, the process liquid velocity is controlled over a narrow range in order to fluidize a fixed quantity of catalyst particles within the confines of the reactor. For liquid entrained operations, smaller catalyst particles are intentionally suspended in the process liquid and are circulated throughout the liquid circulation loop. The process flows and physical dimensions of the hydrodynamic unit broadly resemble that of the Liquid Phase Methanation pilot plant.

A conceptual process flow diagram of the cold flow hydrodynamic unit is shown in Figure 147. For the sake of clarity, only the cocurrent liquid/gas upflow mode of operation has been shown. By properly structuring inlet and outlet piping, alternate flow configurations can be readily established, e.g., liquid and gas cocurrent upflow or liquid downflow - gas countercurrent upflow.

It is anticipated that the hydrodynamic test unit would be constructed of materials that are compatible with a range of organic solvents. The process liquids will be selected to have properties similar to those of the hot process liquids.

Solvents of differing physical properties would be used in the determination of the density, viscosity and surface tension effects on the hydrodynamic character of the process fluid.

4.2.2 Liquid Fluidized Mode

For liquid-fluidized operation in the cocurrent gas/liquid upflow mode (the design configuration of the pilot plant), liquid is introduced through the bottom of the reactor (TW-100) by means of a distributor device that insures a uniform gas bubble distribution throughout the reactor cross-section. The process liquid enters the reactor below the gas distribution device and serves both to fluidize the catalyst bed and under reaction conditions remove the exothermic heat of reaction. Superficial liquid velocity would be controlled over a narrow range in order to expand the catalyst bed over a fixed length, yet contain the catalyst particles within the reactor.

Separation of the solids from the liquid/gas continuous phase occurs in the upper portion of the reactor in a region above the expanded catalyst bed. The liquid and gas streams are taken overhead as a two-phase system for subsequent liquid disengagement in the vapor/liquid separator (VT-100). The process liquid is recirculated through feed pump (CP-100) to the bottom reactor inlet. The gas passes through a demister (VT-101) located on top of the vapor-liquid separator in order to de-entrain any liquid droplets. The gas can either be vented to the atmosphere or fed back to the feed gas compressor (GC-100).

The gas compressor will be equipped with a water cooled aftercooler (HE-100). The gas then flows into a surge tank in order to damp out pressure (or flow) fluctuations prior to passing to the reactor gas distribution system.

4.2.3 Liquid Entrained Mode

In the liquid entrained gas/liquid upflow configuration gas and slurry are co-fed to the bottom of the reactor (TW-100). Gas is introduced through a suitable distribution device while the slurry is introduced below the gas distributor. Catalyst particle size and process liquid flows would be selected so as to intentionally suspend the catalyst in the process liquid and circulate the solids throughout the liquid circulation loop. By design the catalyst solids and process liquids must remain a homogeneous mixture everywhere within the liquid circulation loop. Gas/solids/liquids are taken overhead out of the reactor to the V/L separator (VT-100) where phase separation between gas and slurry phases occurs. The separated slurry phase is recirculated to the reactor inlet through Pump (CP-100). As in the liquid entrained mode of operation, the gas phase passes through a demister (VT-101) to de-entrain any liquid droplets. The gas can then be vented or recycled back to the compressor.

4.2.4 Process Equipment

Reactor

The reactor used for the hydrodynamic study would be constructed of a combination of flange-connected glass and metal sections. The column dimensions (identical to the LPM pilot plant reactor) will be 22 inches inside diameter by 15 feet long. The reactor piping connections at the top and bottom will be flexible. The bottom metal spool piece is designed to support the entire cold flow reactor assembly. Each metal spool piece would be constructed so as to allow for the introduction of sample probes, pressure taps, and other instrumentation as required. The sample probes would be constructed and operated so as to obtain slurry concentration data along the radial and axial direction. A Plexiglass or Lexan shield would be used to enclose the glass column for personnel protection. Sections of the plastic shield would be made removable to allow access to the various sample and pressure taps. Finally, an x-ray source and detector will be mounted so as to traverse the length of the reactor. Such an x-ray source/detector system has been successfully used in the LPM Pilot Plant to monitor the fluid dynamics of the system. Alternately, a series of fixed source/detector pairs may be mounted along the vertical length to obtain the density profile.

Pumps and Compressors

A rotary screw air compressor with a water cooled aftercooler would be used for supplying gas. The present design requires a compressor capable of up to 100 SCFM at 100 psig outlet pressure. The compressor discharges into a surge tank to damp out pressure and flow fluctuations.

Magnetically coupled centrifugal pumps will be selected for the slurry feed and circulation loop. These pumps are magnetically coupled to their motor so as to eliminate problems of liquid or gas leakage across a dynamic seal. In addition, these pumps do not require a seal flush flow. The present design requires a pump capable of 220 gpm maximum flow at 75 feet total dynamic head.

Catalyst Recovery Filter

A plate and frame filter press is included in the design to be used in determining solids holdup within the column. Additional use would be made of the filter in recovering "used" catalyst upon completion of testing.

Vessels

The slurry feed tank (VT-102) was sized (300 gallons) to hold the entire contents of the cold flow hydrodynamic test unit. It is baffled at 90^0 and supplied with an agitator to maintain the catalyst slurry in suspension. Liquid inventory can be monitored by placing the unit on a weigh cell or by using a ΔP cell. If a Δ P cell is used, an inert purge gas must be supplied to the high side of the cell to prevent plugging by catalyst. A slurry feed pump (CP-102) is used to transfer the slurry to the main test unit circulating loop.

The slurry preparation tank (VT-103) has a capacity of 100 gallons and was sized for slurry addition and makeup in multiple batches. It is also baffled at 90^0 and supplied with an agitator. Inventory control would be accomplished by placing the unit on a weigh cell. Slurry is tranferred from the vessel to the feed tank or the main circulation loop through the slurry transfer pump (CP-101).

4.2.5 Experimental Techniques

Test methods for determining hydrodynamic system characteristics can be categorized as being either external or internal monitoring techniques. External techniques are preferential in that they do not interfere with established flow patterns. Internal methods involve the insertion of devices through the test cell wall, consequently inducing flow disturbances downstream of the sample location.

External Methods

Sonic probes and gamma-ray scan techniques have been used to obtain data on the average bulk density in multiphase systems. Gamma-ray techniques make use of differential absorption of radiation by various materials. Being an external technique, it is an excellent method for determing the average density of a multiphase system without creating a flow disturbance. Chem Systems has used a movable density gauge in their LPM program which could traverse the length of the reactor and give point bed density measurements directly. These measurements combined with fluidized bed height measurements give a direct evaluation of the relative liquid, gas and solid phase volume fraction.

Sonic techniques are alternate external methods for determining densities of multiphase systems, using sound rather than radiation. In single-phase systems, phase-time and dual-path sonic probes (which measure sonic impedance) can be used to determine density. These devices can also be used in two-phase, liquid-solid slurry systems, provided that the sonic impedance of the two-phase mixture is a very weak function of slurry concentration. These devices can not be used when a bulk gas phase is present because discrete gas bubbles give rise to interfering sonic reflections. A Doppler shift sonic probe makes use of these sonic reflections. It can measure vertical bubble rise velocity or slurry velocity.

Internal Methods

Several tracer testing methods are known for determining residence time distributions, flow rates and relative phase volumes in multiphase reactors. The techniques employed involve use of a tracer component with an internal or external monitoring device. External detection systems are preferred as they will not interfere with established flow patterns.

In general, flow patterns can be studied by injecting a tracer into a vessel inlet stream and observing the subsequent concentration profile at the outlet. At steady state, methods used consist of injecting a continuous tracer into the inlet of a studied interval and measuring the upstream concentration. For large diameter columns, problems are encountered in obtaining a homogeneous dispersion of the tracer. Further, attempts to obtain an average sample profile across the column can be difficult without disturbing the original flow patterns within the column. When continuous sample withdrawal is employed, sample time effects may distort the measured response. Unsteady state methods of measuring residence time distributions consists of injecting a momentary tracer pulse at the reactor inlet and measuring the response function at the outlet. Pulse injection methods are preferred to step or frequency response methods since inputs requiring large quantities of tracer are impractical on large units. Pulse injection techniques are simple, inexpensive, and require only small quantities of tracer material.

In performing a tracer study, proper tracer selection is extremely important. The hydrodynamic response must be characteristic of the flowing phase and not a function of the tracer component. Any tracer employed should be miscible and have physical properties similar to the bulk fluid phase. The tracer must not be transferrable to the other phases of the system. All tracers under consideration should be accurately detectable in low concentrations to minimize disturbances in the established reactor flow patterns.

To enable tracer detection in fast moving streams, the data recording equipment must offer exceptional sensitivity with a minimal detection response time. For simplicity and accuracy, the response of this equipment should be linear.

Gas, liquid or solid tracers can be injected into a flow system to determine the responses for each phase. For the gas phase, a tracer gas injected into a multi-phase reactor would have its concentration measured by a thermal conductivity or infrared absorption cell. Alternately, a radioisotope is substituted. In using gas phase tracers, absorption into the liquid phase precludes an accurate determination of the gas phase mixing and holdup without an independent measurement of tracer content in other phases. The differing rise velocities of individual bubbles further complicate the detector response. Because of these inherent difficulties in using gas phase tracers, only qualitative data concerning gas phase mixing are available in the literature.

The use of liquid tracers are well accepted industrial practices. Problems associated with their use are the familiar ones of sampling induced errors when internal techniques are used. External techniques employed include the use of dyes coupled with high speed photography and radioactive tracer methods. Unfortunately, photographic techniques relying on photochromatic dyes or particle luminescence cannot be used if the color change is obscured by the catalyst particles. In larger diameter columns wall effects can also obscure the events from photographic interpretation.

For the solid phase, a magnetic tracer can sometimes be used. The concentration of a solid phase tracer may be measured by a capacitance probe if the dielectric constant of the tracer material is substantially different than that of the solid phase. In general, for solid phases, a suitable radioactive tracer is often the most convenient to use. If proper precautions are observed, a radioactive tracer has a distinct advantage over other tracers in that the tracer detection devices can be mounted externally. In this way, no disturbances in the established flow patterns resulting from the presence of probes or sampling devices are encountered. The use of a radioactive tracer permits the time distribution function of a rapidly moving phase to be accurately determined, since scintillation detectors can be interfaced with high speed recorders or with multi-channel analyzers with data storage capabilities.

The use of radioactive tracer technology for hydrodynamic studies should never be promoted simply because it is "glamorous" and novel, nor neglected because of difficulties real or imaginary. The use of alternate methods should always be the first consideration. However, when these have proved to be inadequately sensitive or cumbersome, one must seriously consider radioactive tracers.

4.2.6 Construction Cost Estimate and Schedule

The overall construction program cost and fabrication schedule for the hydrodynamic test unit is detailed in the following sections. The total field cost plus engineering charges is estimated to be $268,580. This cost does not include a contingency fee or any user fees. A breakdown of the total cost indicates a purchased equipment cost of $166,580 with a manpower component of $102,000.

The cost estimate was prepared for a hydrodynamic unit capable of simulating the Liquid Phase Methanol pilot plant reactor loop. This test unit was designed to operate in either a liquid fluidized or liquid entrained mode of operation. The field cost estimate was developed by piecing out all major process equipment items and then applying overall component factors to arrive an an installed cost (Table 1). A detailed equipment list for all major process items is presented in Section 4.2.7. The list delineates the design specifications for each item, including materials of construction, as well as an estimated purchased price on a 3rd quarter 1981 basis. Prices were obtained from either a vendor quote, catalog price list or by direct comparison to recent purchase. Instrumentation costs were derived from the instrument specification sheets (Section 4.2.7) and amount to $34,920 of the toal and are not a factored quantity. This represents a minimum in instrumentation required to operate the unit. It does not include sophisticated data acquisition equipment nor does it include instrumentation required in utilizing radioactive tracer techniques. Also omitted is a combustible vapor alarm required if flammable light hydrocarbon liquids are to be utilized in simulating the actual reactor loop oil properties.

Working from vendor and potential fabricator quoted delivery times, an estimated construction schedule was proposed (Table 2). Overall construction time is approximately 8 months. A portion of the major process equipment and instrumentation can be ordered based on the specifications of the attached major equipment and instrument specification sheets. However, detailed engineering drawings are still required for the vessel supports, major vessels and control panel layout.

The following material highlights the program accomplishments achieved by Chem Systems.

<u>Bench Scale Unit Program</u>

- Experimental work was performed in a bench-scale unit (1 inch x 6 feet). Several catalysts were found suitable for the liquid fluidized system. At least two different types of hydrocarbon liquids; one a paraffinic material, and the other an aromatic liquid, were found to perform acceptably. A kinetic model was developed which could predict reaction rate and catalyst activity over a wide range of process conditions.

Process Development Unit Program

- A larger Process Development Unit (PDU) was designed and built. The liquid fluidized reactor in the PDU is 4 inches diameter by 8 feet long and represented a fifty-fold scale-up from the bench-scale reactor.

- Three-phase fluidization studies were conducted in the PDU using a gamma-ray nuclear device which was used to measure bed densities along the length of the reactor. A correlation was developed which predicts catalyst bed expansion and gas holdup over a wide range of process conditions.

- Process variable scans were performed in the PDU investigating the effect of temperature, pressure, space velocity and gas composition. Results corroborated the kinetic model developed from bench-scale data.

- The use of a liquid-fluidized reactor was extended to synthesis gas feeds containing hydrogen to carbon monoxide ratios lower than three to one (designated Liquid Phase Methanation/Shift (LPM/S)).

Experiments under LPM/S conditions were performed in both the bench-scale unit and PDU. Process variable scans were conducted, and a modified kinetic model developed to describe the results.

Pilot Plant Program

- A larger scale pilot plant was designed and constructed. The reactor was 2 feet in diameter by 15 feet long and capable of handling two million SCFD of synthesis gas (a 100 fold scale-up over the smaller PDU). The pilot plant was installed and operated at IGT's HYGAS test facility, in Chicago, Illinois.

- Feed gases were used with H_2/CO molar ratios ranging from 2.2 to 9.5 and flow rates up to 1.3 million SCFD. Reactor conditions ranged up to 750 psig and 675^{o}F with a variety of circulating oil flow rates. Conversions of CO as high as 100% were observed. Catalyst rate constants were determined and the LPM kinetic model was verified over a wide range of process conditions for three different catalysts.

- Unfortunately, one objective that was not met during the pilot plant program was the determination of the larger scale reactor hydrodynamics. In fact, it was obvious that the fluid flow behavior in the 2 foot diameter reactor was quite different from the flow behavior in the smaller 4 inch PDU reactor. This was predominantly a result of large scale backmixing. Attempts were made to quantify the scale of backmixing, but the program was terminated (for other reasons) before sufficient data could be obtained.

4.2.7 Equipment and Instrumentation Lists

Major Equipment List

Following is a major equipment list of all major process equipment required for a cold-flow unit simulation of the Ebulated Bed/Liquid Entrained Methanol Pilot Plant. Sizes, materials of construction and purchased costs on a 3rd quarter, 1981 basis are shown. The major equipment items are listed alphabetically by section and are numbered the same as appears on the process flowsheets.

MAJOR EQUIPMENT LIST
FOR HYDRODYNAMIC TEST UNIT

		Cost; $ (3rd Quarter, 1981)
CP-100	Main slurry circulation pump (1) 270 gmp x 75.0 head, 25 H.P., CS	6,050
CP-101	Slurry transfer pump (1) 10 gpm x 50 ft head, 3 H.P., CS	1,550
CP-102	Slurry feed pump (1) 10 gpm x 50 ft head, 3 H.P., CS	1,550
CP-103	Liquid transfer pump (1) 10 gpm x 50 ft head, 3 H.P., CS	1,300
CP-104	Slurry transfer pump (1) 10 gpm x 150 ft head, 5 H.P., CS	1,850
F-100	Main slurry filter (1) Sparkler type plate/frame 5990 25 ft^2, CS/CS	5,990
F-101	Final liquid filter (1) pipeline filter with metal element, CS	260
GC-101	Rotary screw gas compressor (1) 110 ACFM @ 100 psig, 30 H.P., SF-1.15 includes: air/oil receiver, ASME coped 150 psig, oil filter, air inlet filter, minimum pressure valve, high temperature	

MAJOR EQUIPMENT LIST
FOR HYDRODYNAMIC TEST UNIT

		Cost; $ (3rd Quarter, 1981)
	shutdown switch, automatic blow-down valve, oil cooler, safety relief valve, Nema T frame motor, magnetic motor starter, hour meter, discharge pressure gauge, oil sump pressure gauge, constant speed unloading control, modulating control	9,800
HE-100	Compressor after cooler 91) shell/tube: CS/CS, 25 ft^2	720
HE-101	Slurry cooler/heater (1) shell/tube: CS/CS, 15 ft^2	520
HT-100	Liquid storage tank (1) 750 gal CS	3,500
TW-100	Hydrodynamic test unit (1) 22" O x 20' T-T, 4 glass sections, 3 CS sections with sample probes and instrumentation taps, top head, bottom head with sparger assembly	26,010
VT-100	Vapor/slurry separator (1) 300 gal, CS	2,950
VT-101	Demister (1) 8" yard pipe x 15" 8" entrainment packing, CS	720

MAJOR EQUIPMENT LIST
FOR HYDRODYNAMIC TEST UNIT

		Cost; $ (3rd Quarter, 1981)
VT-102	Slurry feed tank (1) 500 gal, CS, 5 H.P. agitator	10,960
VT-103	Slurry prep. tank (1) 100 gal CS, 3 H.P. agitator	9,300
VT-104	Compressor discharge surge tank (1) ASME air receiver, 240 gal CS	1,070
VT-105	Absorbent drier (1) ASME coped external heater type desiccant supports, pressure gauges, temperature gauges, relief valves, purge controls, pre-filter, post filter	5,360

	TURBINE FLOWMETERS	SHEET 1 OF 1
		SPEC. NO. / REV.
		CONTRACT / DATE
		REQ. - P.O.
		BY / CHK'D / APPR.

NO	BY	DATE	REVISION

METER	1	Tag Number	FI-100		FI-101	
	2	Service	Vapor		Vapor	
	3	Meter Location				
	4	Line Size	1"		2"	
	5	End Connections	1"NPT		2"NPT	
	6	Body Rating	--		--	
	7	Nominal Flow Range	2-20 ACFM		40-400 ACFM	
	8	Accuracy	± ½%		± ½%	
	9	Linearity	± 1% F.S		± 1% F.S.	
	10	K Factor, Cycles per Vol. Unit	6000		6000	
	11	Excitation	--		--	
	12	Materials: Body	MFR STD		MFR STD	
	13	Support	"		"	
	14	Shaft	"		"	
	15	Flanges	"		"	
	16	Rotor	"		"	
	17	Bearings: Type	MFR STD		"	
	18	Bearing Material	MFR STD		"	
	19	Max. Speed	25 CPS		25 CPS	
	20	Min. Output Voltage	30 MV		30 MV	
	21	Pickoff Type	MAGNETIC		MAGNETIC	
	22	Enclosure Class	CL.1 Grp D		CL.1 Grp D	
	23					
FLUID DATA	24	Fluid	GAS		GAS	
	25	Flow Rate: Min. / Max.	2ACFM / 20ACFM		40ACFM / 400ACFM	
	26	Normal Flow	12 ACFM		240 ACFM	
	27	Operating Pressure	100 PSIG		5 PSIG	
	28	Back Pressure	--		--	
	29	Operating Temp. Max. / Min.	40°F / 120°F		40°F / 120°F	
	30	Operating Specific Gravity	VARIABLE		VARIABLE	
	31	Viscosity Range	VARIABLE		VARIABLE	
	32	Percent Solids & Type	NONE		NONE	
	33					
SECONDARY INSTR.	34	Secondary Instr. Tag No.	FI-100		FI-101	
	35	Preamplifier	YES		YES	
	36	Function	Indicator/IL		Indicator/IL	
	37	Mounting	RACK		RACK	
	38	Power Supply	110 VAC		110 VAC	
	39	Scale Range	0-100%		0-100%	
	40	Output Range	0-10 VDC		0-10 VDC	
OPTIONS	41	Totalizer Type	RESET		RESET	
	42	Compensation	NO		NO	
	43	Preset Counter	NO		NO	
	44	Enclosure Class				
	45	Strainer Size & Mesh	MFR STD		MFR STD	
	46					
	47					
	48					
	49	Manufacturer				
	50	Meter Model No.				
	51	Secondary Instr. Model No.				

Notes:

ISA Form S20.24

Texas Nuclear Division
Ramsey Engineering Company

APPLICATION INFORMATION FORM
SG Density Gauge

Date ______

GENERAL

COMPANY ______

Address ______

PERSON & Position ______

Address ______

Address of Installation ______

Number of Systems ______ Delivery Required ______

**ESSENTIAL INFORMATION; *Important information which may have a significant effect on the measurement.

Tag Nos. RDI-100, 101, 102, 103, 104

MEASUREMENT DATA

Purpose of gauge: [X] Density Control/Indication and/or [ ] Mass Flow of dry solids, [ ] Mass Flow of total fluid

**Density Span 0.4 to 1.8 [X] SGU (g/cc), [ ] % by wt solids, [ ] % by vol solids, [ ] lb/ft³, [ ] lb/gal
[ ] °Baume'L, [ ] °Baume'H, [ ] °API, [ ] °Twaddell, [ ] gms/liter, [ ] metric tons/cubic meter

*Nominal operating density 0.9g/cc; Typical operating range 0.8 to 1.0

**ACCURACY REQUIREMENTS (in % of Density Span) TBD

Precision ± ______ % at ______ % confidence level; Nonlinearity ± ______ %; Max drift ______ %/week

Other Accuracy requirements ______

STANDARDIZATION: STD Block - [X] Yes, [ ] No; Pipe Status for STD - [X] Empty, [ ] H_2O, [X] Process

On Scale Cal plates (Only) [ ] Yes, [ ] No; Other ______

RESPONSE TIME CONSTANT: (Min) TBD Sec, (Max) ______ Sec, (Nom) ______ Sec

*Material temperature compensation required [X] Yes, [ ] No; If Yes: Material temp coef UNK. SGU (g/cc)/°C at ______ °C

Material Temperature range 60 to 120 [ ] °C, [X] °F, Nominal 80 [ ] °C, [X] °F

Meter Scale Calibration Required [ ] (0-10 Standard), [X] other Digital

PROCESS MATERIAL

Material Name ______

Material is a: [ ] Solution, [X] Slurry, [ ] Other ______

Liquid Phase of Slurry or Solvent: Name WITCO 40 MINERAL OIL Chemical Formula PARAFFINIC

*Liquid gravity 0.75 to 0.85 SGU (g/cc), ______ Hydrogen Content ______ %

Content of material with atomic number greater than 50 ALL

Solid Phase of Slurry or Solute: Name METHANOL CATALYST ______ Chemical Formula ______

*Solids gravity 1.1 to 1.3 SGU (g/cc), ______ Hydrogen Content ______ %

*Content of material(s) with atomic number greater than 50 ALL

Material is: - [ ] Corrosive, [X] Abrasive, or [X] Builds up on inside of pipe

Is there air or gas entrainment or entrapment at the point of measurement? [X] Yes, [ ] No Attach detailed explanation

Texas Nuclear Division
Ramsey Engineering Company

APPLICATION INFORMATION FORM
SG Density Gauge

Date ______

GENERAL

COMPANY ______

Address ______

PERSON & Position ______

Address ______

Address of Installation ______

Number of Systems ______ Delivery Required ______

**ESSENTIAL INFORMATION; *Important information which may have a significant effect on the measurement.

Tag Nos. FI-100

MEASUREMENT DATA

Purpose of gauge: [ ] Density Control/Indication and/or [ ] Mass Flow of dry solids, [X] Mass Flow of total fluid

**Density Span 0.4 to 1.8 [X] SGU (g/cc), [ ] % by wt solids, [ ] % by vol solids, [ ] lb/ft³, [ ] lb/gal
[ ] °Baume'L, [ ] °Baume'H, [ ] °API, [ ] °Twaddell, [ ] gms/liter, [ ] metric tons/cubic meter

*Nominal operating density 0.9g/cc ; Typical operating range ______ to ______

**ACCURACY REQUIREMENTS (in % of Density Span) TBD

Precision ± ______ % at ______ % confidence level; Nonlinearity ± ______ %; Max drift ______ %/week

Other Accuracy requirements ______

STANDARDIZATION: STD Block - [X] Yes, [ ] No; Pipe Status for STD - [X] Empty, [ ] H_2O, [X] Process

On Scale Cal plates (Only) [ ] Yes, [ ] No; Other ______

RESPONSE TIME CONSTANT: (Min) TBD Sec, (Max) ______ Sec, (Nom) ______ Sec

*Material temperature compensation required [X] Yes, [ ] No; If Yes: Material temp coef UNK SGU (g/cc)/°C at ______ °C

Material Temperature range 60 to 120 [ ] °C, [X] °F, Nominal 80 [ ] °C, [X] °F

Meter Scale Calibration Required [ ] (0-10 Standard), [X] other Digital

PROCESS MATERIAL

Material Name ______

Material is a: [ ] Solution, [X] Slurry, [ ] Other ______

Liquid Phase of Slurry or Solvent: Name WITCO 40 MINERAL OIL Chemical Formula Paraffinic

*Liquid gravity 0.75 to 0.85 SGU (g/cc), ______ Hydrogen Content ______ %

Content of material with atomic number greater than 50 ALL

Solid Phase of Slurry or Solute: Name METHANOL CATALYST Chemical Formula ______

*Solids gravity 1.1 to 1.3 SGU (g/cc), ______ Hydrogen Content ______ %

*Content of material(s) with atomic number greater than 50 ALL

Material is: - [ ] Corrosive, [X] Abrasive, or [X] Builds up on inside of pipe

Is there air or gas entrainment or entrapment at the point of measurement? [X] Yes, [ ] No Attach detailed explanation

INSTALLATION

**Pipe ID 4 [X] in, [ ] mm; OD ___ [ ] in, [ ] mm; Schedule No. 40

**Wall Material STEEL **Thickness ___ [ ] in, [ ] mm

**Pipe Liner Material N.A. **Pipe Liner Thickness ___ [ ] in, [ ] mm

Pipe Position: [ ] Vertical, [X] Horizontal, [ ] Measurement not being made on a pipe (attach explanation)

	GAUGE HEAD (ELEMENT)	ELECTRONICS (TRANSMITTER)
LOCATION:	[X] Indoor, [ ] Outdoor	[X] Indoor, [ ] Outdoor
ENCLOSURE:	[X] Explosion Proof, [ ] Nema ___	[ ] Nema ___, [X] Panel Mount, [ ] Explosion Proof
TEMPERATURE:	60 to 120 [ ] °C, [X] °F	60 to 120 [ ] °C, [X] °F

Power Available 110 ± ___ VAC @ 60 Hz ± ___ Hz

Cable length required from density measuring heads to electronic unit 50 [X] ft, [ ] m

SIGNALS

MASS FLOW DATA: What is signal from flow meter? 4 to 20 [ ] volts, [X] milliamps, [ ] Hz.

If Hz give details of signal ___

Can negative side of signal line be grounded? [ ] Yes, [X] No; Flow Rate 200 gpm

OUTPUTS: Density [ ] 1-5mA, [ ] 4-20mA, [ ] 10-50mA, [ ] Other ___

Mass Flow [ ] 1-5mA, [X] 4-20mA, [ ] 10-50mA, [ ] Other ___

Totalized Mass Flow - [ ] Total Dry Solids, [ ] Total Mass; [ ] Contact Closure and/or [ ] Pulse

Other ___

COMMENTS

PLEASE MAIL THIS FORM TO:

Texas Nuclear Division

OR

Ramsey Engineering Company
Box 9267
Austin, Texas 78766 USA
Telephone (512) 836-0801
Telex 77-6413

AEFSGX0181

	LEVEL INSTRUMENTS (CAPACITANCE TYPE)	SHEET ___ OF___
	NO / BY / DATE / REVISION	SPEC. NO. / REV.
		CONTRACT / DATE
		REQ. / P.O.
		BY / CHK'D / APPR.

	No.	Item			
GENERAL	1	Tag Number	LIC -100		
	2	Service	SLURRY		
	3	Line No./Vessel No.	VT-100		
	4	Application	SLURRY LEVEL		
	5	Function	TRANSMIT		
	6	Fail-Safe	LOW		
PROBE	7	Model Number			
	8	Orientation	VERTICLE		
	9	Style	ROD		
	10	Material	316SS		
	11	Sheath	N.A.		
	12	Insertion Length	TBD		
	13	Inactive Length	TBD		
	14	Gland Size & Mat'l.	TBD		
	15				
	16	Conduit Connection	½" EMT		
AMPLIFIER	17	Location	LOCAL		
	18	Enclosure	XP		
	19	Conduit Connection	½" EMT		
	20	Power Supply	115 VAC		
SWITCH	21	Type	MFD STD		
	22	Quantity and Form	2-SPOT		
	23	Rating: Volts/Hz or dc	120 | 60 HZ		
	24	Amps/Watts/HP	1		
	25	Load Type	NON INDUCTIVE		
	26	Contacts Open / On / Incr.			
	27	Close / Level / Decr.			
TRANS.	28	Output	4-20MA		
	29	Range	2'		
	30	Enclosure Class	XP		
OPTIONS	31	Compensation Cable	25'		
	32	Local Indicator	NA		
	33	I/P Transducer	NA		
	34	Signal Lights	NA		
	35				
SERVICE	36	Upper Fluid	VAPOR		
	37	Dielectric Constant	AIR		
	38	Lower Fluid	VARIES		
	39	Dielectric Constant	--		
	40	Pressure Max. / Normal	30 PSIA | PSIA		
	41	Temp. Max. / Normal	120°F | 80°F		
	42	Moisture	NA		
	43	Material Buildup	UNKNOWN		
	44	Vibration	UNKNOWN		
	45	Manufacturer			
	46	Model Number			

Notes:

ISA Form S20.27

PRESSURE INSTRUMENTS			SHEET 1 OF 2
NO	BY	DATE	REVISION
SPEC. NO.	REV.	CONTRACT	DATE
REQ.	P.O.		
BY	CHK'D	APPR.	

	1	Tag No.	PI-100, PE-100 Service FEED GAS
GENERAL	2	Function	Record ☒ Indicate ☒ Control ☐ Blind ☐ Trans ☐ Other
	3	Case	MFR STD ☒ Nom Size ____ Color: MFR STD ☐ Other ____
	4	Mounting	Flush ☐ Surface ☐ Yoke ☒ Other ____
	5	Enclosure Class	General Purpose ☐ Weather proof ☐ Explosion proof ☒ Class D For Use In Intrin. Safe System ☐ Other ____
	6	Power Supply	117V 60Hz ☒ Other, ac ____ dc ____ Volts
	7	Chart	____ Strip ☐ ____ Roll ☐ 4" Fold ☒ Circular ____ Time Marks ____ Range 0-100 Number ____
	8	Chart Drive	Speed MFR STD Power 117V 60 HZ
	9	Scales	Type HORIZONTAL Range 1 0-100 2 0-100 3 0-100 4 ____
XMTR	10	Transmitter Output	4-20 mA ☒ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ____ For Receiver See Spec Sheet ____
CONTROLLER	11	Control Modes	P=Prop (Gain) I=Integral (Auto-Reset) D=Derivative (Rate) Sub: s=Slow f=Fast P ☐ PI ☐ PD ☐ PID ☐ If ☐ Df ☐ Is ☐ Ds ☐ Other ____
	12	Action	On Meas. Increase Output: Increases ☐ Decreases ☐
	13	Auto-Man Switch	None ☐ MFR STD ☐ Other ____
	14	Set Point Adj.	Manual ☐ External ☐ Remote ☐ Other ____
	15	Manual Reg.	None ☐ MFR STD ☐ Other ____
	16	Output	4-20mA ☐ 10-50mA ☐ 21-103 kPa (3-15 psig) ☐ Other ____
ELEMENT	17	Service	Gage Press. ☐ Vacuum ☐ Absolute ☒ Compound ☐
	18	Element Type	Diaphragm ☒ Helix ☐ Bourdon ☐ Bellows ☐ Other ____
	19	Material	316 SS ☒ Ber. Copper ☐ Other ____
	20	Range	Fixed ☒ Adj. Range ____ Set at ____ Overrange protection to 150 PSIA MIN.
	21	Process Data	Press: Normal 110PSIA Max 135PSIA Element Range ____
	22	Process Conn.	¼ in. NPT ☐ ½ in. NPT ☒ Other ____ Location: Bottom ☒ Back ☐ Other ____
	23	Alarm Switches	Quantity ____ Form SPST Rating 1 amp
	24	Function	Press ☒ Deviation ☐ Contacts To NC on Inc Press.
OPTIONS	25	Options	Filt-Reg. ☐ Sup Gage ☐ Output Gage ☐ ____ Charts ____ Diaph Seal ☐ Type ____ Diaph ____ Bot Bowl ____ Conn ____ Capillary: Length ____ Mtl. ____ Other ____
	26	MFR & Model No.	

Notes:

ISA Form S20.40a

PRESSURE INSTRUMENTS				SHEET 2 OF 2	
				SPEC. NO.	REV.
NO	BY	DATE	REVISION	CONTRACT	DATE
				REQ. P.O.	
				BY CHK'D	APPR.

Rev.	Tag No.	Adj. Range	Set Range	On Meas. Inc. Output	Service	Notes
	PE, PE-100	FIX	135 PSIA	--	FEED GAS PRESSURE	
	101	FIX	15 PSIA	--	EFFLUENT GAS PRESSURE	
	102	FIX	135 PSIA	--	SLURRY COLUMN INLET PRESS	

Notes:

ISA Form S20.40b

RECEIVER INSTRUMENTS				SHEET ___ OF ___	
NO	BY	DATE	REVISION	SPEC. NO.	REV.
				CONTRACT	DATE
				REQ. P.O.	
				BY / CHK'D	APPR.

	1	Tag No DI-100	Service SLURRY DENSITY
GENERAL	2	Function	Record ☒ Indicate ☒ Control ☐ Blind ☐ Integ ☐ Deviation ☐ Other ___
	3	Case	MFR STD ☒ Nom Size ___ Color: MFR STD ☒ Other ___
	4	Mounting	Flush ☐ Surface ☐ Rack ☒ Multi-Case ☐ Other ___ For Multiple Case, See Spec. Sheet ___
	5	Enclosure Class	General Purpose ☐ Weather Proof ☐ Explosion-Proof ☐ Class ___ For Use in Intrinsically Safe System. ☒ Other ___
	6	Power Supply	117 V 60Hz ☒ Other ac ___ dc ☐ ___ Volts
	7	Chart	___ Strip ☐ ___ Roll ☐ 4" Fold ☒ Circular ___ Time Marks ___ Range ___ Number ___
	8	Chart Drive	Speed ___ Power ___
	9	Scales	Type ___ Range 1 ___ 2 ___ 3 ___ 4 ___
CONTROLLER	10	Control Modes	P = Prop (Gain), I = Integral (Auto Reset), D = Derivative (Rate), Sub: s = Slow, f = Fast P ☐ PI ☐ PD ☐ PID ☐ I_f ☐ D_f ☐ I_s ☐ D_s ☐ Other ___
	11	Action	On Meas. Increase Output: Increases ☐ Decreases ☐
	12	Auto-Man Switch	None ☐ MFR STD ☐ Other ___
	13	Set Point Adj.	Manual ☐ External ☐ Remote ☐ Other ___
	14	Manual Reg	None ☐ MFR STD ☐ Other ___
	15	Output	4-20 mA ☐ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ___
INPUTS	16	Input Signals	4-20 mA ☒ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ___
	17	No. of Inputs	1 ☒ 2 ☐ 3 ☐ 4 ☐
	18	Power for XMTRS	External ☐ This Inst ☒ No. of Independent Supplies ___ For Transmitters, See Spec Sheet. ___
ALARMS	19	Alarm Switches	Quantity ___ Form SPST Rating 1A
	20	Function	Meas. Var. ☐ Deviation ☒ Contacts To ___ On Meas ___ Other ___
	21	Options	Filter-Reg ☐ Supply Gage ☐ Charts ☐ Int. Illumination ☐ Other ___
	22	MFR & Model No.	___

Notes:

ISA Form S20.1a

	DIFFERENTIAL PRESSURE INSTRUMENTS				SHEET 1 OF 2	
	NO	BY	DATE	REVISION	SPEC. NO.	REV.
					CONTRACT	DATE
					REQ. P.O.	
					BY / CHK'D	APPR.

	No.	Item	Specification
	1	Tag No. DPT-100	Slurry Service
GENERAL	2	Function	Record ☒ Indicate ☒ Control ☐ Blind ☐ Trans ☐ Integ ☐ Other ______
	3	Case	MFR STD ☒ Nom Size ______ Color: MFR STD ☒ Other ______
	4	Mounting	Flush ☐ Surface ☐ Yoke ☒ Other ______
	5	Enclosure Class	General Purpose ☐ Weather proof ☐ Explosion proof ☒ Class ______ For use in Intrinsically Safe System ☐ Other ______
	6	Power Supply	117V 60 Hz ☒ Other ac ______ dc ☐ ______ Volts ______
	7	Chart	12 in. Circ. ☐ Other Z-Fold Range 0-100 No. ______
	8	Chart Drive	24 hr Other ______ Elec. ☒ Spring ☐ Other ______
	9	Scale	Type ______ Range: 1 ______ 2 ______ 3 ______
XMTR	10	Transmitter Output	4-20 mA ☒ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ______ For Receiver, See Spec Sheet ______
CONTROLLER	11	Control Modes	P=Prop (Gain), I=Integral (Auto Reset), D=Derivative (Rate) Sub: s=Slow, f=Fast If☐ Df ☐ P ☐ PI ☐ PD ☐ PID ☐ Is ☐ Ds ☐ Other ______
	12	Action	On Meas. Increase Output: Increases ☐ Decreases ☐
	13	Auto-Man Switch	None ☐ MFR STD ☐ Other ______
	14	Set Point Adj.	Manual ☐ External ☐ Remote ☐ Other ______
	15	Manual Reg.	None ☐ MFR STD ☐ Other ______
	16	Output	4-20 mA ☐ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ______
UNIT	17	Service	Flow ☐ Level ☐ Diff. Pressure ☒ Other ______
	18	Element Type	Diaphragm ☒ Bellows ☐ Mercury ☐ Other ______
	19	Material	Body SS Element Alloy
	20	Rating	Overrange 1060" H_2O Body Rating 3000 psig
	21	Diff. Range	Fixed ☐ Adj. Range 150-850" H_2O Set At ______
	22		Elevation ______ Suppression --
	23	Process Data	Fluid Slurry Max Temp. 120°F Max. Press. 100 PSIG
	24	Process Conn.	½ in. NPT ☒ Other ______
	25	Alarm Switches	Quantity 1 Form SPST Rating 1AMP
	26	Function	Meas. Var. ☐ Deviation ☒ Contacts To NC on Inc. Meas.
	27	Options	Pressure Element ☐ Range ______ Material ______ Temp. Element ☐ Range ______ Type ______ Filt Reg. ☐ Sup. Gage ☐ Output Gage ☐ ______ Charts Valve Manifold ______ Cond. Pots ☐ Adj. Damp ☐ Integral Sq. Rt. Ext. ☐ Integrator ______ Other ______
	28	MFR & Model No.	______

Notes:

ISA Form S20.20a

	DIFFERENTIAL PRESSURE INSTRUMENTS	SHEET 2 OF 2
		SPEC. NO. / REV.
	NO / BY / DATE / REVISION	CONTRACT / DATE
		REQ. / P.O.
		BY / CHK'D / APPR.

Rev.	Tag	Adj. Range	Set Range	Scale or Chart	Scale Factor	Service	Notes
	DPI-100	150-850"H_2O	250"	0-100	1.0	SLURRY - COLUMN ΔP	
	-101	20-200"H_2O	90"	0-100	1.0	SLURRY - COLUMN ΔP	
	-102	20-200"H_2O	90"	0-100	1.0	SLURRY - COLUMN ΔP	
	-103	20-200"H_2O	90"	0-100	1.0	SLURRY - COLUMN ΔP	
	-104	20-200"H_2O	90"	0-100	1.0	SLURRY - COLUMN ΔP	

Notes:

ISA Form S20.20b

	POTENTIOMETER INSTRUMENTS				SHEET ___ OF ___	
	NO	BY	DATE	REVISION	SPEC. NO.	REV.
					CONTRACT	DATE
					REQ. P.O.	
					BY	CHK'D / APPR.

	No.	Item	Specification
	1	Tag No. TI-100	Service
GENERAL	2	Function	Record ☐ Indicate ☒ Control ☐ Blind ☐ Transmit ☒ Other ____
	3	Type	Auto Bal. ☒ Man Bal. ☐ Galv ☐ Other ____
	4	Case	MFR STD ☒ Nom Size ____ Color: MFR STD ☒ Other ____
	5	Mounting	Flush ☒ Surface ☐ Rack ☐ Multi-Case ☐ Other ____ For Multiple Case Spec, See Sheet ____
	6	Enclosure Class	Gen Purp ☒ Weather Proof ☐ Explosion-Proof ☐ Class ____ Other ____
	7	Power Supply	117V 60 Hz ☒ Other ____
	8	Chart	____ Strip ☐ ____ Circ ☐ Time Marks ☐ Range ____ No ____ Chart Speed: ____ Change Gears ____
	9	Scale	Type ____ Range 1 ____ 2 ____
	10	Printout	No. of Points ____ Sec Per Point ____ Full Travel Speed ____ Print Character and Color ____ Point Select ☐
	11	Selector Switches	No. and Form ____ In Case ☐ External ☐ Switch Cabinet Specs ____
XMTR	12	Trans. Output	4-20 mA ☒ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ____ Input-Output Isolation ☒ For Receiver See Sheet ____
CONTROLLER	13	Control Modes	P = Prop (Gain), I = Integral (Auto Reset), D = Derivative (Rate), Sub: s=Slow f=Fast I_f ☐ D_f ☐ P ☐ PI ☐ PD ☐ PID ☐ I_s ☐ D_s ☐ Other ____
	14	Action	On Meas. Increase Output: Increases Decreases
	15	Auto-Man Switch	None ☐ MFR STD ☐ Specify ____
	16	Set Point Adj.	Manual ☐ External ☐ Remote ☐ Specify ____
	17	Manual Reg.	None ☐ MFR-STD ☐ Other ____
	18	Output	4-20 mA ☐ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other ____
INPUT	19	Thermocouple Type	J(IC) ☒ K(CA) ☐ T(CC) ☐ E(CHR-CON) ☐ Other ____ Ref Junction Comp ☒ Lead Resistance (Galv) ____
	20	Other Input	Resistance Temp Sensor ☐ Calibration ____ Other ____
ALARM	21	Alarm Switches	Quantity 1 Form SPST Rating 1 AMP
	22	Function	Meas. Var. ☒ Deviation ☐ Contacts to NC measure ____ Other ____
	23		Front Adj X Back Adj ____
OPTIONS	24	T/C Burnout Drive	None ☐ Upscale ☒ Downscale ☐
	25	Accessories	Case Illuminator ☐ ____ Charts Filter Reg. ☐ Other ____
	26	MFR. & Model No.	____

Notes:

	THERMOCOUPLES AND THERMOWELLS				SHEET ___ OF ___	
	NO	BY	DATE	REVISION	SPEC. NO.	REV.
					CONTRACT	DATE
					REQ. P.O.	
					BY CHK'D	APPR.

1. Complete Assembly ☒ Other ______
   MFR. & Model No. ______

ELEMENT

MFR. & Model No. ______
2. ISA Type K Wire Size 22
3. Sheathed: ¼" O.D. Material 316SS
   Exposed ☐ Grounded ☒ Ungrounded ☐
   Enclosed ☒ Beaded Insulators ☐ Spring Loaded ☐
4. Nipple Size NONE Dimension "N" NONE Union ☐
5. Packed Connector ______

HEAD

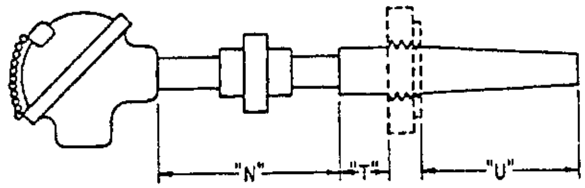
6. Screw-Cap & Chain ☒ Other ______

7. Material Alum. Conduit Conn. ½"EMT
8. Terminal Block: Single ☐ Duplex ☒

WELL OR TUBE

9. Material 316SS
10. Construction: Tapered ☐ Straight ☐
    Drilled ☐ Built-Up ☐ Closed End Tube ☒
11. Dimensions: MFR. STD. ☒ O.D. ¼" I.D. ______
12. Connections: Process ______ INT. ______
13. Other Specs.: ______

Notes:



Rev.	Tag No.	Well Dimens. "U"	Well Dimens. "T"	Element Length	Single Duplex	Type	Gage	Service	Notes
	TE-100	6"	NA	6"	D	K		FEED GAS TEMP.	
	-101	6"	NA	6"	D	K		SLURRY TEMP.	
	-102	6"	NA	6"	D	K		EFFLUENT GAS TEMP	
	-103	6"	NA	6"	D	K		GAS COOLER INLET	
	-104	6"	NA	6"	D	K		GAS COOLER OUTLET	
	-105	6"	NA	6"	D	K		SLURRY COOLER INLET	
	-106	6"	NA	6"	D	K		SLURRY COOLER OUTLET	

Notes:

ISA FORM S20.12a

PRESSURE GAGES				SHEET 1 OF 1	
NO	BY	DATE	REVISION	SPEC. NO.	REV.
				CONTRACT	DATE
				REQ. P.O.	
				BY / CHK'D	APPR.

1. Type: Direct Rdg ☒ 3-15 lb Receiver ☐ Other ____
2. Mounting: Surface ☐ Local ☒ Flush ☐
3. Dial: Diameter 4½" Color MFR STD
4. Case: Cast Iron ☐ Aluminum ☐ Phenol ☒ Other ____
5. Ring: Screwed ☐ Hinged ☐ Slip ☐ Std ☒ Other ____
6. Blow-out Protection None ☐ Back ☒ Disc ☐ Solid Front ☐ Other ____
7. Lens: Glass ☒ Plastic ☐
8. Options: Sylphon ☐ Material; Snubber ☐; Pressure Limit Valve ☐; Movement Damping ☐
9. Nominal Accuracy Required 1%
10. MFR. & Model No. ____
11. Press. Element: Bourdon ☒ Bellows ☐ Other ____
12. Element Mtl: Bronze ☐ Steel ☒ ____ SS Other ____
13. Socket Mtl: Bronze ☐ Steel ☒ ____ SS Other ____
14. Connection-NPT: ¼ in. ☒ ½ in. ☐ Other ____ Bottom ☒ Back ☐
15. Movement: Bronze ☐ SS ☒ Nylon ☐ Other ____
16. Diaphragm Seal MFG. ____ Type ____ Wetted Part Mtl. CS Other Mtl. ____ Fill Fluid GLYCERINE Process Conn. ½" Gage Conn. ½"

Rev. Quan.	Tag No.	Range	Operating Pressure	Service
	PI-100	0-100PSIG	10 PSIG	SLURRY - MAIN CIRCULATION PUMP INLET
	-101	0-100PSIG	35 PSIG	SLURRY - MAIN CIRCULATION PUMP OUTLET
	-102	0-100PSIG	0 PSIG	SLURRY - TRANSFER PUMP INLET
	-103	0-100PSIG	30 PSIG	SLURRY - TRANSFER PUMP OUTLET
	-104	0-15PSIG	0 PSIG	VAPOR - LIQUID STORAGE TANK
	-105	0-100PSIG	50 PSIG	SLURRY-FILTER INLET
	-106	0-100PSIG	30 PSIG	LIQUID -TRANSFER PUMP
	-107	0-15PSIG	5 PSIG	VAPOR - LIQUID SEPARATOR
	-108	0-150PSIG	110 PSIG	VAPOR - FEED GAS SORGE TANK

Notes:

ISA FORM S20.41a

5.0 REFERENCES

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6.0 PATENTABLE INVENTIONS

No patentable inventions were conceived during the course of this project.