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MEASUREMENT OF PRESSURE, FLUIDIZED BED LEVEL AND DENSITY IN THE SYNTHANE PILOT PLANT COAL GASIFIER

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ABSTRACT

MEASUREMENT OF PRESSURE, FLUIDIZED BED LEVEL, AND DENSITY IN THE SYNTHANE PILOT PLANT COAL GASIFIER

Fluid bed densities and levels are usually obtained from measurement of differential pressures between taps with a known vertical separation. Historically, this measurement has been difficult in high pressure coal gasification processes primarily due to plugging of the pressure taps and process instrument tubing. Likewise, the achievement of accurate and reliable pressure and differential pressure recordings is affected by similar circumstances.

These typical problems were experienced at the SYNTHANE Pilot Plant at Bruceton which is operated for the U. S. Energy Research and Development Administration by the C. E. Lummus Company. Major changes were required in instrument location and selection, piping configuration, and methods of purging. Consistent and accurate data is now obtained.

BACKGROUND

The gasifier at the ERDA SYNTHANE Pilot Plant, as depicted in Figure No. 1, is a 101 foot tall pressure vessel designed to operate to 1000 psi. The vessel is divided into two sections and is separated by an internal head that is designed to withstand 25 psi pressure differential. The top section, which is 76 feet high and 60 inches inside diameter, is used for gasification. This section has a carbon steel shell monel clad, insulated with 9 inches of cast refractory and has a 37 inch ID Incoloy 800 internal shroud which extends halfway up the gasifier section. The char cooler section is located below the gasifier section. This section is 25 feet high, 30 inches in diameter, is uninsulated and of carbon steel construction.

Both sections of the gasifier operate with fluidized beds. Steam and oxygen are introduced into the gasifier section through the plenum zone which is located just above the internal head. This flow is then distributed into the gasifier through an Incoloy 800 cone containing 128 nozzles. Steam only is used to fluidize the char cooler section. The steam enters through a similar but smaller cone which is located in the bottom head of the char cooler.

Coal is fed to the gasifier by pneumatic transport from a pressurized Petrocarb lock hopper system using carbon dioxide. In the Synthane process, approximately 65% of the coal feed is converted to gas. The product gas resulting from the gasification process passes overhead through an internal cyclone into a gas scrubbing section and then to process units that maximize the production of methane. The char is withdrawn through the bottom of the gasifier cone through a standpipe and trickle valve to the char cooler. From the char cooler, the char is withdrawn by differential pressure through a 1 inch line to a vessel where it is slurried with water and then transferred to the filter area for dewatering and disposal as landfill.

Gas was first produced by the SYNTHANE Plant in July of 1976. As of this date, 2,590 tons of coal have been processed through the plant. The gasifier has been operated at 600 psi and at bed temperatures varying from 1300°F to 1550°F.

GASIFIER PRESSURE CONTROLS

The gasifier was designed with the following pressure and level instrument control systems:

Bed Level Indication in Gasifier and Char Cooler Sections

Bed level in the gasifier and char cooler sections, as shown in Figure No. 2, is determined by utilizing two vertical dip tubes which are located within the fluidized beds and of known distance apart and a third dip tube which is located above the bed. Differential pressure instruments of 100 inch range are installed across the legs. One d/p transmitter is located across the dip tubes that are separated by 6 feet and another d/p transmitter is located across the lower dip tube and a dip tube which is above the bed height. The dip tubes are purged with inert gas and are made of Incoloy 800 pipe. The difference in pressure resulting from the fluidized beds across the 6 feet spans is sensed by PDT-203 and PDT-205. This reading is used to determine the bed density in the gasifier and in the char cooler. The difference in pressure across the taps, PDT-202 and PDT-204, measures the pressure exerted by the full bed heights. Assuming that the fluidized beds are uniform in density, the bed heights in each section are then determined by calculating the ratio of the readings of the total bed height and the bed density indications and multiplying this value by the known distance of 6 feet. The calculation of bed heights and densities are displayed and refreshed on the Computer CRT in the Control Room.

Gasifier Pressure Control

The pressure control system for the gasifier is presented in Figure No. 3. The overhead pressure of the gasifier was originally designed to be sensed by pressure transmitter PT-206 which was located in piping some distance downstream from the gasifier. Between this sensing point and the gasifier, there were several vessels through which gas would pass before the pressure would be recorded. Prior to startup, the mode of gasifier pressure control was changed. Pressure transmitter, PT-295, was installed on the top portion of the gasifier. The signal from PT-295 was then transmitted to the Control Room where PIC-295 controls a valve that is located in the outlet line of the gas scrubbing system.

The differential pressure between the gasifier and char cooler is designed to be controlled by sensing the pressure between the char cooler and gasifier sections on a -10 to 0 to +10 psi differential pressure instrument, PDT-257. The output of this instrument is transmitted to the Control Room where PDIC-257 sends a signal to a control valve, PDCV-202, which is located in the effluent gas line of the char cooler. The instrument senses changes in the gasifier or char cooler pressure and the signal is transmitted to PDCV-202 to adjust the char cooler pressure so that the proper differential is maintained. Because the gasifier has an internal head that will withstand only 25 psi in pressure differential, close control of the pressure differential between the plenum chamber, the gasifier, and the char cooler is critical to the operation.

Bed Level Control in Gasifier

The level of the fluid bed within the gasifier reaction zone, as shown in Figure No. 4, is designed to be controlled by PDIC-202 which takes its signal from PDT-202. This instrument, as well as the char cooler differential pressure controller PDIC-257, operates PDCV-202. An alarm indicating a high pressure differential and a manual switch are provided to allow the operator to switch from level control to pressure differential control in the event that a high differential in pressure results, or if a high bed level is noted in the char cooler. When placed on automatic, the PDIC-202 controller senses a high bed level and opens the control valve, PDCV-202. This causes the char cooler pressure to drop resulting in more char flow through the standpipe from the gasifier to the char cooler. Conversely, if the gasifier fluid bed level drops too low, PDCV-202 closes causing the char cooler pressure to increase thus slowing or stopping the flow of char from the gasifier.

Bed Level Control in the Char Cooler

Bed level control in the char cooler, as shown in Figure No. 5, is designed to be adjusted by the bed level differential signal from PDIC-204 which controls the action of slide valve PDCV-204 located in the outlet line of the char cooler. Char is moved from the char cooler to the char slurry tank by maintaining a constant pressure differential between the two vessels using steam as the transport medium. The char is then transferred from the char slurry tank to the char filter area by pressure letdown.

ORIGINAL INSTRUMENT INSTALLATION

Although the concepts of the instrument design for the SYNTHANE gasifier were sound, simple and straightforward, the pressure sensing systems and controls, as installed, were essentially inoperable. The typical instrument installation, as originally installed, is shown in Figure No. 6.

As seen in the drawing, high pressure inert gas was used to provide instrument purge. The purge system which was provided consisted of a configuration of block valves, a check valve, and a rotameter. A connection was made from the purge line to the pressure transmitter which was mounted below the sensing taps.

The system as designed was inoperable for the following reasons:

1. The bed level and density instruments were sensitive to small variations in purge flows.

2. The purge lines plugged with solids when the flows were reduced to levels that did not affect the transmitter indications.

3. Steam migrated up the sensing lines and filled the pressure transmitter legs with condensate.

4. Rotameters stuck due to dirty CO_2 and failed to operate.

5. The check valves were spring loaded and put an uneven back pressure on the pressure transmitters.

6. The location of pressure taps was poor. Too many instruments were connected to the same tap. Some taps were located in dead legs and in areas which were subject to fouling.

7. Instrument range control was too wide for accurate control.

INSTRUMENT REVISIONS

Major changes were made to all of the pressure sensing instruments within the first three months of operation. In a stepwise manner, each of the problems mentioned was overcome. The primary goal emphasized the necessity of gaining pressure sensing reliability. Modifications involved relocating transmitters above the taps, relocating sensing lines, purchasing new rotameters, adding needle valves to the rotameter stations, replacing the spring check valves with bonnet lift check valves and finally, redesigning the entire purge stations.

During the first phase of redesign, all of the pressure sensing instruments were modified as shown in Figure No. 7.

The specifics, as shown, are:

1. All d/p transmitters were relocated at least 10 feet above the pressure taps.

2. The holes in the outlet of the dip tubes were enlarged from 1/4 to 1/2 inch.

3. The CO_2 purges were changed to enter directly into the purge tubes to minimize the effect of purge on the instruments.

4. The check valves were removed from the lines to the pressure transmitters and were relocated in the CO_2 purge lines.

5. The purge rotameter bypass stations were provided with double block and bleed valves.

6. Needle valves were provided for rotameter control.

7. All sensing lines were sloped back to the gasifier and all pockets were removed.

This interim design increased sensing reliability considerably. Subsequently however, it was determined that additional reliability could be achieved by purging the complete systems from the pressure transmitters to the outlet of the dip tubes. These revisions shown in Figure No. 8 include the following:

1. Rotameters with a range of 0-500 SCFH were installed on each sensing line at the pressure transmitters.

2. A continuous CO_2 purge was injected at each pressure transmitter leg. This purge was normally 230 SCFH based upon a rate of 1 foot per second through the opening in the purge piping.

3. Needle valves were installed at each rotameter for control.

4. 1/8 inch Capillary tubes approximately 25 inches long, were installed between the rotameters and the sensing lines to help control flow of CO_2 purge.

5. Condensate pots were installed in the sensing lines at the gasifier flanges.

6. The CO_2 purge connections at the vessel taps were converted to blast purges and are now used in case of instrument malfunction.

The instrument revisions, as described in Figure No. 8, have given the SYNTHANE Plant reliable bed level, density and pressure indications. Prior to startup of each gasifier run, scheduled sequence checks are made to assure compliance with the test directives. This includes setting of the purge rates and zero checking of bed level and density instruments to the control board and computer.

As instrument reliability was achieved, more attention was given to improving process control. Improved gasifier pressure control was achieved with PT-295 by adding another pressure transmitter of narrower range. For startup purposes the full range 0 to 1200 psi pressure transmitter that was originally provided is used. When the vessel is up to operating pressure, the parallel unit is placed in service. Since the gasifier is being operated at 600 psi, the parallel pressure transmitter is ranged from 500 to 700 psi.

Further improvement in gasifier pressure control was also achieved by providing a similar parallel pressure transmitter for the high pressure steam pressure controller PIC-338 which controls the steam pressure to the gasifier. The parallel instrument was ranged from 600 to 750 psi such that a constant 100 psi differential over the gasifier pressure could be obtained.

As shown in Figure No. 9, a major change has recently been made to control the flow of char from the gasifier. The trickle valve in the standpipe between the gasifier and char cooler has been modified for automatic control. A valve actuator has been mounted on a flange on the outside of the shell of the char cooler with the valve stem extending through the char cooler and attached to the flapper of the trickle valve. The PDIC-202 bed level controller in the gasifier section now operates this trickle valve and the differential pressure controller, PDIC-257, controls only differential pressure between the gasifier and char cooler.

In addition to the revisions covered in the current design, it should be pointed out that cold weather conditions can and do compound all the problems encountered. The need for upgrading the steam and electrical tracing of transmitters and process instrument tubing for freeze protection became apparent and this task was undertaken and accomplished.

During the course of plant operation, it was also found that gas used for purge must be free of particulates. It was necessary to install suction filters on the CO_2 compressors in the SYNTHANE plant not only to minimize compressor wear but to keep the purge lines free of solids that can plug rotameters and lines.

CONCLUSIONS AND RECOMMENDATIONS

In future scaleup of Coal Gasification Plants, or in existing facilities where pressure measurement problems of this nature may exist, the following suggestions are made:

1. The inert gas source used for purging should be properly filtered to maintain lines free of particulates.

2. Purge tap openings of 1/2 inch are recommended with purge velocities of 1 foot per second.

3. Transmitters should be located at least 10 feet above the pressure taps and lines should slope and contain no pockets.

4. Purging from the pressure transmitters through the entire sensing line will keep the sensing lines clear of condensate and particulates.

5. Condensate pots at the nozzle taps will collect any condensate which forms in the system and provide a means of blowdown.

6. The location for pressure taps should be chosen away from possible points of contamination.

SYNTHANE GASIFIER

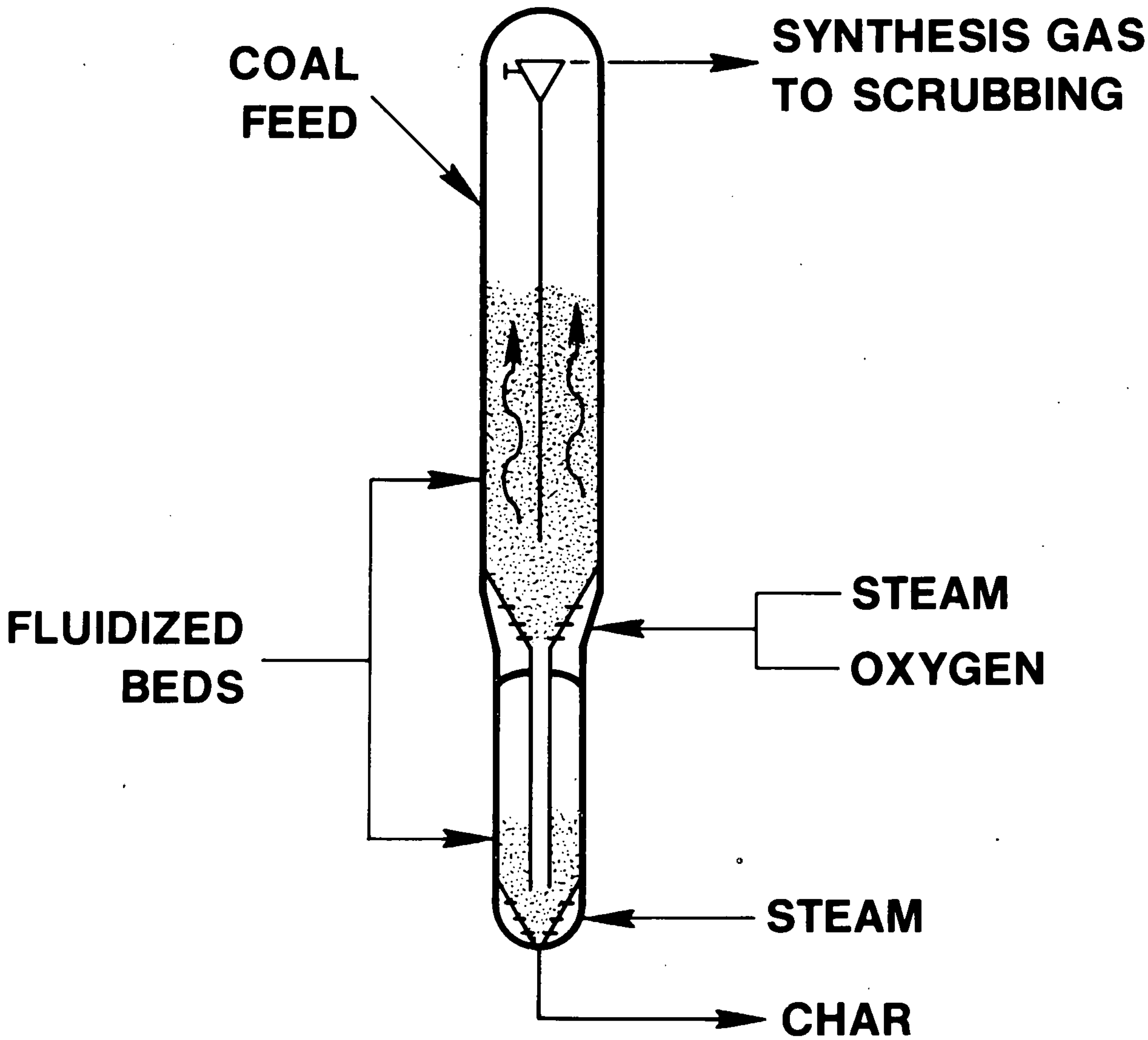

FIGURE NO. 1

SYNTHANE GASIFIER
BED LEVEL INDICATIONS

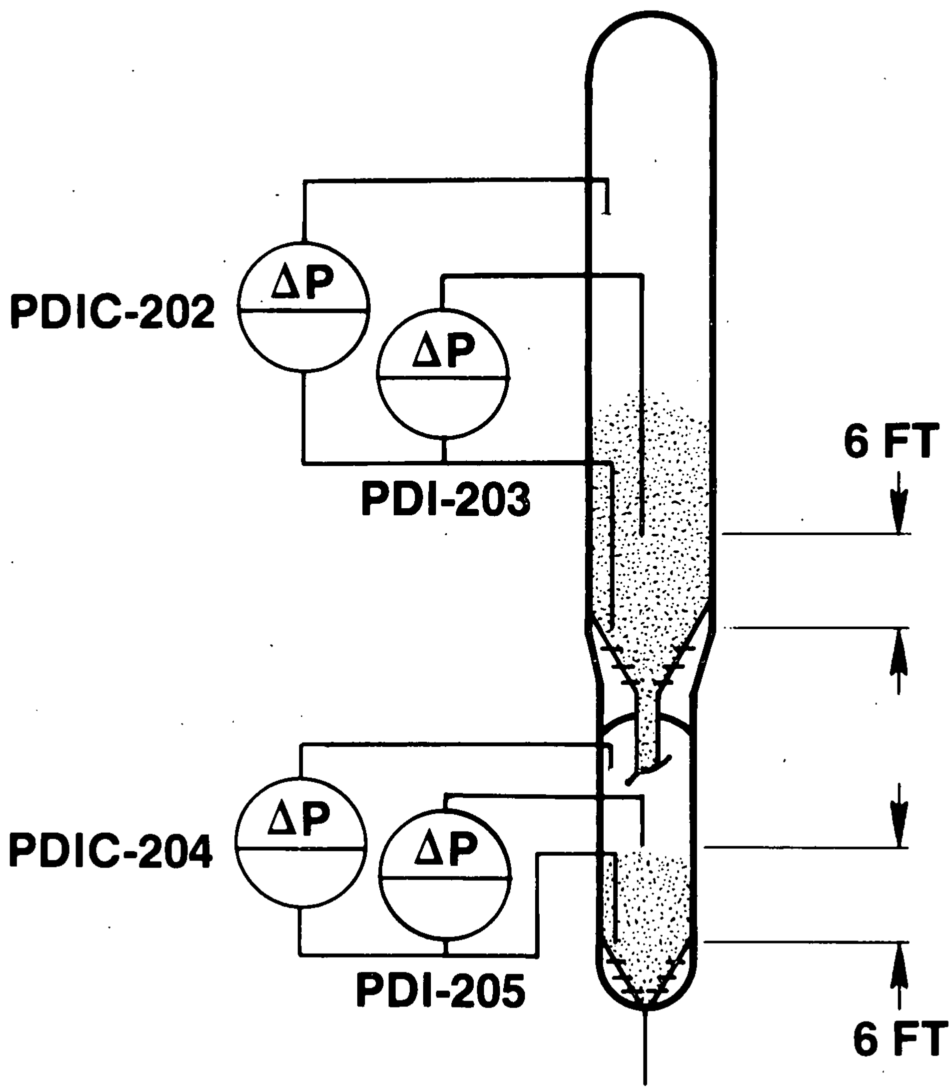

FIGURE NO. 2

SYNTHANE GASIFIER
PRESSURE CONTROL SYSTEMS

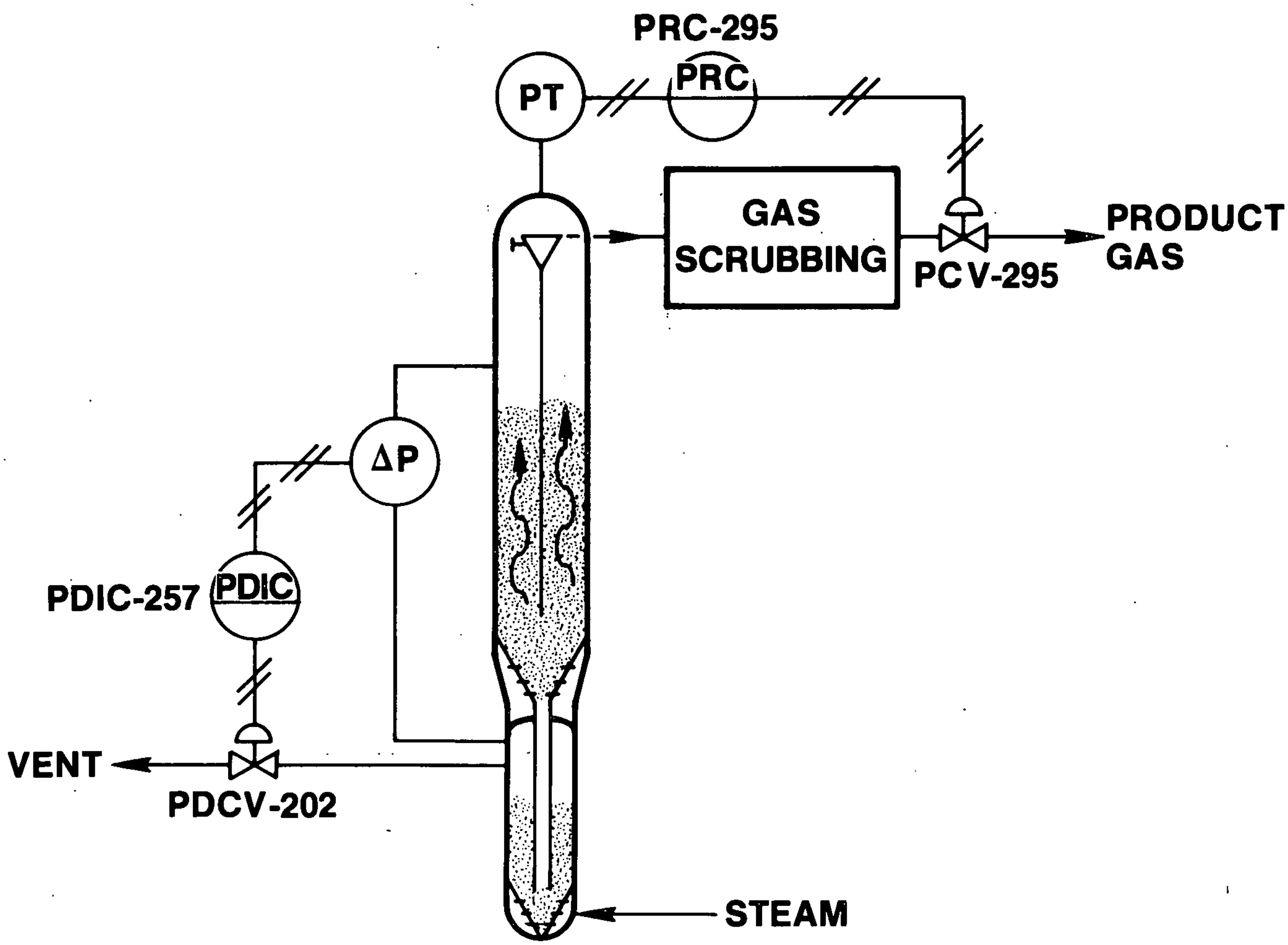

FIGURE NO. 3

SYNTHANE GASIFIER
GASIFIER BED LEVEL CONTROL

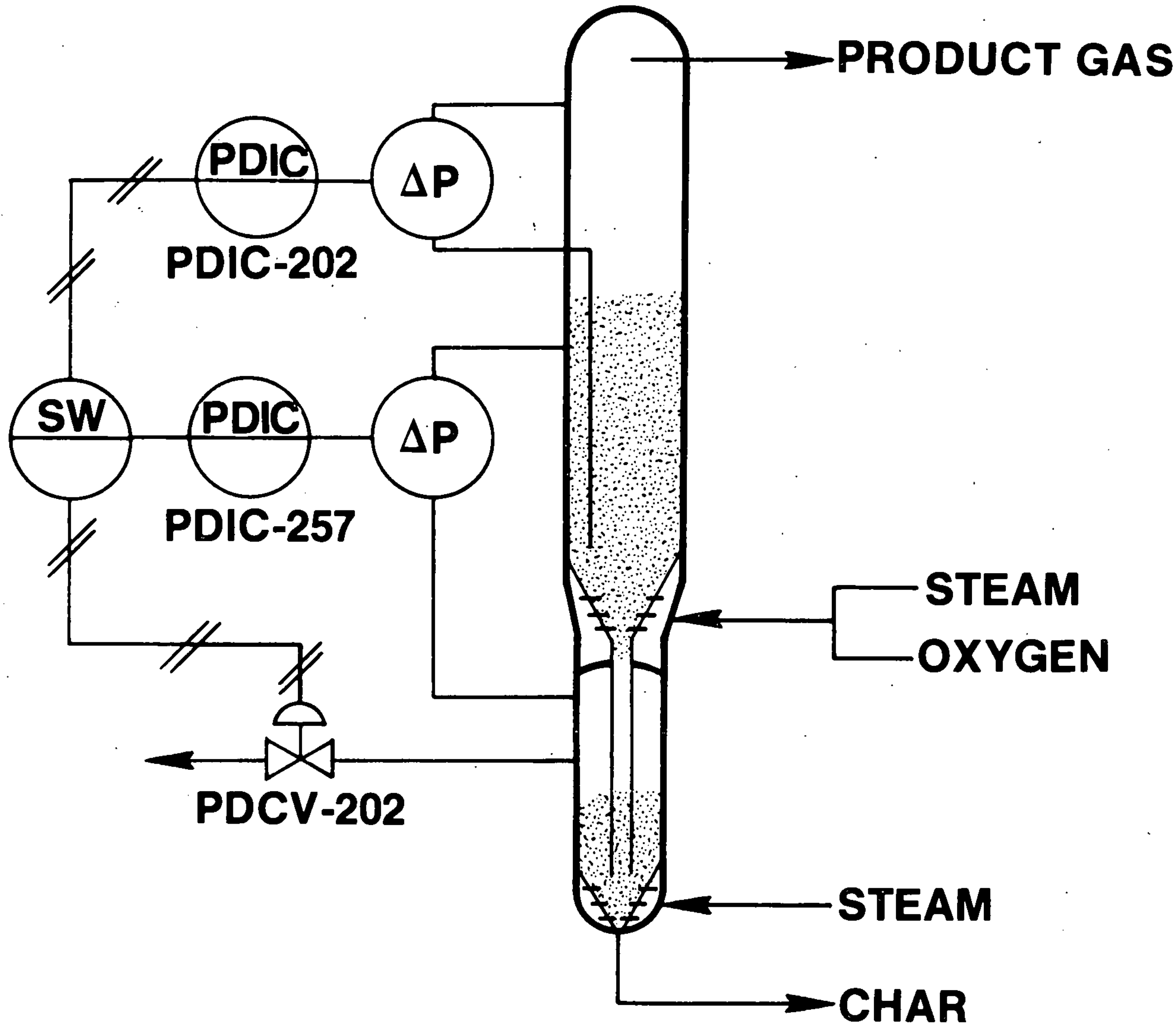

FIGURE NO. 4

SYNTHANE GASIFIER
CHAR COOLER
LEVEL CONTROL

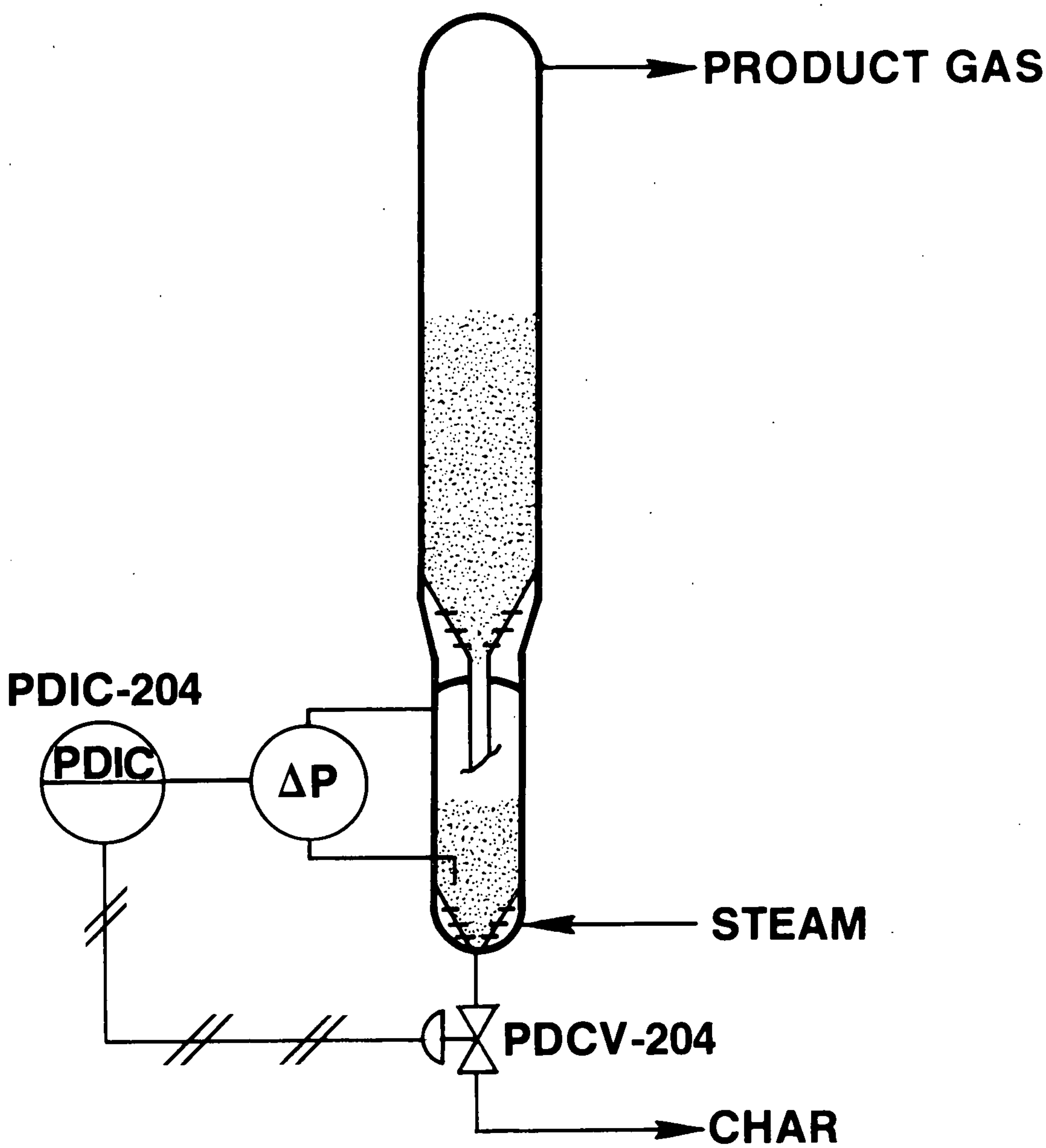

FIGURE NO. 5

SYNTHANE GASIFIER ORIGINAL PRESSURE TRANSMITTER INSTALLATION

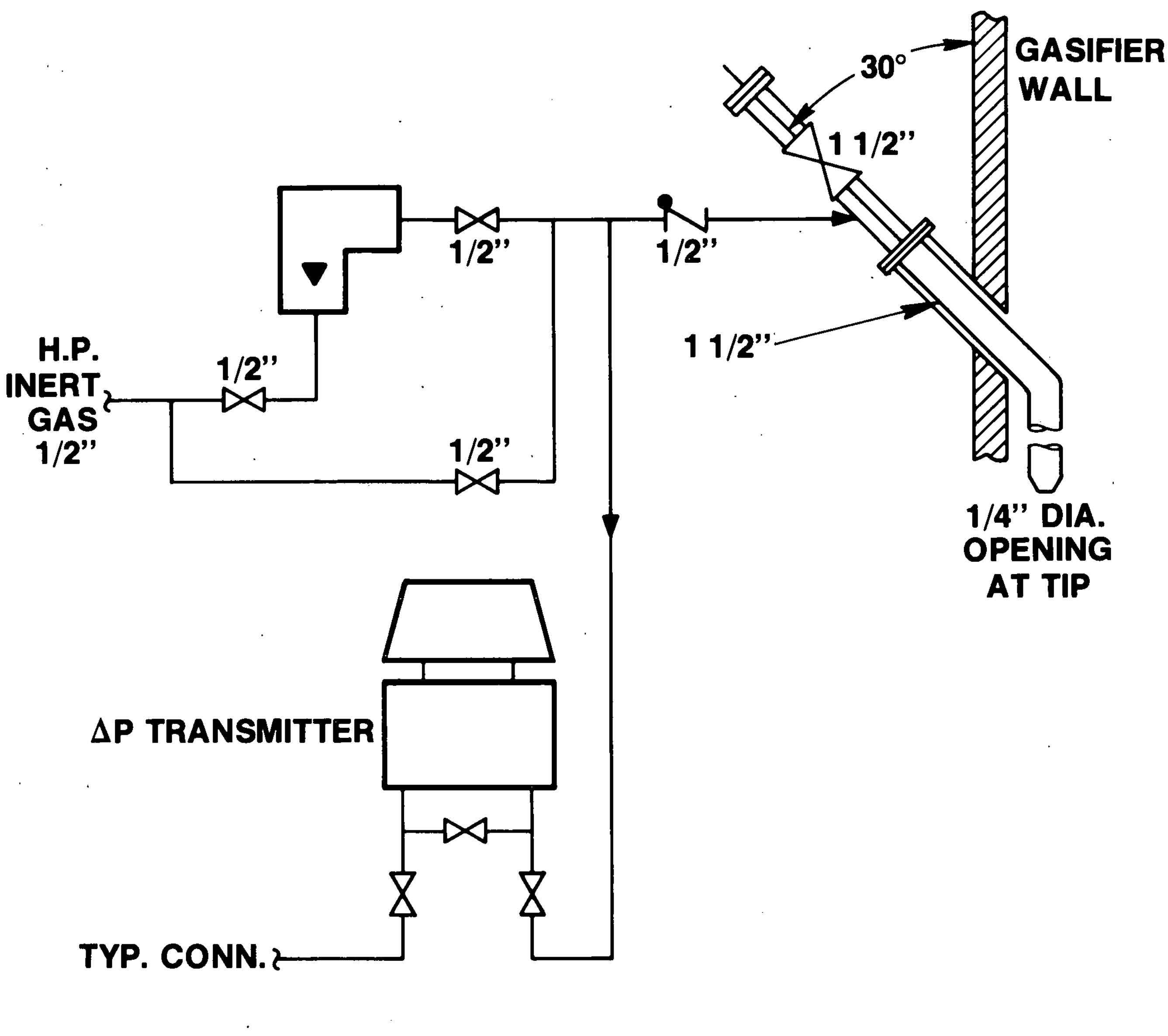

FIGURE NO. 6

SYNTHANE GASIFIER INTERIM TRANSMITTER INSTALLATION

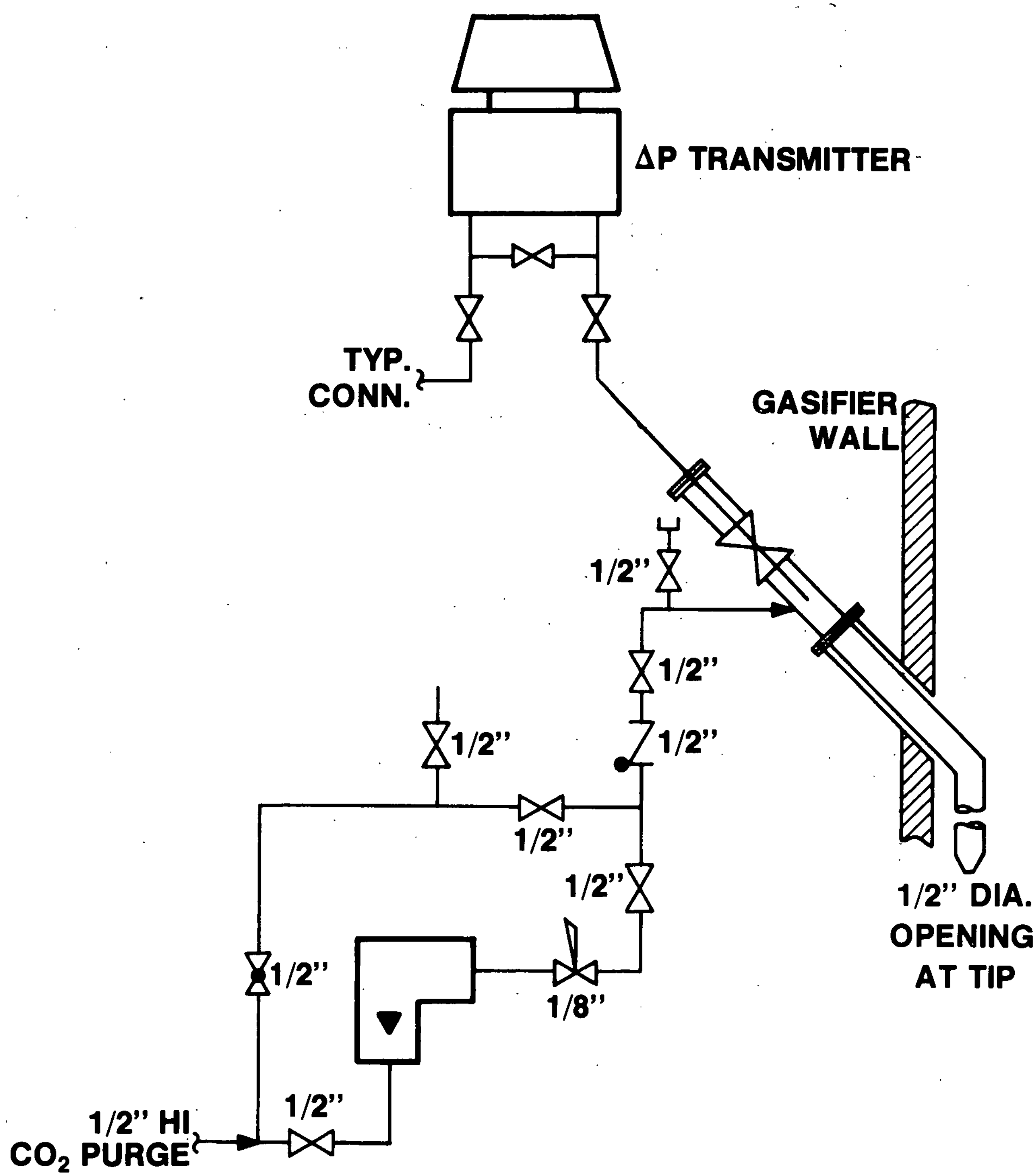

FIGURE NO. 7

SYNTHANE GASIFIER
CURRENT TRANSMITTER INSTALLATION

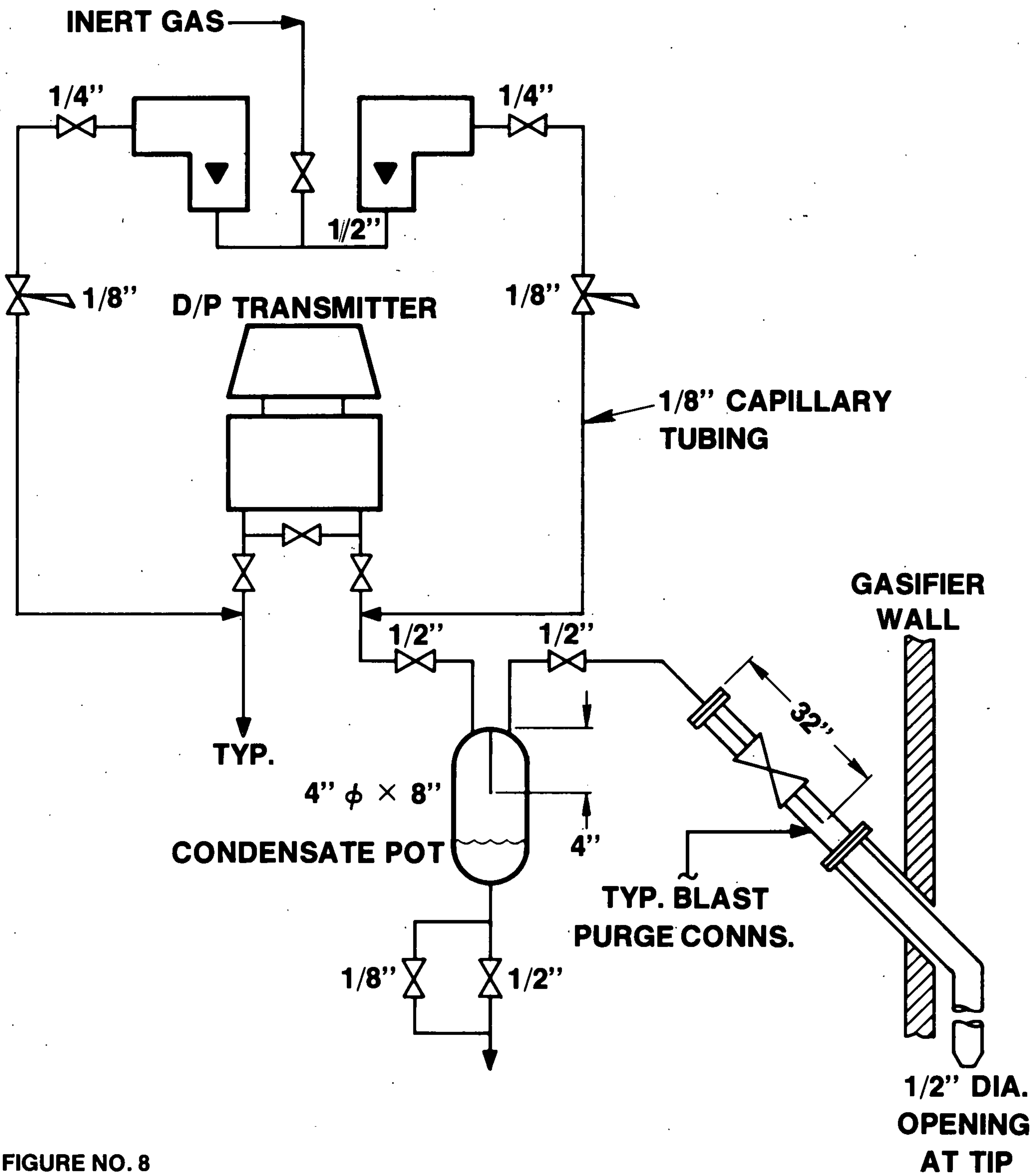

FIGURE NO. 8

SYNTHANE GASIFIER
MODIFIED GASIFIER
LEVEL CONTROL

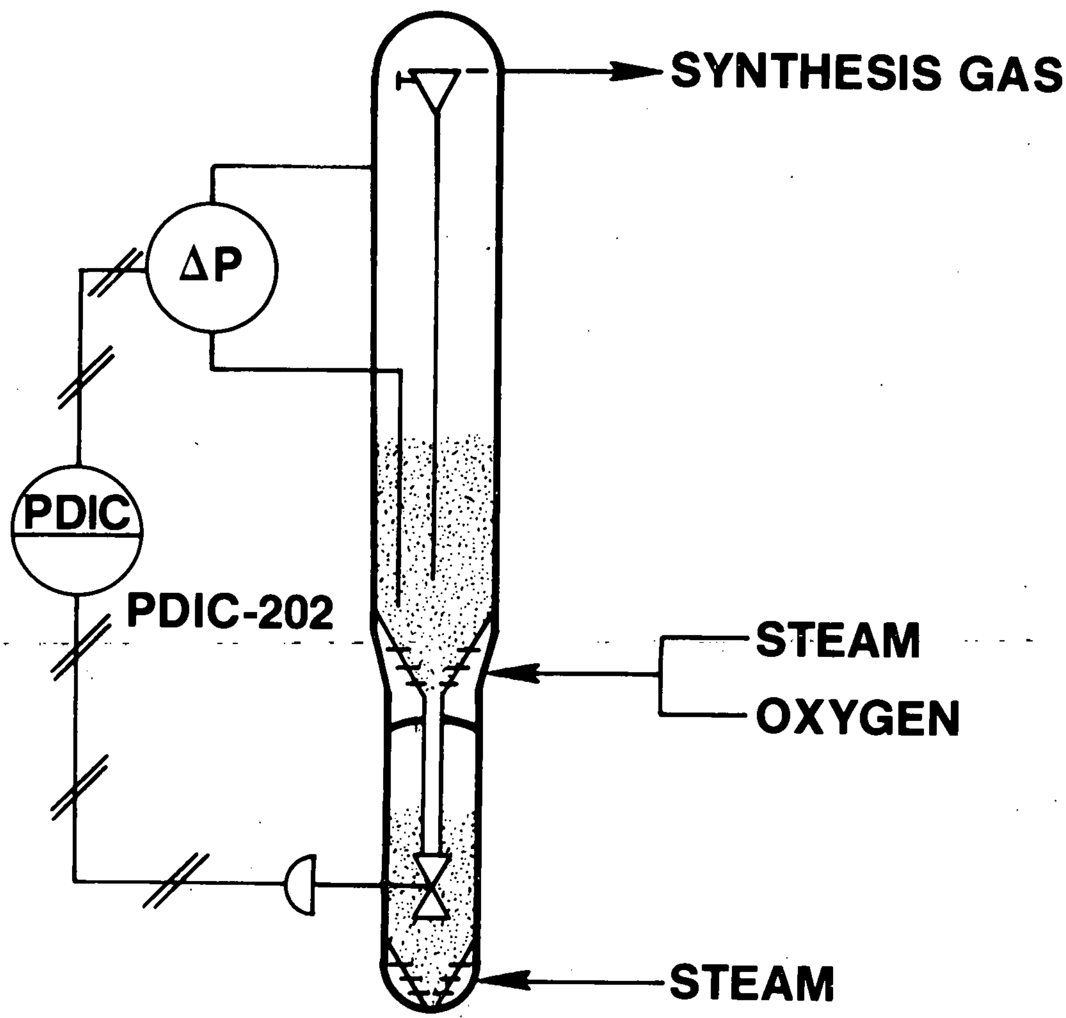

FIGURE NO. 9