DESIGN, FABRICATION, ASSEMBLY AND BENCH TESTING OF A TEXACO INFRARED RATIO PYROMETER SYSTEM FOR THE MEASUREMENT OF REACTION CHAMBER TEMPERATURE

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PUBLIC ABSTRACT

Reliable measurement of gasifier reaction chamber temperature is important for the proper operation of slagging, entrained-flow gasification processes. Historically, thermocouples have been used as the main measurement technique, with the temperature inferred from syngas methane concentration being used as a backup measurement. While these have been sufficient for plant operation in many cases, both techniques suffer from limitations. The response time of methane measurements is too slow to detect rapid upset conditions, and thermocouples are subject to long-term drift, as well as slag attack, which eventually leads to failure of the thermocouple.

Texaco's Montebello Technology Center (MTC) has developed an infrared ratio pyrometer system for measuring gasifier reaction chamber temperature. This system has a faster response time than both methane and thermocouples, and has been demonstrated to provide reliable temperature measurements for longer periods of time when compared to thermocouples installed in the same MTC gasifier. In addition, the system can be applied to commercial gasifiers without any significant scale-up issues. The major equipment items, the purge system, and the safety shutdown system in a commercial plant are essentially identical to the prototypes at MTC.

The desired result of this DOE program is "a bench-scale prototype, either assembled or with critical components (laboratory) tested in a convincing manner." The prototype of the pyrometer system (including gasifier optical access port) that was designed, assembled and tested for this program, has had previous prototypes that have been built and successfully tested under actual coal and coke gasification conditions in three pilot units at MTC. It was the intent of the work

performed under the auspices of this program to review and update the existing design, and to fabricate and bench test an updated system that can be field tested in one or more commercial gasifiers during a follow on phase of this program. For all intents and purposes, the development, bench testing and pilot unit testing of this temperature measurement system has already been done, and was mostly a matter of getting the hardware ready for a commercial field test. The benefits of field-testing are 1) Texaco will gain long-term commercial operating experience and 2) commercial gasifier operators will gain confidence that this system can perform reliably under true commercial plant conditions. This work was performed by Texaco at its Montebello Technology Center in South El Monte, California.

CURRENT STATE OF UNDERSTANDING AND COMMERCIAL PRACTICE

The U.S. Department of Energy's Vision 21 co-production plant concept involves gasification-based manufacturing plants capable of converting a variety of hydrocarbon feeds into some combination of electricity, steam, fuels, chemicals and hydrogen. The heart of these plants is the gasifier, where gaseous, liquid or solid hydrocarbon feeds are reacted with sub-stoichiometric amounts of oxygen to produce a product gas called synthesis gas, or syngas, consisting primarily of hydrogen and carbon monoxide. This gas can be easily cleaned and then used to produce a wide variety of environmentally clean products.

Several types of gasifiers have been developed and commercialized, including entrained-flow gasifiers. In an entrained-flow gasifier, the reactions are typically carried out at high temperature and pressure within a reactor vessel that is lined internally with several layers of refractory material. Depending on the composition of the hydrocarbon feed, the hot gases produced in the reactor will contain entrained particles of unconverted carbon, reacting hydrocarbon fuel, molten ash and, possibly, non-molten, high-melting-temperature ash material. The interior refractory wall of the reaction chamber in such a process tends to develop a layer of molten ash, or slag, that runs down the vertical wall towards a bottom exit.

The operation of an entrained-flow gasifier is controlled primarily by regulating the flow rates of the feeds: oxygen, hydrocarbon and, in some cases, a temperature moderator such as water or steam. For a given reactor configuration and heat loss, gasifier reaction chamber temperature depends strongly on the ratio(s) of the feeds to the gasifier. Although it is not the primary control parameter for an entrained-flow gasifier, a reliable measurement of reaction chamber temperature is still very important. This is because the gasifier temperature must be maintained in a narrow range. The upper bound is set by the need to limit the rate of refractory deterioration. The lower bound is set by the need to control the viscosity of the slag to a low enough value so that it will flow down the wall and, thus, ensure adequate slag removal through the bottom of the reactor. In addition, an accurate knowledge of gasifier temperature is very important during gasifier preheat and startup. And, during normal operation, the temperature instrumentation must provide a rapid and reliable indication of deviation from normal operation, such as a failure of one of the feed systems or a sudden change in feed quality.

The interior of an entrained-flow gasifier is a very hot, aggressive environment. Any instrument designed to measure the temperature of that environment must be designed to contend with that environment. The measurement technique and the design of the measurement device will dictate which elements of that environment must be endured or contended with in order to provide an accurate, reliable measurement of gasifier temperature.

Gasifier temperature measurement techniques can be classified into three categories, as follows: 1) intrusive/contact techniques, 2) intrusive/non-contact techniques and 3) non-intrusive techniques. Although each category may contain many different measurement techniques, in each case, there is one key technical problem that must be solved in order to obtain accurate and reliable measurements using a technique chosen from that category. The following paragraphs describe each category and the key technical problem associated with each one.

Intrusive/Contact Measurements

Intrusive/contact temperature measurements involve insertion of the temperature sensor into the gasifier itself, and are characterized by the requirement that the sensor must be in direct contact with, and at the same temperature as, the gasifier reaction chamber. The key to a successful measurement technique is either finding a rugged material for sensor construction that can withstand long exposure to the high temperature and the aggressive reaction chamber environment, or devising some means of protecting less rugged materials. This category includes thermocouples, optical fiber thermometers and other devices using materials which produce a signal that depends on the temperature of the sensor material itself.

The key technical problem in this category is a materials problem. The sensor, or it's protective covering, must be able to resist chemical attack by the gases, liquids and solids inside the gasifier. It must be resistant to the erosive action of particles (if present) carried along by the swirling reactor gases. It must be able to withstand the thermal shock associated with startup and shutdown events. It must be able to resist, or comply with, the mechanical forces generated by the layers of gasifier refractory as they shift relative to each other upon heating and cooling. And in those cases where the gasifier is preheated using an oxidizing flame (e.g. the Texaco gasifier), the material must also be able to withstand both oxidizing and reducing environments.

Historically, the most common means used to measure gasifier temperature has been from this category, namely, thermocouples. Gasifier thermocouples have usually been constructed using noble metal thermocouple wire (such as Type R) encased within some sort of sheath that is designed to protect the relatively fragile wire from the aggressive gasifier environment. The design of the sheath varies depending on the type of hydrocarbon being fed to the gasifier. The thermocouple assembly is then inserted into a gasifier through a channel formed in the refractory lining. In order to minimize the effects of corrosion and erosion and extend lifetime, the tip of the thermocouple is usually installed flush with, or slightly retracted behind, the hot face of the refractory lining.

Natural gas and oil fed gasifiers have tended to employ relatively simple sheathes made from one or more layers of ceramic material, such as high purity alumina. Alumina withstands both oxidizing and reducing environments, and it is sufficient to bear up under the relatively mild chemical and erosive attack occurring inside a natural gas or oil fired gasifier. In addition, when it comes to inserting the thermocouple into the gasifier, the penetration through the refractory lining can be made in such a way that there is little interference from shifting refractory. If sufficient care is taken with their design, construction and installation, gasifier thermocouples in natural gas and oil service are accurate and reliable and tend to have acceptably long lifetimes.

But with ash containing feeds such as petroleum coke and coal, the situation is much more severe, and much more sophisticated and expensive refractory sheaths are required to combat the chemical attack and erosion. Refractory compositions containing high percentages of chromium, often with other elements such as magnesium and zirconium, are required. Commercial grades of these more rugged refractory materials can be found that offer a reasonable tradeoff between density (which is important for resisting slag penetration, chemical corrosion and erosion) and porosity (which contributes to thermal shock resistance). In addition to resisting the chemically and physically aggressive oxidizing and reducing environment, the thermocouple must contend with the layers of gasifier refractory, which shift relative to each other upon heating or cooling. This is made difficult by the presence of slag, which works its way into the channel through which the thermocouple penetrates the gasifier. Even thermocouple sheaths that are made with a certain amount of flexibility tend to become rigidly fixed in the refractory lining and subject to breakage after contact with sufficient quantities of slag.

Current, state-of-the-art gasifier thermocouples have life times that are shorter than desired. The combination of chemical attack, erosion, thermal shock from startup and shutdown events and mechanical breakage due to shifting refractory lead to average thermocouples life times of several months, at best. A number of techniques have been used to extend life times. The most common approach is to embed a series of thermocouples in a protective refractory sheath in such a way that each thermocouple junction in the series is slightly retracted from the preceding junction. By knowing the offset between the "B" and "A" junction, and between the "C" and "A" junction, etc., the temperature of the gasifier can be inferred from the "B" and "C" junction measurements even after the "A" junction has failed. Although this design provides usable temperature measurements that last longer than a single thermocouple, the readings are less accurate and respond more slowly than a thermocouple junction located close to the hot face of the refractory lining.

A variation of the above technique involves inserting a thermocouple behind the innermost, or hot face, layer of gasifier refractory. While this can extend the life of the thermocouple reading to as long as the life of the hot face lining, it sacrifices accuracy and response time. Nevertheless, when calibrated with other, more conventional thermocouples, the "behind-the-brick" thermocouple can be used to monitor gross changes in gasifier operation over long periods of time.

Thermocouples, as described above, are the current state-of-the-art for measuring gasifier reaction chamber temperature. The advantage of thermocouples is that they are easy to make and relatively inexpensive, compared to the purchase price of other temperature measurement instruments. They also have the advantage that one always knows exactly what is being measured, namely, the temperature of the sensor itself (i.e. the thermocouple junction). Although the protective refractory sheath and the accumulated layer of molten slag do create a certain amount of offset between the temperature of the thermocouple junction and the actual reactor temperature, the obtained reading is useful for monitoring the operation of the gasifier and making operational adjustments when needed. Also, virtually all of the existing data on pilot unit and commercial plant gasifier operation has been correlated using thermocouple measurements.

The disadvantages of thermocouples include their slow response time, especially as the thickness of the slag layer on the gasifier wall increases, and their short lifetimes. This second shortfall can have a major economic impact on plant revenues. Once a thermocouple fails, it can only be replaced by shutting down the gasifier. This is a drawback that is not suffered by measurement techniques in the following two categories. Despite the fact that individual thermocouples are generally less expensive than intrusive/non-contact and non-intrusive instruments, their more frequent failures lead to significant replacement costs and can result in increased gasifier downtime and decreased revenues associated with lost production.

Intrusive/Non-contact Measurements

In intrusive/non-contact temperature measurements, the sensor is not in contact with, nor is it at the same temperature as, the temperature field being measured. However, the sensor must communicate in some way, usually optically, with the temperature field. In the case of a refractory lined gasifier, the sensor must communicate with the reaction chamber via a hole drilled through the refractory wall. The key to the success of such methods involves keeping the hole open and straight. Temperature measurement methods in this category include radiation pyrometry and laser spectroscopy.

The key technical problem in this category is an operational problem rather than a materials problem or a sensor design problem - the sight path must be maintained free of obstructions. Obstructions can come from particles entrained in the swirling gases inside the gasifier, from the molten slag that runs down the inner wall of the reaction chamber and from shifting layers of refractory which may intervene between the sensor and the reaction chamber.

There are many commercially available instruments that will measure gasifier temperature using optically-based techniques, as long as there is a clear sight path. But, to the best of our knowledge, there is currently no commercially available means to maintain an open sight path into process vessels containing high temperature, high pressure, chemically aggressive, dirty environments.

This report contains a description of an optical access port that meets the technical requirements of providing long-term, reliable optical access into high pressure, slagging, entrained-flow gasifiers for the purpose of making optically-based reactor temperature measurements. The optical access port was developed at Texaco's Montebello Technology Center where it was tested on three gasification pilot units over the course of many years. A custom-modified, commercially available ratio pyrometer made by Ircon was used in conjunction with the optical access port to successfully measure reactor temperatures during the gasification of a wide range of ash containing feeds, including coal and petroleum coke. This temperature measurement system is disclosed in U.S. Patent No. 5,000,580. While it has become a standard temperature measurement instrument at Montebello, it has not yet been tested commercially. It is the aim of the work performed under the auspices of this DOE program to construct and bench-test one of these systems. Then, in a follow-on phase of this program, the system can be installed and tested in a commercial gasification plant, such as the one at Tampa Electric's Polk Power Station or the one at the Motiva’s Delaware City Refinery.

<u>Non-Intrusive Measurements</u>

In non-intrusive temperature measurements, the sensor not only does not have to be in contact with the high temperature environment, but it does not even have to intrude into the interior of the gasifier. Microwave-based temperature measurements are an example of a method that fits in this category. In this technique, microwave energy generated by the hot gasifier propagates through the gasifier refractory to a sensor that calculates gasifier temperature from the signal intensity at a specific microwave frequency. The key to a successful temperature measurement involves finding materials that will not extensively attenuate the microwave signals while still performing the desired function as a refractory lining for the gasifier. Thus, the key technical problem in this category is also a materials problem, as with the first category.

Inferential Methods

One other category of techniques to determine gasifier temperature deserves mentioning here, for the sake of completeness. These techniques do not fall within one of the foregoing three categories because they do not involve direct measurements of gasifier temperature using instruments. These method use on-line product gas composition measurements and flow rate information to calculate the gasifier temperature from a knowledge of the thermodynamics of the process. Texaco has had success in using material and energy balances for this purpose. In order to use this technique, predetermined values for the heat of combustion and composition of the feed must be known. A drawback of this technique is that the calculated temperatures are very sensitive to the gas composition and changes in the feed. Usually, several instruments must be well maintained and calibrated in order for this technique to work with any sort of reasonable accuracy.

The concentration of methane in the product gas can also be used as a temperature indicator, and has been used as such in many oil gasification plants. In addition to gasifier temperature, the methane content of the syngas depends on other variables, primarily the steam-to-oil ratio and feed composition. In coal and coke gasification the methane concentration is quite low, so that it is more difficult to use it as an indicator. A small number of Texaco Gasification Process licensees operating on solids fuels do use this method to continue to run after all of their gasifier thermocouples have failed. This, of course, can be done. But when a plant chooses to do this, they then lack a measurement that is a very useful indication of what is going on inside the gasifier and that provides a good means to check what the rest of the gasifier instrumentation is saying about the operation of the unit.

DISCUSSION OF TECHNICAL REQUIREMENTS FOR A GASIFIER TEMPERATURE MEASUREMENT SYSTEM

The most important technical requirement for gasifier temperature measurement instrumentation is long-term reliability. Thermocouples, the current state-of-the-art, have an average life of only a few months, which is far short of the one- to two-year life that is desired. Ideally, one would like to replace gasifier thermocouples on the same schedule as the hot face refractory lining. Because of the short life of thermocouples, when all of the thermocouples in a gasifier have failed, plants are faced with making the choice to either shut down and replace the thermocouples or to continue operating without a direct measurement of gasifier temperature. Most plants choose to continue running rather than suffer the expense of lost production. When this choice is made, plants must operate using inferential methods to calculate the temperature inside the gasifier. As already stated, a plant can be operated in this mode. But when this is done, the gasification plant operators lack a measurement that is a very useful indication of what is going on inside the gasifier. It makes it more difficult to make operating adjustments to maintain the gasifier temperature within the range bounded above by the need to limit refractory deterioration and bounded below by the need to ensure adequate slag drainage from the gasifier.

Temperature measurement accuracy is a secondary concern. The gasifier temperature measurement techniques in the three categories described above all measure different temperatures within the gasifier, and they are all useful measurements in one way or another. Intrusive/contact techniques such as thermocouples give the temperature of the sensor itself. As long as the sensor is placed near the gasifier reaction chamber wall, a temperature reading that is close to the temperature of the refractory hot face and the slag layer will be obtained. This is probably the most useful temperature to have, for it is used to adjust the operation of the gasifier to ensure that it doesn't get so cold that slag drainage is impaired or so hot that refractory life is reduced. Intrusive/non-contact techniques such as pyrometers give a weighted average of the temperature in a small volume of particle containing gas inside the gasifier reaction chamber. The measurement volume is defined by the cross-sectional area of the optical sight path and an optical path length into the gasifier that depends on the number density of particles entrained within the gas. In gasifiers fed with natural gas, the number density of particles inside the reactor is very low, and the optical path length extends all the way to the far wall of the reaction chamber. In gasifiers fed with high ash-content coal, the optical path length is fairly short, and may extend into the reaction chamber only a few inches. Optical techniques tend to measure the surface temperatures of the particles in the reactor gas. Texaco's experience with infrared pyrometer measurements has shown that it is not uncommon for the measured temperature to be as much as 200 °F higher than the temperature measured by gasifier sidewall thermocouples.

Often the offset is not as great. The good news is that the optically measured temperature can easily be related to the temperature at the wall that is measured by thermocouples. This ability to calibrate the pyrometer reading using thermocouples means that even after all the thermocouples have failed, the temperature at the wall (which is probably the most useful temperature) can be deduced from the pyrometer reading.

The advantage of choosing an intrusive/non-contact temperature measurement technique over an intrusive/contact technique is that the sensor is removed from the aggressive gasifier environment. This offers the possibility of a temperature measurement with a long life, provided that the optical sight path can be maintained straight and clear. It also means that, if the sensor does fail, it can be replaced while the gasifier is running.

Texaco's Montebello Technology Center (MTC) has developed an infrared ratio pyrometer system for measuring gasifier reaction chamber temperature. The system attaches to the gasifier using one of the sidewall nozzles normally used for gasifier thermocouples. It views the interior of the refractory lined gasifier reaction chamber through a purged, optical access port. This system has a faster response time than both thermocouples and inferential techniques using syngas methane measurements, and has been demonstrated to provide reliable temperature measurements for longer periods of time when compared to thermocouples installed in the same MTC gasifier. In addition, the system can be applied to commercial gasifiers without any significant scale-up problems. The major equipment items, the purge system and the safety shutdown system in a commercial plant will be essentially identical to the installations at MTC. Texaco has already built and tested two prototypes of this system in MTC gasification pilot plants. Under the auspices of this DOE program, Texaco has built an updated version of this temperature measurement system to prepare for commercial field testing in a follow on phase of this program. The system and its operation are described in detail in the following pages.

DESCRIPTION OF THE TEXACO INFRARED RATIO PYROMETER SYSTEM

Overview

The Texaco Infrared Ratio Pyrometer System built for this DOE program consists of three sub-sections: 1) an optical train which bolts on to the gasifier, 2) a purge control cabinet that contains all the control valves and instrument used to monitor and control the optical access port purge gas and, 3) a control cabinet that contains the PLC that controls the operation of the system. The two cabinets have been constructed to make it easy to transport and set up at a field test site. In the following paragraphs, the description of the proposed temperature measurement system refers to figures in Appendices A and D. Figure 1 shows a scale drawing of the components of the pyrometer optical train which bolts onto the gasifier sidewall nozzle. In this drawing, the pyrometer camera is to the left of the drawing, and the gasifier reaction chamber is to the right, just to the right of the refractory. Figure 2 shows a P&ID of the entire system, including the safety shutdown and sight tube purging system. Figure 13 – 18 shows pictures of the system components. Figures 19 – 25 shows the cabinet panel and wiring diagrams.

Overview of the Optical Train

The optical train consists of the infrared ratio pyrometer camera and an optical access port that provides pressure containment, gas purging, and safety shutdown functions. Referring to Figure 1, it can be seen that the pyrometer camera (part 1) is sighted into the gasifier reaction chamber through an optical sight path consisting of several pieces of equipment which are joined together in series by flanged connections. The entire system is bolted onto one of the flanged gasifier nozzles that normally might be used for a thermocouple. The double sight glass spool piece (part 5) maintains the pressure integrity of the gasifier vessel while at the same time allowing visible and infrared light to pass out of the vessel to the pyrometer camera. In the event that one of the sight glasses should fail (this has never happened in over 10 years of pilot plant testing) a safety system causes the gate valve (part 7) to close in order to maintain the pressure integrity of the vessel. Purge gas [A & B] introduced through the primary purge ring (part 6) and the sight tube centering ring (part 8) is used to keep the sight hole into the reaction chamber open and to protect the molybdenum sight tube (part 11) during oxidizing preheat periods. Optical alignment of the pyrometer camera with the axis of the sight tube is adjusted with the alignment ring (part 4). Signals generated by the pyrometer camera are sent to the digital readout (not shown) in the control room via the special combination signal/power cable (part 2).

The optical train is supported by a gas purge system and a safety shutdown system. These are shown on Figure 2. The notes on that drawing and on Figure 1 provide a good general description of how the entire system fits together and how it operates. A more detailed description of the system and its operation is given below.

<u>Pyrometer Camera</u>

The proper selection of the pyrometer and its features are important to the success of this system. An infrared ratio pyrometer from Ircon, Inc. of Niles, Illinois is used. This type of a pyrometer is sometimes also known as a two-color, or dual wavelength, or emissivity independent pyrometer. The ratio feature is important because of its relative immunity to obscuration effects and because the overall emissivity of the reaction chamber is an unknown. The particular model used in this system is a custom-modified Ircon R-Series pyrometer, model no. 3R-99F05-0-0-0.

There are two modifications to the standard R-Series design that are important. First, the "signal reduction ratio" has been increased from 20:1 to the maximum of 100:1. This means that the pyrometer will still provide an accurate indication even if the radiation intensity reaching the detector is decreased by 99%. Second, the pyrometer response time has been set at about 10 seconds in order to dampen the rapid oscillations characteristic of the reaction chamber emissions.

Referring to schematic drawing Figure 1, visible and infrared light enter the pyrometer camera through an adjustable-focus achromatic objective lens at the front of the camera. The light then passes through an aperture and a window seal to a specially coated first-surface mirror. Visible light passes straight through the mirror to a viewing eyepiece. The camera can be focused properly by looking through this eyepiece and adjusting the objective lens until a target at a specified distance forms a sharp image. In this application, the camera is normally focused at a distance of 127 cm (50 inches) so that the objective lens receives a collimated beam of light from the reaction chamber. Infrared light is reflected downward by the first-surface mirror onto the tip of a fiber optic cable which transmits the light to the detector. The cable has a large number of fibers arranged in a random configuration so that the infrared energy is spread over a wide area on the detector surface to prevent "hot spots" which could produce erratic signals.

The detector module is a specially designed, temperature compensated, solid state device consisting of two silicon detector elements which view the incoming energy continuously. The first element is sensitive to a waveband centered around 0.95 microns, and the second element is sensitive to a waveband centered around 1.05 microns. (Strong absorption and emission wavelengths of syngas species are avoided.) It is the ratio of the signals generated by these two detectors that is electronically processed and displayed by the digital readout (not shown) as temperature in degrees Fahrenheit.

Sight Glass and Safety Shutdown System

The high-pressure sight glass (part 5) is a crucial part of the system because it forms a sight hole through the gasifier wall while at the same time maintaining the integrity of the pressure vessel. The sight glass used in this system is a custom designed double sight glass spool piece purchased from Pressure Products Company. Each sight glass is a polished cylinder of commercial grade quartz held in place by a circumferential compressive force resulting from the compression of the surrounding packing material. The spool piece is rated for 2500 psi at 550 degrees F (172.4 bars at 288 C.) However, the quartz pieces are designed with a seven times safety factor.

Because the sight glass spool piece is a potential weak spot in the pressure containment shell of the gasifier and its various flanged nozzles, it is necessary at all times to monitor the integrity of the sight glass and its associated seal. In over ten years of experience at MTC, Texaco has never had a sight glass fail. However, in case there ever was a failure, the safety shutdown system and high-pressure sight tube purge system are designed to prevent the vessel from depressuring through the pyrometer nozzle.

The cavity between the two sight glasses is connected to a source of nitrogen [C] at a pressure that is several hundred psi higher than the pressure in the gasifier reaction chamber. (Note: Sufficient high-pressure nitrogen gas is normally available in Texaco gasification plants because the nitrogen is used in the gasifier safety shutdown purging sequence.) If a pressure decrease or flow greater than zero is detected in the line connecting the cavity and the nitrogen source, then the shutdown system activates the closing of the safety gate valve (part 7). The gate valve actuator is designed to close against full system differential pressure.

The primary sight glass is the one closest to the reaction chamber. If this one were to break, there would be a positive flow of nitrogen into the gasifier while the gate valve was in the process of closing. No syngas would leak out through the gasifier nozzle to which the pyrometer system is connected. If the secondary, or rear, sight glass were to break, nitrogen would flow towards the pyrometer camera while the gate valve was closing. Again, no depressuring of the gasifier vessel would occur.

In the unlikely event of a failure, the change in pressure in the shutdown line, which can be monitored in the control room, could be used to infer which sight glass had failed. If the pressure dropped to roughly the level of gasifier pressure, it would indicate that, most likely, the primary sight glass had failed. If the pressure in the line dropped below gasifier pressure, that would indicate that the rear sight glass had failed.

Sight Path and Purging Systems

SIGHT PATH: The pyrometer communicates with the gasifier reaction chamber via the sight path described above. For proper operation of the system, the sight path must be kept straight and free of all obstructions. The sight path is kept straight by adjusting the optical alignment ring (part 4.1) and by using a refractory metal sight tube (part 11) which has good dimensional stability. The sight path is kept free of all obstructions by the primary purge stream and the sight tube pulsing procedure, both of which are described below.

SIGHT TUBE: A sight tube (part 11) made of a titanium-zirconium alloy (TZM) of molybdenum provides the dimensional stability needed under a wide range of operating conditions. A refractory metal sight tube is used because of its ability to withstand the thermal shock stresses placed on it by the sight tube pulsing procedure, which is described below. Also, this special alloy has good high temperature strength, which enables the sight tube to resist any shearing forces that may be exerted on it by shifting layers of gasifier refractory.

PRIMARY PURGE STREAM: The primary purge stream [A] serves two purposes. It keeps the primary sight glass clean and cool. It also is used to keep the sight tube free of obstructions. Nitrogen is normally used as the purge gas, although process gas can also be used under certain conditions discussed in a later paragraph. Purge gas is introduced into the primary purge stream through the primary purge ring (parts 6.1 & 6.2). The purge ring distributes the gas over the front face of the primary sight glass, keeping it cool and clean.

From the sight glass, the gas then flows through the sight tube into the reaction chamber, and thus exits the gasifier along with the syngas. (See Figure 1.) Under normal operating conditions, a continuous flow of gas is maintained which keeps the sight path open and free of particles. Operation of the primary purge system under normal gasifier startup, operating and shutdown conditions is discussed below.

Even though the primary purge stream is effective in keeping particles out of the sight path, the continuous discharge of cold gas into the reaction chamber creates a cold spot in the wall that causes slag to freeze around the sight tube opening. The size of the frozen slag accumulation increases slowly over time, gradually occluding the sight tube opening. Because the slag occlusion is slightly cooler than the reaction chamber interior, the growing accumulation causes a slight decrease in pyrometer reading over time. The rate of decrease will vary in a manner that is difficult to correlate with run conditions. However, the pyrometer can be restored to proper operation by using the sight tube pulsing procedure discussed below.

SECONDARY PURGE STREAM: The secondary purge stream [B] is used to create an inert gas blanket around the sight tube during oxidizing preheat conditions in order to prevent oxidation of the molybdenum. Although optically clean, recycled process gas could be used as the purge gas while the gasifier is running, nitrogen must be used any time an oxidizing atmosphere prevails throughout the gasifier. Purge gas is introduced into the secondary purge stream through the sight tube centering ring (parts 8.1 & 8.2). The centering ring distributes the gas into the annular space formed by the outside of the sight tube and the insertion channel drilled through the gasifier refractory brick.

Even though the main function of the secondary purge stream is to protect the sight tube against oxidizing preheat atmospheres, it is also used when the gasifier is running in order to keep the annular space clean. The flow rate of purge gas in the secondary purge line is limited to about

5-10% of the flow rate in the primary purge line by a small regulating valve. The total purge gas flow rate to both lines is controlled by the main flow control valve.

Purge System Operation

GENERAL PURGE REQUIREMENTS: The purge gas, whether nitrogen, cleaned syngas or fuel gas, must be optically clean. This means that the gas must be moisture, vapor and particulate free. Moisture and vapor can condense on the first surface of the primary sight glass, altering its optical surface and causing erroneous readings. Particles carried along by the purge gas at high velocities impinge upon the sight glass and essentially sandblast the optical surface, in time, making it nearly optically opaque. For this reason it is essential that only stainless steel pipe, tubing and fittings be used for the purge and shutdown lines. Carbon steel lines are a source of rust particles.

PURGE REQUIREMENTS DURING GASIFIER PREHEAT/COOLDOWN: Nitrogen purging of the sight tube is required during gasifier preheat and cooldown to prevent the molybdenum alloy sight tube from burning up in the oxidizing environment. Molybdenum oxidizes very rapidly, particularly above 482 degrees C (900 F), and it is possible to loose an entire sight tube in less than eight hours. For this reason, the bypass hand valve on the secondary purge line is kept open during preheat and cooldown. This ensures that, even if instrument air were to fail and the gate valve (part 7) and the secondary purge line valve were to close, the sight tube will at all times be blanketed with nitrogen.

The primary sight glass must also be purged during preheat/cooldown in order to prevent condensation from forming on the first surface. Total nitrogen purge flow rates on the order of 0.28 to 1.42 m3/h (10 to 50 SCFH) are used during preheat and cooldown.

PURGE REQUIREMENTS DURING GASIFIER STARTUP: Prior to startup, right before the slurry and oxygen streams are diverted into the gasifier, the total nitrogen purge flow rate is increased to more than 28.32 m3/hr (1000 SCFH) by opening the flow control valve wide open. This prevents slurry and unreacted solid particles from entering the sight tube during reaction initiation and initial gasifier heatup. Once the gasifier has begun to line out, the nitrogen purge rate can be reduced to the desired operating set point. If a process gas is to be used as a sight tube purge gas, then the process gas can be switched into the purge system after this time.

PURGE REQUIREMENTS DURING LINED OUT OPERATION: The total flow rate of purge gas required for lined out operation depends upon the slurry feed to the gasifier. In petroleum coke gasification, roughly 8.50 m3/hr (300 SCFH) of purge gas has been sufficient. In coal gasification where the total ungasifiable (ash) material is less than about 10-12% and the coal is not a high ash fusion temperature coal, approximately 21.24 m3/hr (750 SCFH) of purge gas has been used. In practice, the purge gas flow rates required for various feeds are determined in the field.

SIGHT TUBE PULSING PROCEDURE: Once the gasifier has lined out following startup, and the purge rate has been adjusted to the desired operating set point, the pyrometer system should not require much attention. However, slag, which naturally freezes around the cool opening of the sight tube into the gasifier, will eventually accumulate to the point where the optical sight path becomes sufficiently occluded and the temperature readings begin to be affected. The occurrence of sight path occlusion is indicated by a decrease in the pyrometer temperature readings to a value noticeably lower than expected. Often the decrease happens suddenly after a long period of steady readings, and it will be quite obvious from the temperature trend recorder that something has begun to occlude the sight path. The length of time between startup and the first appearance of any evidence of occlusion depends on the ash fusion temperature of the feed and on how high above that temperature the gasifier is operated.

Occlusion of the sight path can be cleared up by using a technique called "sight tube pulsing". In this technique the purge gas, which cools the sight tube and freezes slag around the opening, is shut off for a short period of time by closing the safety gate valve. During this time the frozen slag accumulation around the sight tube opening is allowed to reheat by exposure to the hot gases inside the reaction chamber. While the slag accumulation is heating up, the purge gas flow control valve is opened wide to allow the purge gas to "pack" the line behind the closed safety gate valve. After the line is packed and the required reheat period has elapsed, the gate valve is reopened. The pulse of purge gas creates a shock wave that blows the softened slag occlusion away from the sight tube opening and restores the required clear sight path. When the temperature reading is restored, the purge gas flow rate is readjusted to the operating set point. This entire sight tube pulsing procedure can be carried out manually, or it can be automated.

PURGE REQUIREMENTS DURING SHUTDOWN: The purge gas flow rate is maintained at the operating set point during the shutdown event. Following shutdown the purge flow rate is reduced to the rate used during preheat and cooldown. If a process gas such as cleaned fuel gas is used as the purging medium during gasification operation, nitrogen or some other inert purge gas must be substituted as the purging medium before the process injector is removed and air (oxygen) is allowed into the hot gasifier. This must be done in order to protect the molybdenum sight tube from rapid oxidation.

Electronics Purge

As shown in Figure 2, the pyrometer camera is purged with a very small flow of nitrogen in order to satisfy explosion proof requirements. Purge gas leaving the camera housing fills the weather head and exits to the outside. In the event that purge gas were to fail, an alarm is initiated in the control room.

RESULTS OF WORK PERFORMED

The desired result of this project was an assembled bench-scale prototype that was tested in a convincing manner (laboratory environment). The pyrometer system (including gasifier optical access port) that was designed, assembled and tested for this program had a predecessor that had been built and tested under actual coal and coke gasification conditions in three pilot units at Texaco's Montebello Technology Center. The 20 ton/day pilot units at Montebello were large enough that they provide a realistic test of equipment because the gasifiers were only slightly smaller than the smallest Texaco commercial units. As it turns out, the pyrometer system equipment tested at Montebello is exactly the same size as the equipment that will be used for the commercial field tests. No scale up of equipment was required.

It was the intent of the work performed under the auspices of the DOE program to review and update the existing design and to fabricate and bench test an updated system that can be field tested in one or more commercial gasifiers during a follow on phase of this program. For all intents and purposes, the development, bench testing and pilot unit testing of this temperature measurement system had already been done, and it was mostly a matter of getting the hardware ready for a commercial field test. The one new area of work that was completed was the automation of the safety system and the automation of the sight tube pulsing procedure. When this system was originally built and tested at Montebello in the mid-80's, it was interfaced with pilot units using pneumatic and electronic controls. In order to easily interface with newer commercial plants, such as Tampa Electric's coal gasifier and Motiva's Delaware City Refinery coke gasifier, Texaco purchased and programmed a stand-alone controller (PLC) to control all of the optical access port safety system functions and the sight tube pulsing procedure. The original control logic was translated into the appropriate code for the new controller.

The following is a list of tasks that was completed during the course of this program.

TASK 1 - DETAILED SYSTEM DESIGN AND SPECIFICATION: Texaco reviewed and updated the existing drawings, equipment specifications and design philosophy. The deliverables which was completed include a complete set of manufacturing drawings and specifications ready for procurement and fabrication. (See Appendix A for drawings, pictures and specifications).

TASK 2 - PROCUREMENT: Texaco procured the commercially available parts and equipment (custom-modified ratio pyrometer, controller, safety system hardware, purge system hardware). This includes parts 1, 2, 3, 5 and 7 shown on Figure 1. Texaco also procured the raw materials needed to make the Texaco-fabricated items in the optical train connected to the gasifier (see Figure 1, parts 4.1 - 4.5, 6.1, 6.2, 8.1, 8.2, 9, 10 and 11). The deliverables which were completed include the receipt of all parts and materials needed to complete Tasks 3 through 5. (See Appendix B for Equipment List and Recommended Vendor List).

TASK 3 - FABRICATION: Texaco made all Texaco-fabricated items listed in Task 2. The completed deliverables included all items fabricated according to specifications. Pictures of the control panel, PLC panel, and pyrometer, valve, and spool pieces are shown as Figures 13 – 16 in Appendix A.

TASK 4 - ASSEMBLY AND BENCH TESTING: Texaco assembled the complete pyrometer system optical train as shown in Figure 1. Texaco also tested the assembly for alignment and proper functioning by focusing it on a target heated to gasifier temperature. Figures 17 and 18 (Appendix A) show the actual test against a heated object. The pyrometer was checked against a thermocouple to insure that the temperature readings were in the same order of magnitude. The pyrometer had a faster response time than the thermocouple. The pyrometer indicated a temperature of 1276 C (2328 F) while the thermocouple indicated a range of temperature that fluctuated above 1093 C (+2000 F). An accurate thermocouple temperature could not be attained due to the rapid changes in temperature of the metal and the relative crude test set up. Experience has shown that a better test of the pyrometer occurs when it is installed in a preheating gasifier. Under those conditions, the pyrometer and thermocouple readings normally agree to within a few degrees F. The deliverables completed for this task include an assembled and properly functioning pyrometer system optical train. (See Appendix C for Assembly Instructions).

TASK 5 - CONTROLLER PROGRAMMING AND TESTING: Texaco programmed the controller with the logic needed to automate the safety system and the sight tube purging procedure. Texaco also tested the proper functioning of the controller by simulating appropriate inputs to it and observing its response. The completed deliverables include a programmed and debugged controller. (See Appendix D for Controller Programming – includes PLC block diagram, Figure 19, and description of each subroutine and the electrical panel diagram of the PLC panel.)

TASK 6 - FIELD TEST PLANNING: Plant personnel at both Tampa Electric's Polk Power Station (coal gasifier) and Motiva's Delaware City Refinery (petroleum coke gasifier) have already verbally expressed interest in testing this system at their facilities. Texaco is proceeding with plans to field test this system at one or both of those plants during a follow on phase of this program. Cooperative Agreements between Texaco and the proposed test sites are being negotiated. Planning has included determining all needed interconnects and the materials and supplies needed to install the system in the field. Operating expenses have also been determined. The deliverables completed for this task include having all the information in place to write a solid, credible proposal for field testing in the follow on phase of this program. (See Appendix E for Draft Field Test Proposal and Estimated Cost).

ASSESSMENT OF COMMERCIAL POTENTIAL

The infrared pyrometer assembly that Texaco's Montebello Technology Center (MTC) has developed can be applied to commercial gasifiers with no significant scale-up issues. The major equipment items, the purge system and the shutdown system that will be used in commercial plants such as Tampa Electric's Pole Power Station or Motiva's Delaware City Refinery will be the same as that which was successfully tested on Montebello pilot units during coal and coke gasification. The only difference from plant to plant of any significance is in part 8, which contains the flange that mates with the gasifier nozzle.

Installation in a commercial gasification facility involves simply deciding which gasifier nozzle to use and bolting the major pieces of the optical train onto the gasifier using the correct adapter flange (part 8.1). The sight tube is sized to fit the specific gasifier by adjusting the length of part 9. The safety shutdown and sight tube purging systems shown in Figure 2 are duplicated in the plant and tied into the plant utilities. The automation controller is installed and tied into the plant data collection and control system. No design changes or scale up factors are necessary. The internal diameter of the sight tube remains the same from plant to plant, so the amount of purge gas required should be relatively constant from gasifier to gasifier (The actual amount will depend on the properties of the feed). Since the pressure-containing parts of the optical train have been designed for 83.7 bars (1200 psig), and have already been successfully tested at high pressure on Montebello's 1200 psig-rated pilot units, there should be virtually no commercial plant that cannot use this system as is. This system is designed to be a standardized instrument that can be installed on any gasifier in the world with no modifications needed except for the mounting flange. It is very easy to install and maintain. The commercially available pyrometer communicates with modern digital control systems via conventional data connections, as does the digital safety shutdown and purge control system that Texaco developed for this project. Fully automated, this temperature measurement system will run unsupervised, requiring operator attention only when an alarm condition is triggered. Should the pyrometer camera ever fail for some reason, it is easy to replace while the gasifier is running, something that cannot be done with thermocouples. The safety shutdown system is designed to rapidly and safely isolate the pyrometer system from the gasifier if a sight glass should ever fail. Since hot gas escaping from the gasifier through a failed sight glass would severely damage the reactor, the safety system is designed to prevent this from ever happening by forcing high pressure nitrogen into the gasifier. If the safety shutdown system is ever activated, it rapidly isolates the pyrometer from the gasifier, but operation of the gasifier continues unabated.

As stated earlier, the intent of this project was to produce a ready-to-install temperature measurement system that can be field-tested on a commercial gasifier during a follow on phase of this program. The benefits of field-testing are 1) Texaco will gain long-term commercial operating experience and 2) commercial gasifier operators will gain confidence that this system can perform reliably under true commercial plant conditions.

Gaining long-term commercial operating experience is important because the Montebello pilot unit tests were limited to one to two weeks in length. It will be important to show that this system can provide usable gasifier temperature readings for, at a minimum, longer periods of time than the conventional thermocouples. Assuming that long-term operation will be demonstrated, Texaco will be able to show that, even though the initial purchase price of a pyrometer system is an order of magnitude more expensive than a complete set of new gasifier thermocouples, the cost is considerably less than the ongoing thermocouple replacement cost and the losses in revenue suffered if the gasifier has to be shut down to replace the thermocouples.

The benefit of commercial plant owners and operators gaining confidence in this system through a commercial demonstration is important for the future commercialization of this temperature measurement technology. Despite the fact that this system has been well tested at Montebello, most commercial plant operators are reluctant to be the first facility to try something new like this, particularly in the case where a purged, pressurized sight glass is being installed on a side wall nozzle of their gasifier. This DOE program will help overcome this resistance by reducing the perceived risk, financially, that a plant faces in being the first one to try this new system.

CONCLUSIONS

Texaco's' Montebello's Technology Center (MTC) successfully completed all work specified in the six tasks of the DOE sponsored project.

1. All drawings and design specifications for the infrared ratio pyrometer were reviewed and updated.
2. All required equipment and materials were procured
3. All custom components and assemblies were fabricated.
4. All elements of the system were assembled and their integrated operation confirmed during bench testing.
5. The pyrometer system control system was programmed and debugged and its proper operation was confirmed.
6. All the information that was needed to write a field testing proposal was developed. MTC worked with both Tampa Electric's Polk Power Station (coal gasifier) and Motiva's Delaware City Refinery (petroleum coke gasifier) to determine the requirements and cost to field test this infrared ration pyrometer system. Significant progress was made with Tampa Electric, and it is likely that the first commercial field test of this system will occur at the Polk Power Station sometime in 2001.

In summary, Texaco constructed an infrared ratio pyrometer system capable of measuring the temperature inside the reaction chambers of entrained-flow gasifiers. The integrated operation of the system has been checked and verified on the instrument bench, and the system is ready for transport to a commercial site for field testing. Firm proposals for field testing at both Tampa Electric and Motiva gasifiers are in the field stages of preparation. Texaco will work with the DOE to make these commercial field tests happen some time in 2001.

Appendix A

Drawings, Pictures and Specifications

The following set of drawings show the pyrometer system P&ID, configuration of the optical train equipment and fabrication drawings for each of the special items which cannot be purchased off the shelf from commercial vendors. A brief description of each drawing is given below.

SYSTEM P&IDS

Figure 2 - System P&ID showing the shutdown system and various purge gas and instrument air lines in relation to the equipment bolted directly onto the gasifier.

OPTICAL TRAIN CONFIGURATION

Figure 1 - Shows the equipment which is bolted directly onto the gasifier. These items form the optical train of the Ircon pyrometer system. This drawing functions as an assembly and installation drawing for the optical train.

SIGHT TUBE AND SIGHT TUBE CENTERING RING

Figure 3 - Machining drawing for the TZM alloy molybdenum sight tube. This drawing contains the information given to the outside vendor who fabricates the sight tubes. Dimension "L" must be specified for the specific plant and is equal to the gasifier vessel shell inner radius minus the reaction chamber radius.

Figure 4 - This drawing, along with Figure 5, contains the machining information for the sight tube centering ring body (part 8.1).

Figure 5 - Machining drawing of the threaded insert (part 8.2) for the sight tube centering ring, Figure 4. This insert is also called the secondary purge ring.

PRIMARY PURGE RING

Figure 6 - This drawing, along with drawing Figure 7, contains the machining information for the primary purge ring body (part 6.1).

Figure 7 - Machining drawing of the threaded insert (part 6.2) for the primary purge ring, Figure 6.

HIGH PRESSURE DOUBLE SIGHT GLASS

Figure 8 - This drawing is adapted from Pressure Products Co. drawing no. lY28-10391-1. It is to shows details of the high pressure double sight glass. Not all interior dimensions were provided by Pressure Products and are therefore, not shown. However, enough information is provided to correctly specify the equipment.

OPTICAL ALIGNMENT RING

Figure 9 - Machining drawing for part 4.1 of the optical alignment ring.

Figure 10 - Machining drawing for part 4.3 of the optical alignment ring.

Figure 11 - Machining drawing for part 4.5 of the optical alignment ring.

Figure 12 - Assembly drawing for optical alignment ring (part 4); shows location of welds and orientation of parts 4.1, 4.2, 4.3, 4.4 and 4.5.

Figure 1

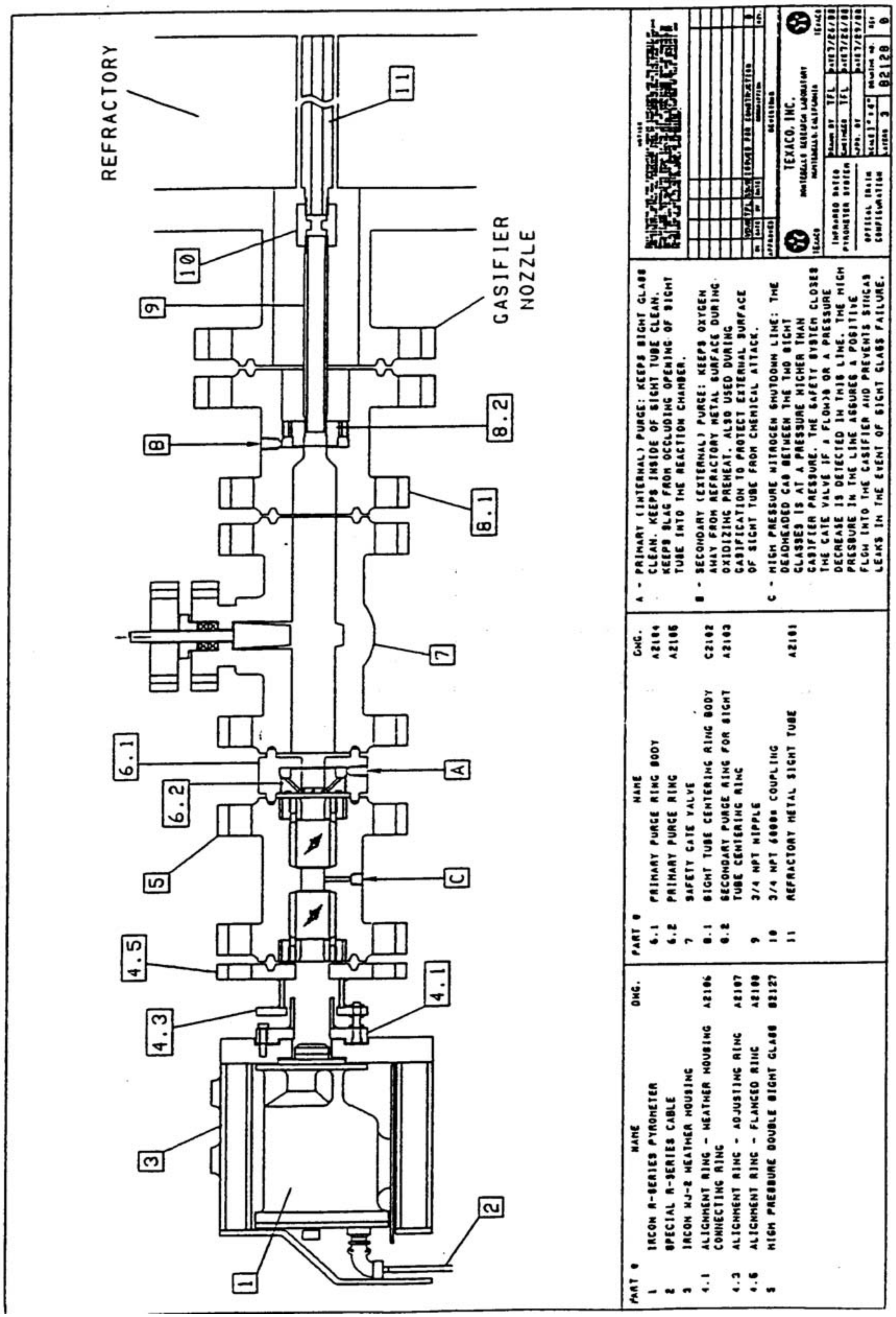


Figure 2

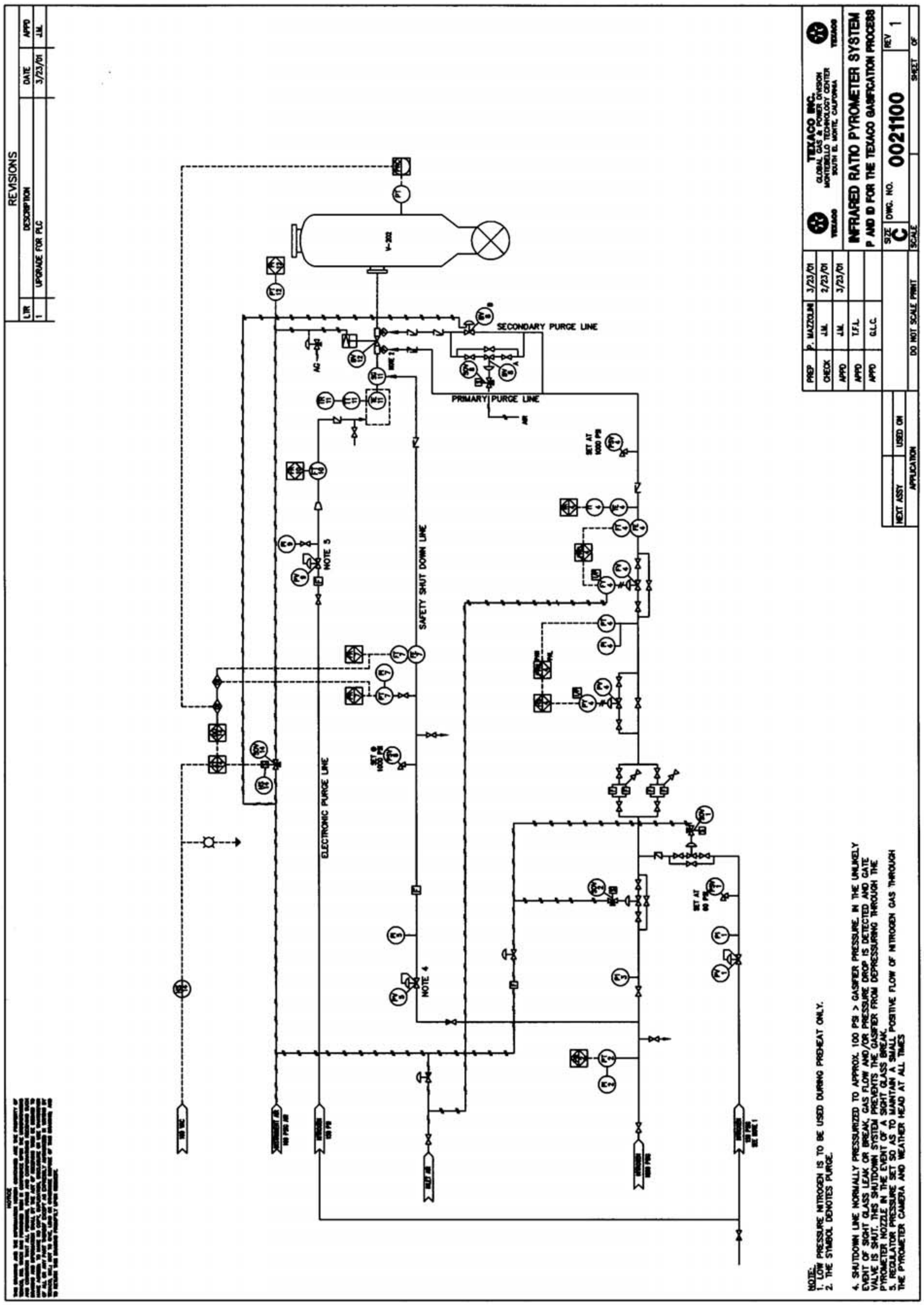
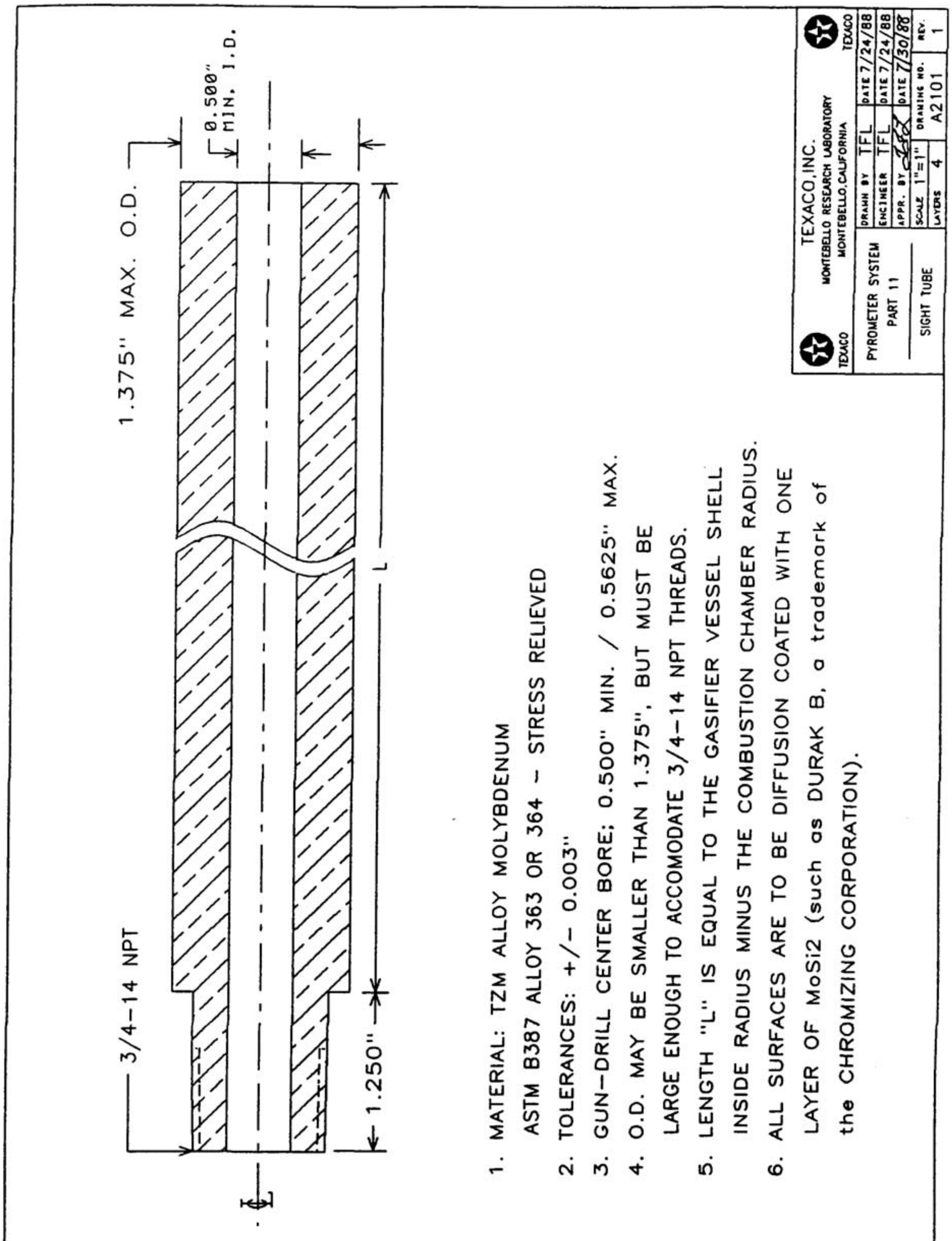

REVISIONS
UPGRADE FOR PLC
3/23/01
J.M.
SECONDARY PURGE LINE
PRIMARY PURGE LINE
SAFETY SHUT DOWN LINE
ELECTRONIC PURGE LINE
NOTE 4
NOTE 5
V-202
NOTE:
1. LOW PRESSURE NITROGEN IS TO BE USED DURING PREHEAT ONLY.
2. THE SYMBOL DENOTES PURGE.
4. SHUTDOWN LINE NORMALLY PRESSURIZED TO APPROX. 100 PSI > GASIFIER PRESSURE. IN THE UNLIKELY EVENT OF SIGHT GLASS LEAK OR BREAK, GAS FLOW AND/OR PRESSURE DROP IS DETECTED AND GATE VALVE IS SHUT. THIS SHUTDOWN SYSTEM PREVENTS THE GASIFIER FROM DEPRESSURING THROUGH THE PYROMETER NOZZLE IN THE EVENT OF A SIGHT GLASS BREAK.
5. REGULATOR PRESSURE SET SO AS TO MAINTAIN A SMALL POSITIVE FLOW OF NITROGEN GAS THROUGH THE PYROMETER CAMERA AND WEATHER HEAD AT ALL TIMES
TEXACO INC.
INFRARED RATIO PYROMETER SYSTEM
P AND ID FOR THE TEXACO GASIFICATION PROCESS
DWG. NO.
0021100
REV
1
DO NOT SCALE PRINT

Figure 3



1.375" MAX. O.D.
0.500" MIN. I.D.
3/4-14 NPT
1.250"
L
1. MATERIAL: TZM ALLOY MOLYBDENUM
ASTM B387 ALLOY 363 OR 364 - STRESS RELIEVED
2. TOLERANCES: +/- 0.003"
3. GUN-DRILL CENTER BORE; 0.500" MIN. / 0.5625" MAX.
4. O.D. MAY BE SMALLER THAN 1.375", BUT MUST BE
LARGE ENOUGH TO ACCOMODATE 3/4-14 NPT THREADS.
5. LENGTH "L" IS EQUAL TO THE GASIFIER VESSEL SHELL
INSIDE RADIUS MINUS THE COMBUSTION CHAMBER RADIUS.
6. ALL SURFACES ARE TO BE DIFFUSION COATED WITH ONE
LAYER OF MoSi2 (such as DURAK B, a trademark of
the CHROMIZING CORPORATION).
TEXACO
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
TEXACO
PYROMETER SYSTEM
PART 11
SIGHT TUBE
DRAWN BY TFL DATE 7/24/88
ENGINEER TFL DATE 7/24/88
APPR. BY DATE 7/30/88
SCALE 1"=1"
LAYERS 4
DRAWING NO. A2101
REV. 1

Figure 4

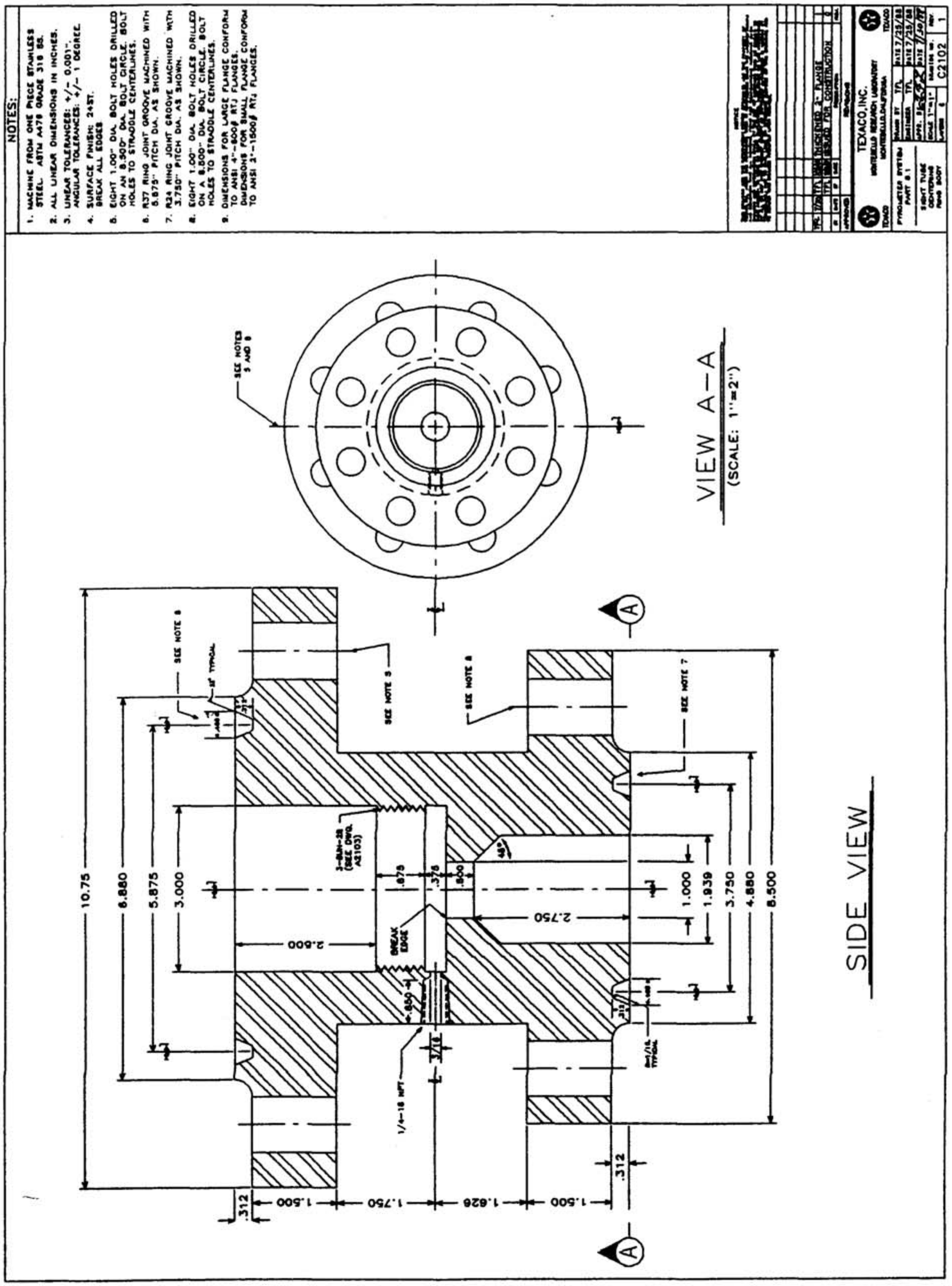


Figure 5

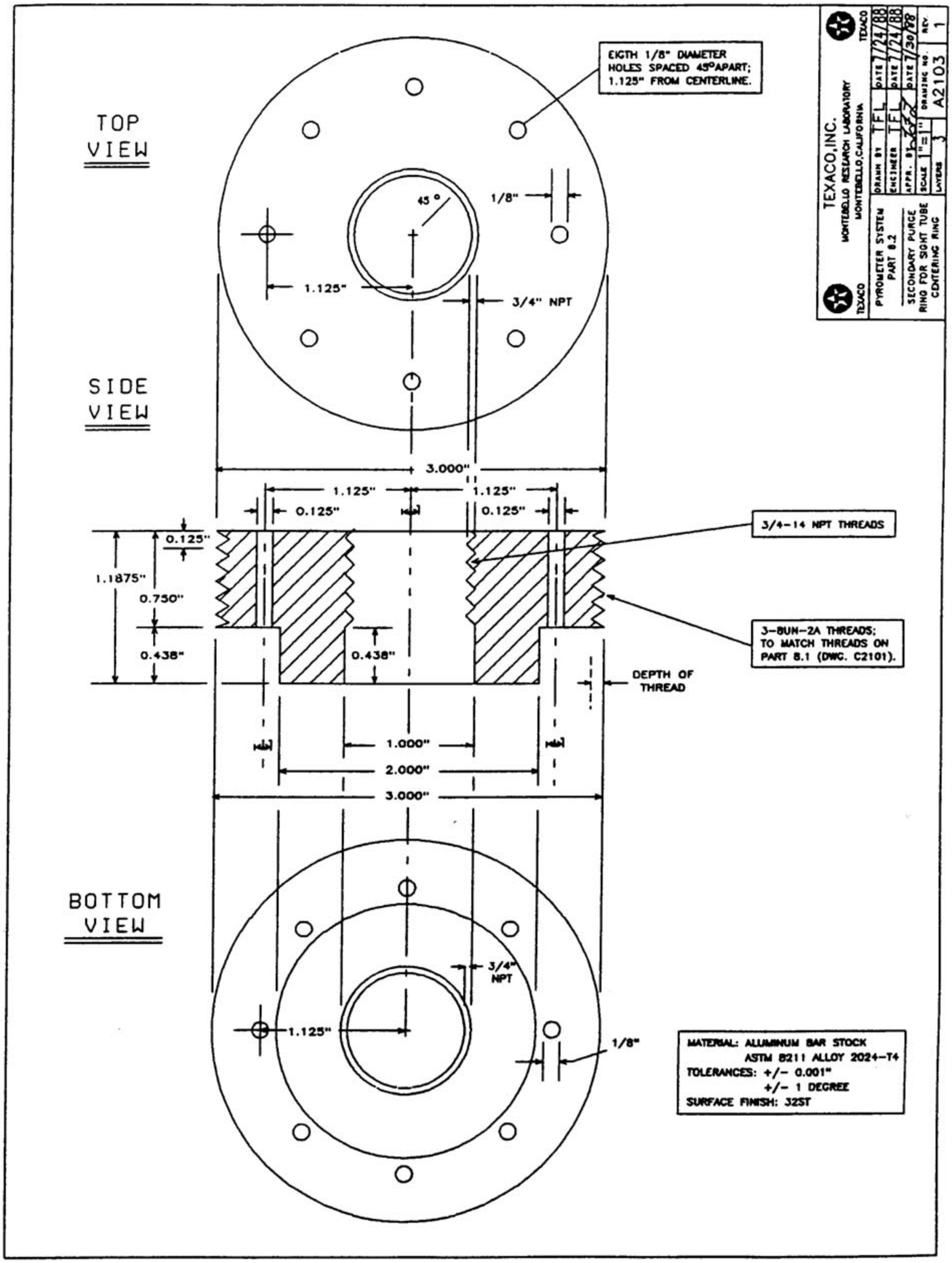

TOP VIEW
SIDE VIEW
BOTTOM VIEW
EIGTH 1/8" DIAMETER HOLES SPACED 45°APART; 1.125" FROM CENTERLINE.
45°
1/8"
1.125"
3/4" NPT
3.000"
1.125"
0.125"
0.125"
1.1875"
0.750"
0.438"
3/4-14 NPT THREADS
3-8UN-2A THREADS; TO MATCH THREADS ON PART 8.1 (DWG. C2101).
DEPTH OF THREAD
1.000"
2.000"
MATERIAL: ALUMINUM BAR STOCK ASTM B211 ALLOY 2024-T4
TOLERANCES: +/- 0.001" +/- 1 DEGREE
SURFACE FINISH: 32ST
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
PYROMETER SYSTEM PART 8.2
SECONDARY PURGE RING FOR SIGHT TUBE CENTERING RING
A2103

Figure 6

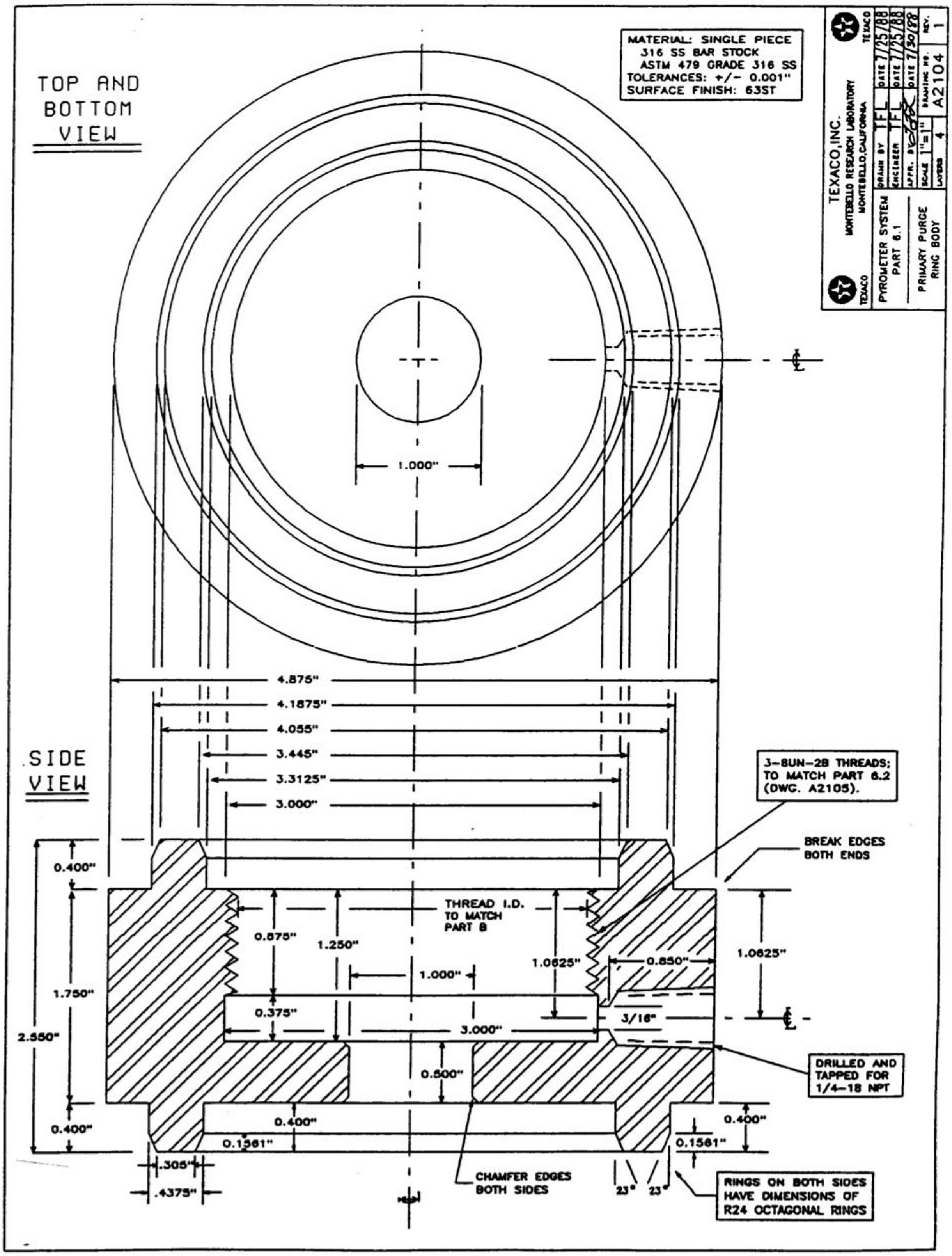

MATERIAL: SINGLE PIECE
316 SS BAR STOCK
ASTM 479 GRADE 316 SS
TOLERANCES: +/- 0.001"
SURFACE FINISH: 63ST
TOP AND BOTTOM VIEW
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
PYROMETER SYSTEM PART 6.1
PRIMARY PURGE RING BODY
DRAWN BY TFL DATE 7/25/88
ENGINEER TFL DATE 7/25/88
APPR. BY DATE 7/30/88
SCALE 1"=1"
LAYERS 4
DRAWING NO. A2104
REV. 1
1.000"
4.875"
4.1875"
4.055"
3.445"
3.3125"
3.000"
SIDE VIEW
3-8UN-2B THREADS; TO MATCH PART 6.2 (DWG. A2105).
BREAK EDGES BOTH ENDS
0.400"
THREAD I.D. TO MATCH PART B
0.875"
1.250"
1.0625"
0.850"
1.0625"
1.000"
1.750"
0.375"
3/16"
3.000"
2.550"
0.500"
DRILLED AND TAPPED FOR 1/4-18 NPT
0.400"
0.400"
0.400"
0.1561"
0.1561"
.305"
.4375"
CHAMFER EDGES BOTH SIDES
23°
23°
RINGS ON BOTH SIDES HAVE DIMENSIONS OF R24 OCTAGONAL RINGS

Figure 7

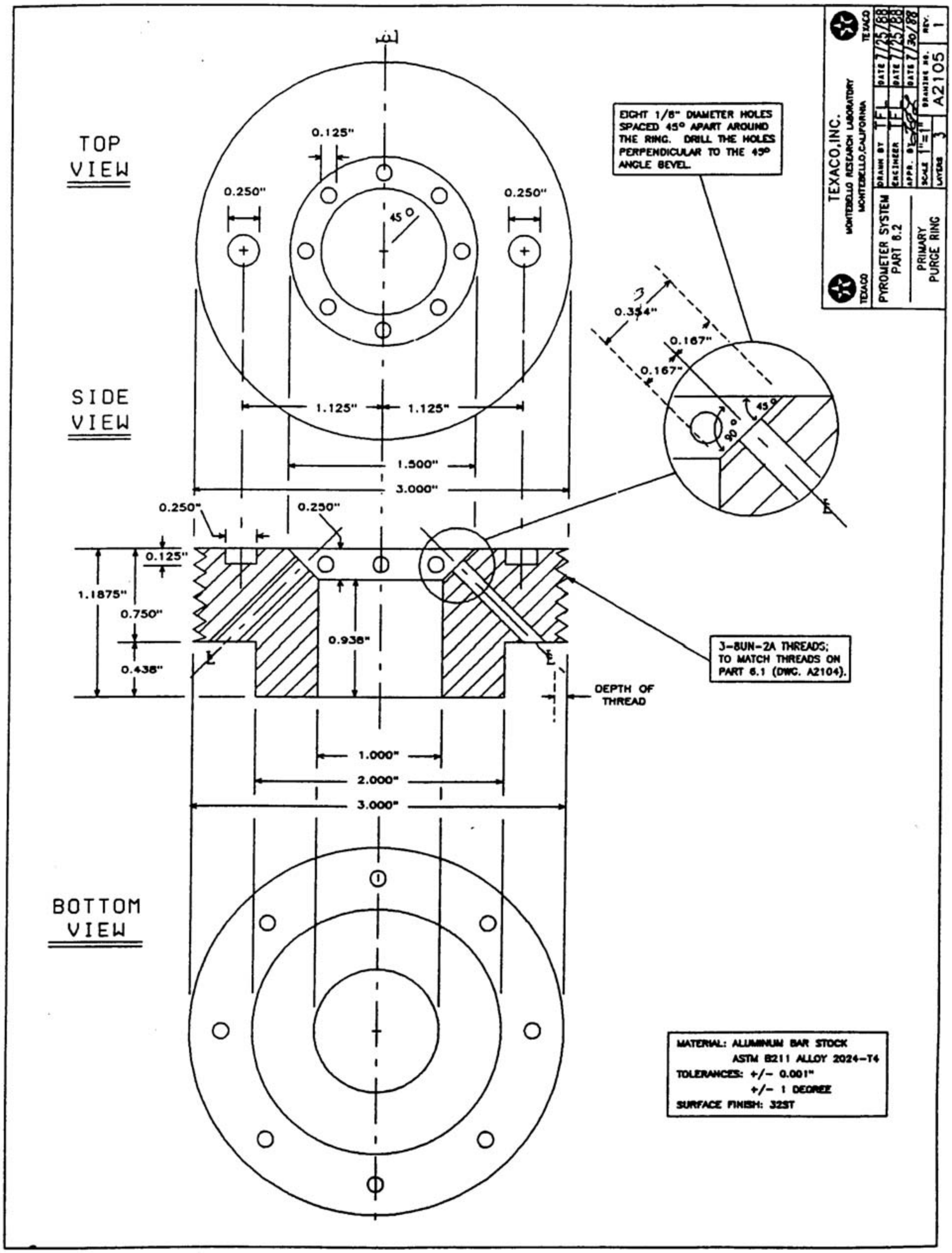

TOP VIEW
SIDE VIEW
BOTTOM VIEW
0.125"
0.250"
0.250"
45°
1.125"
1.125"
1.500"
3.000"
0.250"
0.250"
0.125"
1.1875"
0.750"
0.438"
0.938"
1.000"
2.000"
3.000"
DEPTH OF THREAD
EIGHT 1/8" DIAMETER HOLES SPACED 45° APART AROUND THE RING. DRILL THE HOLES PERPENDICULAR TO THE 45° ANGLE BEVEL.
0.354"
0.167"
0.167"
45°
90°
3-8UN-2A THREADS; TO MATCH THREADS ON PART 6.1 (DWG. A2104).
MATERIAL: ALUMINUM BAR STOCK ASTM B211 ALLOY 2024-T4
TOLERANCES: +/- 0.001" +/- 1 DEGREE
SURFACE FINISH: 32ST
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
TEXACO
PYROMETER SYSTEM PART 6.2
PRIMARY PURGE RING
DRAWN BY TFL DATE 7/25/88
ENGINEER TF DATE 7/25/88
APPR. BY DATE 7/30/88
SCALE 1"=1"
LAYERS 3
DRAWING NO. A2105
REV. 1

Figure 8

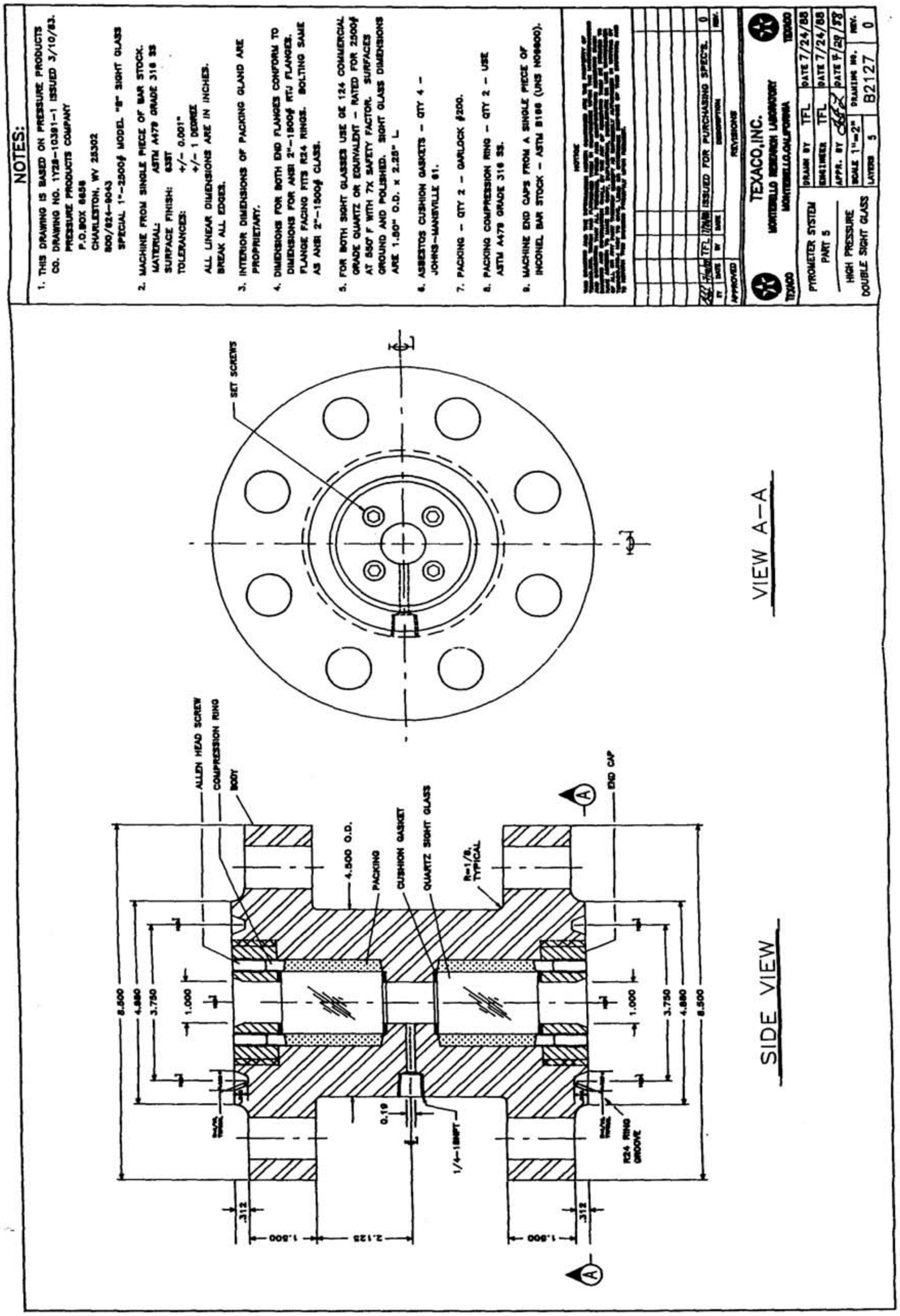

NOTES:
1. THIS DRAWING IS BASED ON PRESSURE PRODUCTS CO. DRAWING NO. 1Y28-10391-1 ISSUED 3/10/83.
PRESSURE PRODUCTS COMPANY
P.O.BOX 6656
CHARLESTON, WV 25302
800/624-9043
SPECIAL 1"-2500# MODEL "B" SIGHT GLASS
2. MACHINE FROM SINGLE PIECE OF BAR STOCK.
MATERIAL: ASTM A479 GRADE 316 SS
SURFACE FINISH: 63ST
TOLERANCES: +/- 0.001"
+/- 1 DEGREE
ALL LINEAR DIMENSIONS ARE IN INCHES.
BREAK ALL EDGES.
3. INTERIOR DIMENSIONS OF PACKING GLAND ARE PROPRIETARY.
4. DIMENSIONS FOR BOTH END FLANGES CONFORM TO DIMENSIONS FOR ANSI 2"-1500# RTJ FLANGES. FLANGE FACING FITS R24 RINGS. BOLTING SAME AS ANSI 2"-1500# CLASS.
5. FOR BOTH SIGHT GLASSES USE GE 124 COMMERCIAL GRADE QUARTZ OR EQUIVALENT - RATED FOR 2500# AT 550° F WITH 7X SAFETY FACTOR. SURFACES GROUND AND POLISHED. SIGHT GLASS DIMENSIONS ARE 1.50" O.D. x 2.25" L
6. ASBESTOS CUSHION GASKETS - QTY 4 - JOHNS-MANSVILLE 61.
7. PACKING - QTY 2 - GARLOCK #200.
8. PACKING COMPRESSION RING - QTY 2 - USE ASTM A479 GRADE 316 SS.
9. MACHINE END CAPS FROM A SINGLE PIECE OF INCONEL BAR STOCK - ASTM B166 (UNS N06600).
NOTICE
ISSUED FOR PURCHASING SPEC'S. 0
BY DATE DESCRIPTION REV.
APPROVED
REVISIONS
TEXACO
TEXACO,INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO,CALIFORNIA
PYROMETER SYSTEM
PART 5
HIGH PRESSURE
DOUBLE SIGHT GLASS
DRAWN BY TFL DATE 7/24/88
ENGINEER TFL DATE 7/24/88
APPR. BY DATE
SCALE 1"=2"
DRAWING NO. B2127
REV. 0
LAYERS 5
SET SCREWS
VIEW A-A
ALLEN HEAD SCREW
COMPRESSION RING
BODY
END CAP
4.500 O.D.
PACKING
CUSHION GASKET
QUARTZ SIGHT GLASS
R=1/8, TYPICAL
8.500
4.880
3.750
1.000
0.19
1/4-18NPT
R24 RING GROOVE
.312
1.500
2.125
SIDE VIEW

Figure 9

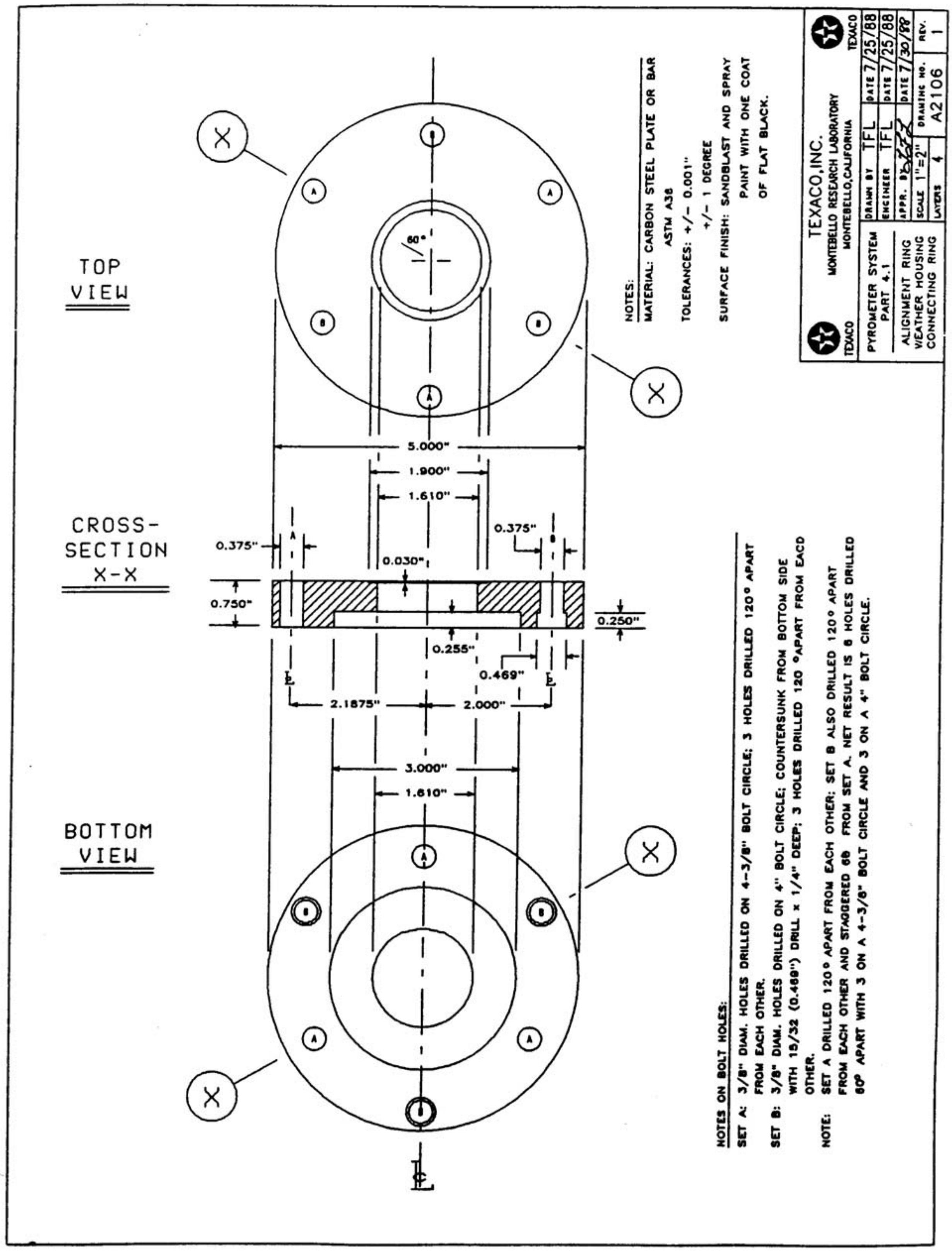

TOP VIEW
CROSS-SECTION X-X
BOTTOM VIEW
60°
5.000"
1.900"
1.610"
0.375"
0.375"
0.030"
0.750"
0.250"
0.255"
0.469"
2.1875"
2.000"
3.000"
1.610"
NOTES:
MATERIAL: CARBON STEEL PLATE OR BAR ASTM A36
TOLERANCES: +/- 0.001"
+/- 1 DEGREE
SURFACE FINISH: SANDBLAST AND SPRAY PAINT WITH ONE COAT OF FLAT BLACK.
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
TEXACO
PYROMETER SYSTEM PART 4.1
ALIGNMENT RING WEATHER HOUSING CONNECTING RING
DRAWN BY TFL DATE 7/25/88
ENGINEER TFL DATE 7/25/88
APPR. BY DATE 7/30/88
SCALE 1"=2"
DRAWING NO. A2106
REV. 1
LAYERS 4
NOTES ON BOLT HOLES:
SET A: 3/8" DIAM. HOLES DRILLED ON 4-3/8" BOLT CIRCLE; 3 HOLES DRILLED 120° APART FROM EACH OTHER.
SET B: 3/8" DIAM. HOLES DRILLED ON 4" BOLT CIRCLE; COUNTERSUNK FROM BOTTOM SIDE WITH 15/32 (0.469") DRILL x 1/4" DEEP; 3 HOLES DRILLED 120 °APART FROM EACD OTHER.
NOTE: SET A DRILLED 120° APART FROM EACH OTHER; SET B ALSO DRILLED 120° APART FROM EACH OTHER AND STAGGERED 60 FROM SET A. NET RESULT IS 6 HOLES DRILLED 60° APART WITH 3 ON A 4-3/8" BOLT CIRCLE AND 3 ON A 4" BOLT CIRCLE.

Figure 10

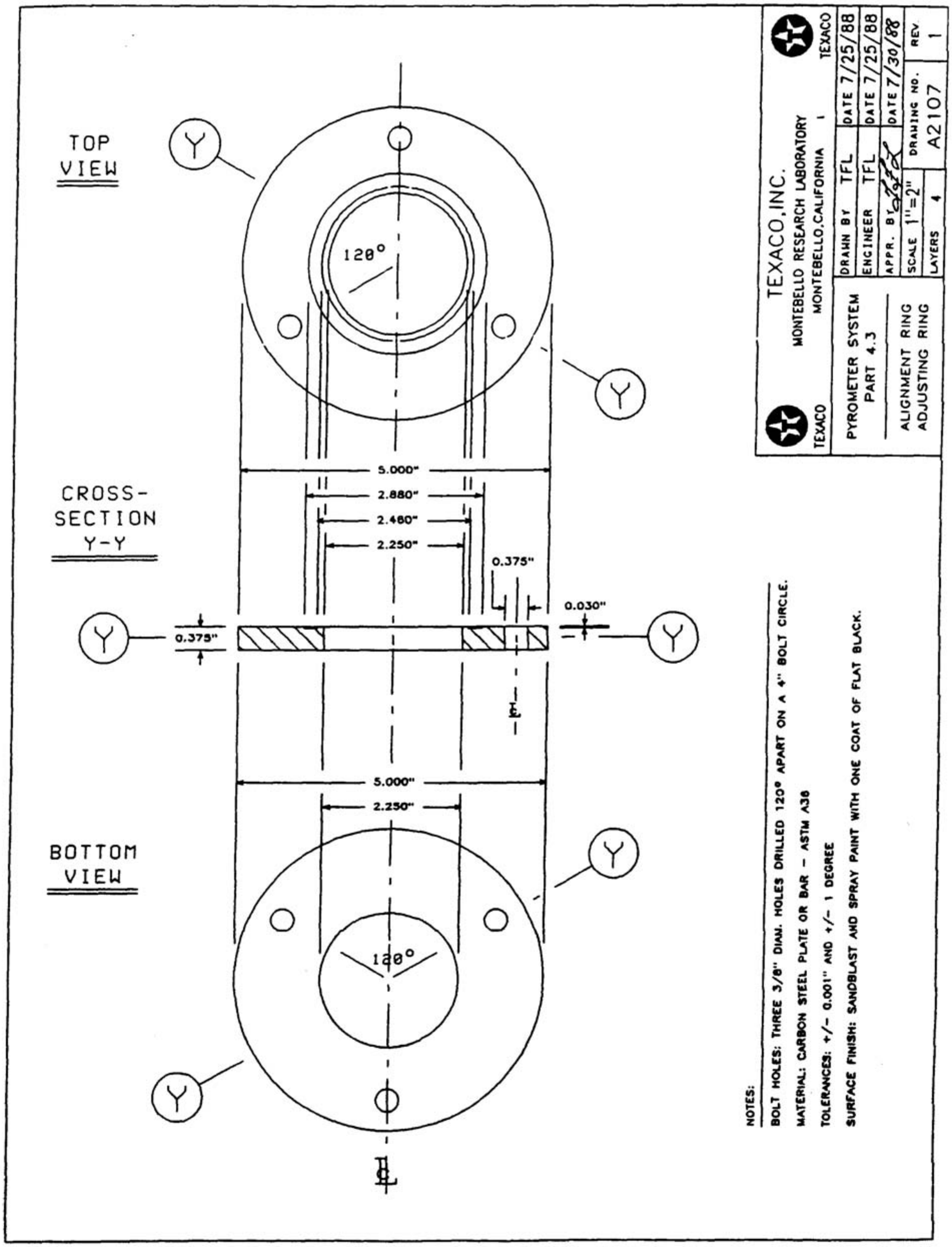

TOP VIEW
CROSS-SECTION Y-Y
BOTTOM VIEW
120°
5.000"
2.880"
2.460"
2.250"
0.375"
0.030"
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
TEXACO
PYROMETER SYSTEM
PART 4.3
ALIGNMENT RING
ADJUSTING RING
DRAWN BY TFL DATE 7/25/88
ENGINEER TFL DATE 7/25/88
APPR. BY DATE 7/30/88
SCALE 1"=2"
DRAWING NO. A2107
REV. 1
LAYERS 4
NOTES:
BOLT HOLES: THREE 3/8" DIAM. HOLES DRILLED 120° APART ON A 4" BOLT CIRCLE.
MATERIAL: CARBON STEEL PLATE OR BAR – ASTM A36
TOLERANCES: +/– 0.001" AND +/– 1 DEGREE
SURFACE FINISH: SANDBLAST AND SPRAY PAINT WITH ONE COAT OF FLAT BLACK.

Figure 11

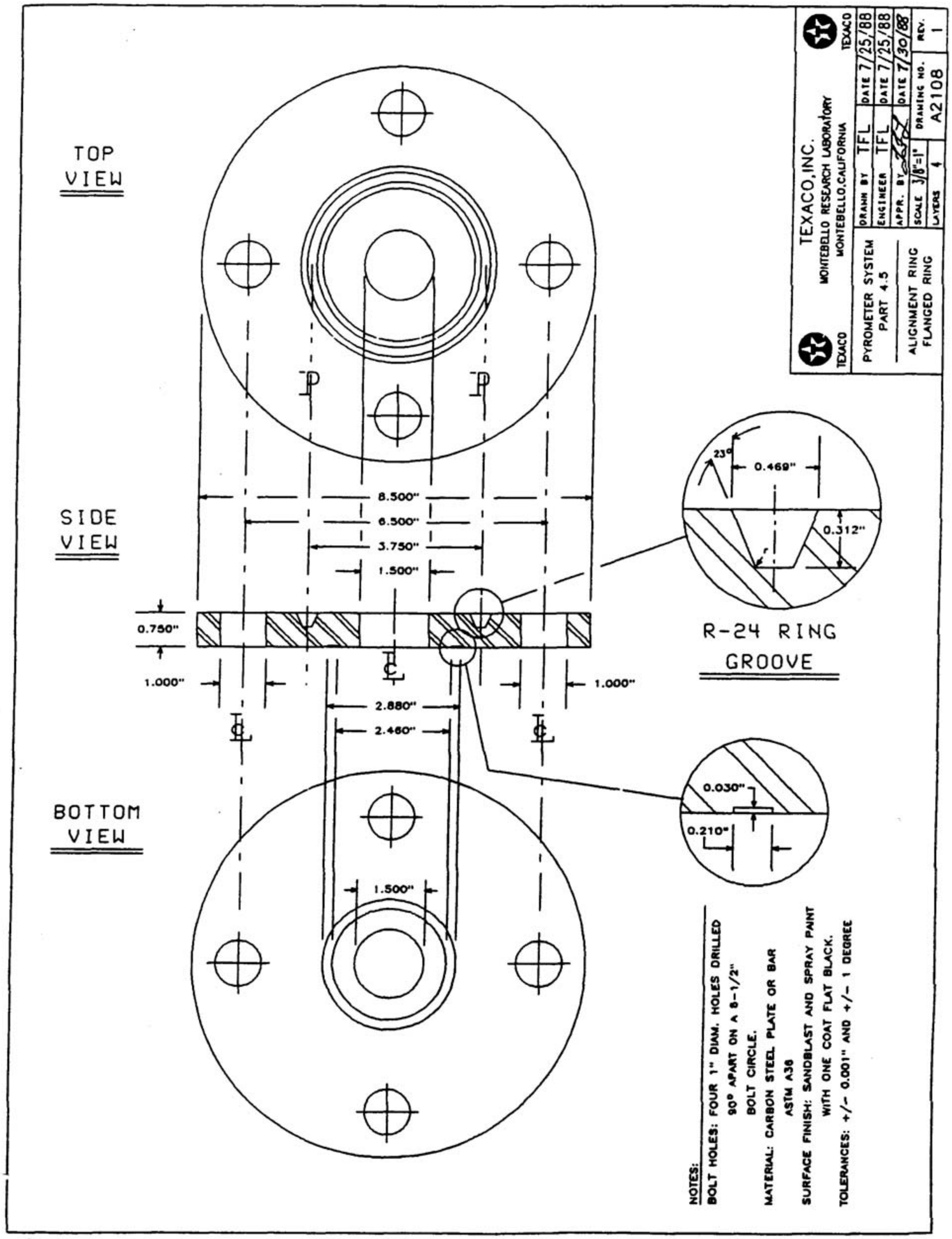

TOP VIEW
SIDE VIEW
BOTTOM VIEW
8.500"
6.500"
3.750"
1.500"
0.750"
1.000"
1.000"
2.880"
2.460"
1.500"
23°
0.469"
0.312"
R-24 RING GROOVE
0.030"
0.210"
NOTES:
BOLT HOLES: FOUR 1" DIAM. HOLES DRILLED 90° APART ON A 6-1/2" BOLT CIRCLE.
MATERIAL: CARBON STEEL PLATE OR BAR ASTM A36
SURFACE FINISH: SANDBLAST AND SPRAY PAINT WITH ONE COAT FLAT BLACK.
TOLERANCES: +/- 0.001" AND +/- 1 DEGREE
TEXACO
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
PYROMETER SYSTEM
PART 4.5
ALIGNMENT RING
FLANGED RING
DRAWN BY TFL
DATE 7/25/88
ENGINEER TFL
DATE 7/25/88
APPR. BY
DATE 7/30/88
SCALE 3/8"=1"
LAYERS 4
DRAWING NO. A2108
REV. 1

Figure 12

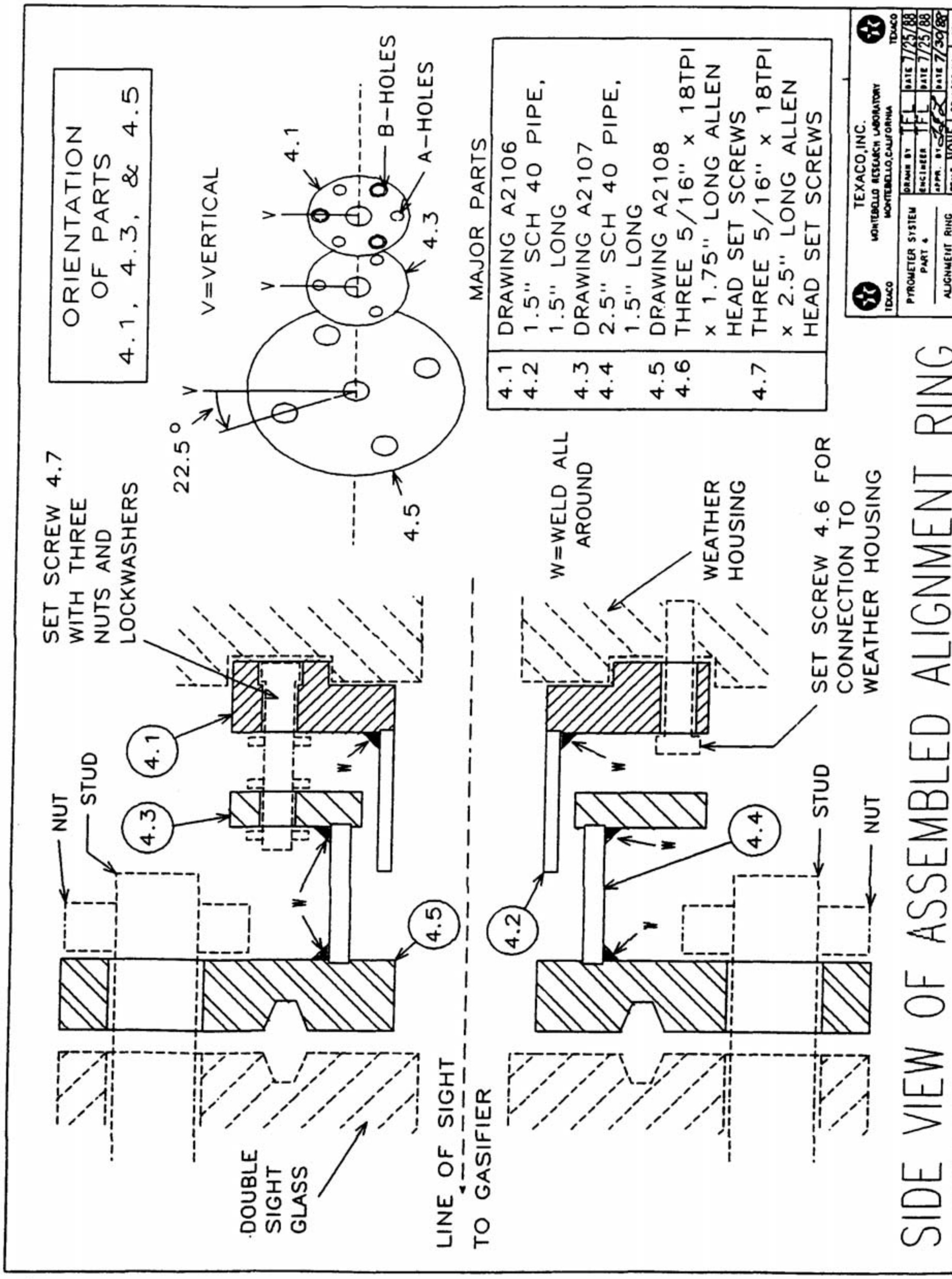
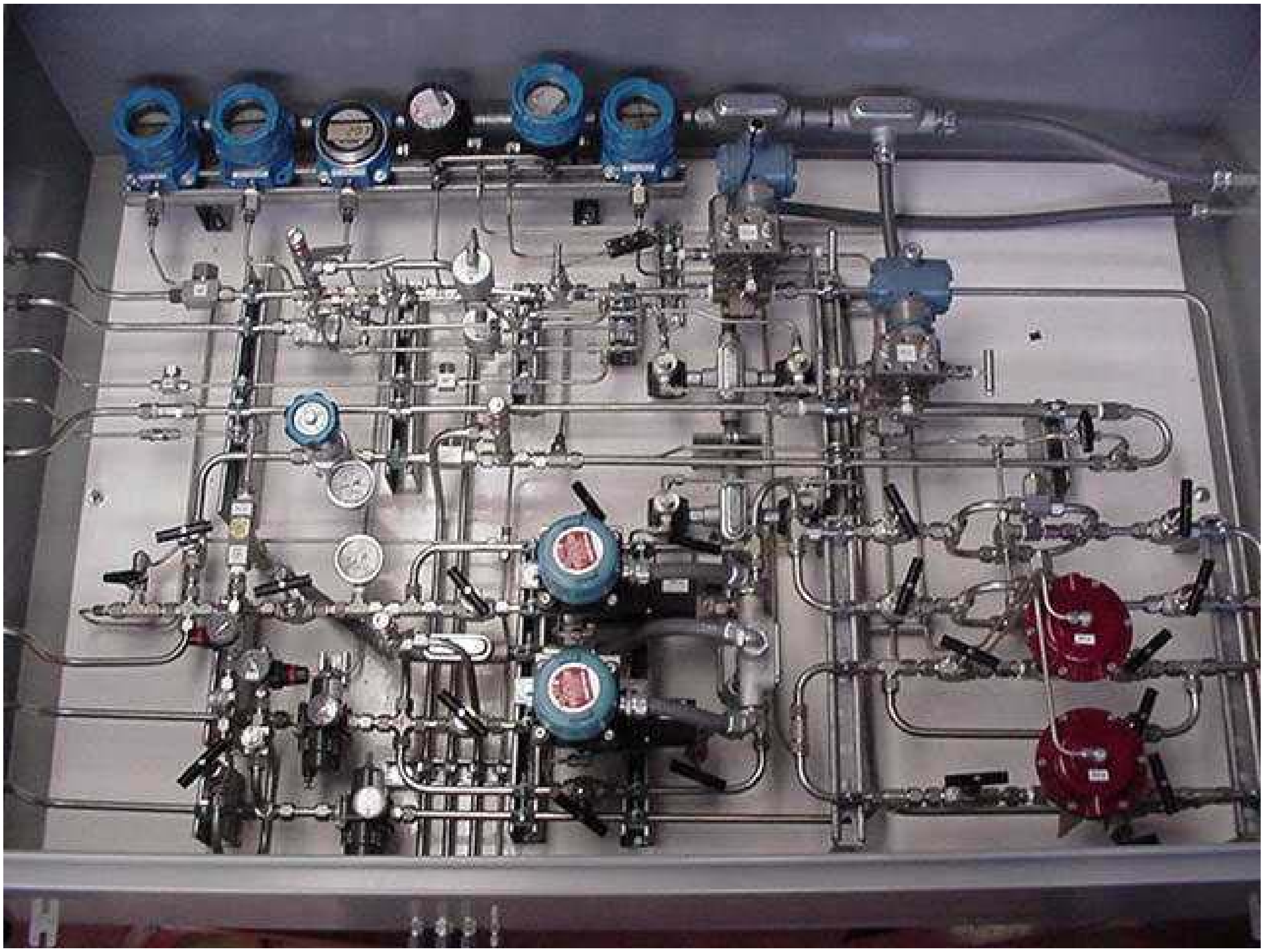

SIDE VIEW OF ASSEMBLED ALIGNMENT RING
ORIENTATION OF PARTS 4.1, 4.3, & 4.5
V=VERTICAL
22.5 °
B-HOLES
A-HOLES
4.1
4.3
4.5
4.2
4.4
SET SCREW 4.7 WITH THREE NUTS AND LOCKWASHERS
NUT
STUD
W
W=WELD ALL AROUND
WEATHER HOUSING
SET SCREW 4.6 FOR CONNECTION TO WEATHER HOUSING
DOUBLE SIGHT GLASS
LINE OF SIGHT
TO GASIFIER
MAJOR PARTS
4.1 DRAWING A2106
4.2 1.5" SCH 40 PIPE, 1.5" LONG
4.3 DRAWING A2107
4.4 2.5" SCH 40 PIPE, 1.5" LONG
4.5 DRAWING A2108
4.6 THREE 5/16" x 18TPI x 1.75" LONG ALLEN HEAD SET SCREWS
4.7 THREE 5/16" x 18TPI x 2.5" LONG ALLEN HEAD SET SCREWS
TEXACO, INC.
MONTEBELLO RESEARCH LABORATORY
MONTEBELLO, CALIFORNIA
TEXACO
PYROMETER SYSTEM PART 4
ALIGNMENT RING COMPLETE ASSEMBLY
DRAWN BY TFL
ENGINEER TFL
DATE 7/25/88
DATE 7/25/88
DATE 7/30/88
SCALE NONE
LAYERS 6
DRAWING NO. A2109
REV. 1

Figure 13 – Control Panel



All instrument air control and nitrogen tubing are shown above. The lower left tubing is the inlet tubing and the upper left being the outlet tubing to the pyrometer camera and sight tube. The red control valves on the lower right are used to control nitrogen flowrates. The top blue displays are for various pressures and flowrates.

Figure 14 - Front of PLC Panel

The front of the PLC panel contains the pyrometer temperature read out (upper left side.) Flow rates and pressure readings are shown in the digital displays. Status of valves (open/close) are shown as red/green lights. A manual shut down button in red is located on the lower right side.

Figure 15 – Inside PLC Panel

All electronic controls are housed in the PLC panel. The actual PLC is shown as the rectangular gray boxes on the bottom row of the panel box.

Figure 16 - Shut Down Valve and Pyrometer Camera

The shutdown valve is shown attached to the pyrometer camera (Oval silver-colored box in upper right side of the picture). Between the camera and valve are the spool pieces that house the quartz sight glasses and primary purge ring. The flanged spool piece in the lower right is the part that bolts on to the gasifier. This spool piece contains the secondary purge ring. The entire optical train assembly is heavy enough that it requires external support when connected to a gasifier.

Figure 17 – Testing the Pyrometer Against the Thermocouple

A temperature test with the pyrometer and a thermocouple was done to verify that the pyrometer system was working as designed. The thermocouple is the silver-colored wire taped on the carbon steel plate. The target area of the pyrometer is highlighted with white chalk on the steel plate. The bright spot on the carbon steel is the area that was heated up by a welding torch.

Figure 18 – Pyrometer Reading During Temperature Test

The pyrometer indicated a temperature of 1276 C (2328 F) while the thermocouple indicated a range of temperature that fluctuated above 1093 C (+2000 F). An accurate thermocouple temperature could not be attained due to the rapid changes in temperature of the metal and the relative crude test set up.

Appendix B

Equipment List and Recommended Vendor List

PYROMETER OPTICAL TRAIN EQUIPMENT-FIGURE 1

#	ITEM	QTY	COMPANY	SPEC'S
1	Pyrometer	1	Ircon, Inc.	Ircon Modline 3 IRT 1M3#3744 Pyrometer Model: 3R-99F05-0-0-0-0 Temp. Range: 1500-4000 degree F Min. Object Size: 0/50 Response Time @ Output: 10 sec. To 95% of F.S. Special Features: Temp. Range 1500-4000 Degree F; with Signal Reduction Ratio of 100/1 Note: drill 2 holes in camera housing and thread with 1/4" NPT; for inert gas purge
2	Cable	1	Ircon, Inc	Modline 3 Cable
3	Weather Housing	1	Ircon, Inc.	Type WJ-2 "water cooling jacket"
4	Alignment Rings	1	Century Industries	Ref. Texaco, Inc. MTC Drawing A2106, A2107, A2108 and A2109.
5	Sight Glass	1	Pressure Products Co.	Ref. Pressure Products Co. Drawing 1Y28-10391-1
6	Purge Rings	1	Century Industries	Ref. Texaco, Inc. MTC Drawing A2104 and A2105.
7	Gate Valve	1	EVSI	2" 1500# ANSI RTJ flanged ATI Model L183SRE80 spring return actuator
8	Centering Ring	1	Century Industries	Ref. Texaco, Inc. MTC Drawing C2102 and A2103

PYROMETER OPTICAL TRAIN EQUIPMENT-FIGURE 3

#	ITEM	QTY	COMPANY	SPEC'S
11	Sight Tube	2	A1 Carbide	35” TZM molybdenum, ¾” NPT male end

OTHER EQUIPMENT ITEMS – FIGURE 2

#	ITEM	QTY	COMPANY	SPEC'S
12	N2 PCV	1	Ponton Industries	Research Control Value 1/4" stainless steel globe valve; ATC 50 pneum. Actuator; I, K or L size linear trim 10011GCN36SVCSILN
13	N2 FCV	1	Ponton Industries	Research Control Value 1/4" stainless steel globe valve; ATC/50 pneum. Actuator; G size linear trim 1001GCN36SVCSGLN36
14	Thermcouple	1	Wilcon Industries	J Type 0.125-J-316-U-5”-PJ WO84

15	Flex Hose	2	MCMaster Carr	316 SS braided, NPT male x NPT male, 1/4” ID x 0.45” OD x 12”, 1800 F, 1075 psi #57693K101
16	Hi Temp Valve	3	Valin Corp	¼” NPT 4Z-U6LR-G-SS-HT.
17	Bulkhead Connectors	6	Valin Corp	SS ½” CPI union 8-8 WBZ-SS.
18	Solenoid Valves	4	Caltrol	3-way ¼” NPT #EF8320G202
19	Quick Exhaust	1	Caltrol	Model#V0431
20	Hi Press Regulator	1	Mitech Controls	¼” GO SS 2000psi inlet, 0-1000 psi outlet PR501F11A3K1H1
21	Flow Switch	2	Mitech Controls	Dwyer I/P Model# 2213-O-E
22	Hi Press Gauge	2	Mitech Controls	Reotemp 0-3000 psi #PG25C2AP32
23	Electronic Press Gauge	4	Mitech Controls	PSI-Tronix, 4-20 mA output, #PG3000-2000-G
24	Unistrut	10 ft	Howland Electric	Pre-galvanized #PS100-10-PGAL
25	Minuature Press Regulator	2	Supelco	Model # 5-13-010
26	Pressure Transmitter	1	Rosemount	Differential, 3051CD2A02A1AS5S4E5 with integral manifold and orifice
27	Pressure Transmitter	1	Rosemount	Differential, 3051CD1A02A1AS5S4E5 with integral manifold and orifice
28	PLC Equipment	1	Wang Controls	Slic 500 PLC
29	Electrical Panel	1	Wang Controls	
30	Computer	1	Dell	Latitude LS Laptop
31	Pressure Transmitter	3	Mitech Controls	1 ½”, 0-100 psi, 1/8” center back mount PD15N2CP18
32	Pressure Transmitter	1	Mitech Controls	2”, 0-1000 psi, ¼” center back mount PD20N2C4P25
33	Pressure Transmitter	1	Mitech Controls	2.5”, 0-3000 psi, ¼” center back mount PG25C2C4P32
34	Pressure Transducer	1	Mitech Controls	0-2000 psi; 2500 F
35	Plug	2	Mitech Controls	¼” square bar stock plug, 316 SS
36	Elbow	2	Mitech Controls	¼” SS 90 elbow, NPT 3000#, 316 SS
37	Nipple	2	Mitech Controls	¼” x 1 ½” sch 80, 316 SS
38	Nipple	2	Mitech Controls	¼” CLS 316 SS Sch 80, 316 SS
39	Tubing	100 ft	Valin	¼” 316 SS tubing 0.035” thick
40	Tubing	50 ft	Valin	½” 316 SS tubing
41	Steel Panel	1	Cross Brothers	CBN12-48 x 72 18 HC NEMA 12 Hinge cover, double door, lockable ANSI 61 Gray
42	Female Adapter	6	Orange Valve & Fitting	Swagelok ½” ½” NPT SS-8-TA-7-8
43	Female Adapter	3	Orange Valve & Fitting	Swagelok 1/4” 1/4” NPT SS-4-TA-7-4
44	Reducer	1	Orange Valve & Fitting	Swagelok ¼” ½” SS-400-R-8

45	Elbow	8	Orange Valve & Fitting	Male SS-400-2-2
46	Hi Temp Check Valves	2	Orange Valve & Fitting	¼" NPT SS-53S4
47	Hi Temp Check Valves	1	Orange Valve & Fitting	1/2" NPT SS-58S8
48	Ball Valves	2	Orange Valve & Fitting	Pneumatic with switches SS-45S8-330-L1
49	PSV	3	Orange Valve & Fitting	Set @1000 psi, SS-R4S8
50	Spring kit for PSV	2	Orange Valve & Fitting	177-13K-R4-A
51	Spring kit for PSV	1	Orange Valve & Fitting	177-13K-R4-C
52	Hi Temp Valve	1	Orange Valve & Fitting	SS-HBS4-O
53	Tee	3	Orange Valve & Fitting	Female SS-810-3-4TTF
54	Union Cross	4	Orange Valve & Fitting	SS-810-4 SS.
55	Ball Valves	2	Orange Valve & Fitting	S-43M4
56	Male Adapters	1	Orange Valve & Fitting	SS-8-TA-1-4
57	Bulk Head Fittings	2	Orange Valve & Fitting	SS-400-61
58	Filters	6	Orange Valve & Fitting	SS-8TF-7
59	Ball Valves	19	Orange Valve & Fitting	SS-18VS18
60	Check Valves	3	Orange Valve & Fitting	SS-8C-1
61	Hi Temp Valve	1	Orange Valve & Fitting	SS-HBS4-C
62	Valve	1	Orange Valve & Fitting	SS-43S4
61	Sintered Filter	6	Orange Valve & Fitting	SS-8F-K4-7
62	Union Tees		Orange Valve & Fitting	B-600-3, SS-400-3, B-600-6, SS-810-3
63	Male Connectors		Orange Valve & Fitting	SS-810-1-4, SS-810-1-8, SS-600-1-4, SS-400-1-4, SS810-1-2
64	Female Connectors		Orange Valve & Fitting	SS-400-7-8
65	Gasket	1	Industrial Gasket & Supple Co	Flexible Graphite, Calgraph "BSSC" 1/8" x 60" x 60"

66	Stud Bolts	8	Orange Valve & Fitting	7/8" dia. X 6" L. std. Studs, ASTM A193 grade B7
67	Hex Nuts	16	Any Vendor	7/8" dia. Sstd. Nuts, ASTM A194 grade 2H
68	2" flange ring	2	Any Vendor	R-24 octagonal flange ring
69	Stud bolts	12	Any Vendor	7/8" dia. X 5-3/4" L std stud, ASTM A193 grade B7
70	Stud bolts	8	Any Vendor	7/8" dia. X 8-1/2" L std stud, ASTM A193 grade B7
71	Hex Nuts	40	Any Vendor	7/8" dia. Std. Nuts, ASTM A194 grade 2H

Vendor List
The following is a list of addresses for the vendor for the items purchased for this project:

1) Pressure Products Company, Inc.
   4540 West Washington Street, Charleston, WV 25313
   (304)744-7871

2) Industrial Gasket & Supply Co.
   23018 S. Normandie Ave., Torrance, CA 90502
   (310)530-1771

3) Ircon Inc.
   7300 N. Natchez Avenue, Niles, IL 60714
   (847)967-5151

4) Century Industries
   1130 West Grove Avenue, Orange, CA 92865
   (714)637-3691

5) Ponton Industries, Inc.
   8118 Allport Avenue, Sante Fe Springs, CA 90607
   (562)945-1621

6) Wilcon Industries
   2116 Troy Avenue, South El Monte, CA 91733
   (626)579-0268

7) McMaster-Carr
   9630 Norwalk Blvd, Sante Fe Springs, CA 90670-2932
   (562)692-5911

8) Valin Corporation
   760 E. Kingshill Place, Carson, CA 90746
   (310)217-1311

9) Caltrol
   2011 East Financial Way, Glendora, CA 91740

(626852-3552

10) Mitech Controls
PO Box 382, Yorba Linda, CA 92885
(714)695-2999

11) Howland Electric Wholesale
2806 Tyler Avenue, PO Box 4338, El Monte, CA 91734-0338
(626)444-0503

12) Orange Valve & Fitting Company
2333 S. Manchester Avenue, Anaheim, CA 92808
(714) 634-0216

13) Supelco
Supelco Park, Bellefonte, PA 16823-0048
(800)247-6628

14) Rosemount Inc.
PO Box 70114, Chicago, IL 60673-0114
(952)949-5200

15) EVSI
Engineered Valve Specialties, Inc.
3500 South Richey, Suite 170, Houston, TX 77017
(713)947-8844

16) A1 Carbide
1649 Miraloma Ave, Placentia, CA 92870
(714) 630-9422

Appendix C

Fabrication and Assembly

Note: The assembly and installation instructions in this section are written in checklist format. They can be photocopied, along with Figure 1, and used as instruction sheets for the instrumentation personnel who will be performing the work.

A) <u>SIGHT TUBE - SIGHT TUBE CENTERING RING</u>

REFERENCES: Figure 3 (part 11), Figure 4 (part 8.1), and Figure 5 (part 8.2).

REQUIRED MATERIALS:

1. body of sight tube centering ring machined from stainless steel according to drawing C2102 (Figure 4)

2. threaded aluminum insert (the one with the straight holes1 machined according to drawing A2103 (Figure 5)

3. a sheet of 1/8" thick graphite asbestos gasket material large enough to cut a 3" disk

4. 3/4" sch 80 stainless steel pipe of length X, 3/4-14 NPT both ends; NOTE - length X must be determined - length X should be long enough so that when the fully assembled sight tube and centering ring are installed in the gasifier, the free end of the sight tube will be flush with the wall of the reaction chamber

5. 3/4-14 NPT 6000# 316 stainless steel threaded coupling

6. molybdenum sight tube of length L, obtained from vendor according to the specifications on drawing A2101 (Figure 3)

7. 1.75" O.D. diamond tipped refractory brick core drill and drilling equipment

REQUIRED FOR CONNECTION TO GASIFIER AND GATE VALVE:

8. one (1) R-37 octagonal ring

9. eight (8) 7/8" diam. x 6" long std. studs, ASTM A193 grade B7

10. sixteen (16) 7/8" diam. std. nuts, ASTM A194 grade 2H

11. one (1) R-24 octagonal ring

12. eight (8) 7/8" diam. x 5-3/4" long std. studs, ASTM A193 grade B7

13. sixteen (16) 7/8" diam. std. nuts, ASTM A194 grade 2H

ASSEMBLY AND INSTALLATION:

1. Cut a 3" O.D. disk out of the sheet of gasket material and cut a 1.25" I.D. hole in the center.

2. Place the gasket in the bottom of the 3" diam. threaded well in the stainless steel body of the centering ring.

3. Screw the aluminum insert into the body until the 2" diam. face of the insert compresses the gasket.

4. Screw the sight tube, coupling and threaded nipple together. Be careful **not to scratch the oxidation resistant coating on the sight tube.** Then screw the nipple into the aluminum insert.

5. Drill a 1.75" diam. hole through the gasifier refractory. This hole must be aligned with the central axis of the gasifier nozzle in which the pyrometer will be installed.

6. The centering ring - sight tube assembly are now ready for installation in the gasifier. When bolted in place, the free end of the sight tube should be flush with the wall of the reaction chamber.

B) PRIMARY PURGE RING

REFERENCES: Figure 6 (part 6.1) and Figure 7 (part 6.2).

REQUIRED MATERIALS:

1. body of primary purge ring machined from stainless steel according to drawing A2104 (Figure 6)

2. threaded aluminum insert (the one with the angled holes) machined according to drawing A2105 (Figure 7)

3. a sheet of 1/8" thick graphite asbestos gasket material large enough to cut a 3" disk

REQUIRED FOR CONNECTION TO DOUBLE SIGHT GLASS AND VALVE:

4. eight (8) 7/8" diam. x 8-1/2" long std. studs, ASTM A193 grade B7

5. sixteen (16) 7/8" diam. std. nuts, ASTM A194 grade 2H

ASSEMBLY AND INSTALLATION:

1. Cut a 3" O.D. disk out of the sheet of gasket material and cut a 1.25' I.D. hole in the center.

2. Place the gasket in the bottom of the 3" diam. threaded well in the stainless steel body of the purge ring.

3. Screw the aluminum insert into the body until the 2' diam. face of the insert compresses the gasket.

4. When assembling the optical train, use the long stud bolts to fasten the purge ring in between the sight glass spool piece and the gate valve just like an extra thick flange ring.

C) OPTICAL ALIGMENT RING

REFERENCES: Figure 9 (part 4.1), Figure 10 (part 4.3), Figure 11 (part 4.5) and Figure 12 (part 4 assembly).

REQUIRED MATERIALS:

1. 3/4" thick carbon steel plate; large enough for one 8.5" O.D. disk and one 5" O.D. disk parts 4.5 & 4.1

2. 3/8" thick carbon steel plate; large enough for one 5" O.D. disk; part 4.3

3. 1-1/2" sch 40 x 1-1/2" long carbon steel pipe; part 4.2

4. 2-1/2" sch 40 x 1-1/2" long carbon steel pipe; part 4.4

5. welding rods for carbon steel welding

6. flat black spray paint

7. three (3) 5/16" x 18 TPI x 1-3/4" long Allen head screws; part 4.6; these fit exactly into the type WJ-2 weather housing made by Ircon for the R-Series pyrometer

8. three (3) 5/16" x 18 TPI x 2-1/2" long Allen head screws; part 4.7

9. nine (9) 5/16" x 18 TPI nuts

10. twelve (12) 5/16" lock washers

11. twelve (12) 5/16" regular washers

REQUIRED FOR CONNECTION TO DOUBLE SIGHT GLASS:

12. one (1) R-24 octagonal ring

13. four (4) 7/8" diam. x 5-3/4" long std. studs, ASTM A193 grade B7

14. eight (8) 7/8" diam. std. nuts, ASTM A194 grade 2H

FABRICATION:

1. Machine parts 4.1, 4.3 & 4.5 according to drawing A2106, A2017, A2108 (Figure 9 – 11).

2. Weld part 4.2 to 4.1 and part 4.4 to 4.3 & 4.5 as shown in drawing A2109 (Figure 12). Take special note in drawing A2109 (Figure 12) of the orientation of part 4.3 with respect to part 4.5. With the top one of the four holes in part 4.5 offset from the vertical counterclockwise by 22.5 degrees, the top one of the three holes in part 4.3 should be lined up exactly on the vertical.

3. Sandblast finished sub-assemblies 4.1-4.2 and 4.3-4.4-4.5 to remove all rust, dirt and millscale. Spray paint immediately with one coat flat black.

ASSEMBLY AND INSTALLATION:

NOTE: The optical alignment ring MUST be assembled <u>with</u> the weather housing!

1. See drawing A2109 (Figure 12) for final assembly and orientation.

2. Insert the part 4.7 screws through the "b-Holes" in part 4.1 so that their heads fit into the sockets in the back side of part 4.1. Secure them in place with one regular washer, one lock washer and one nut on each screw.

3. Secure sub-assembly 4.1-4.2 to the Ircon Type WJ-2 weather housing using the three part 4.6 screws and one lock washer and one regular washer on each screw. The part 4.6 screws thread into the 5/16" x 18 TPI threaded holes in the front face of the Ircon weather housing.

4. Connect the weather housing and sub-assembly 4.1-4.2 to sub-assembly 4.3-4.4-4.5 by three Allen head screws (part 4.7). One nut, one lock washer and one regular washer are threaded onto each one of the three part 4.7 screws about half way. The three part 4.7 screws then fit through the three holes in part 4.3 and are secured by one regular washer, one lock washer and one nut on each screw.

5. The alignment ring is now completely assembled and can be bolted onto the back side of the double sight glass using the octagonal ring and the studs and nuts. From here on the alignment ring and weather housing should be treated as one complete assembly.

6. By independently adjusting the position of the nuts on either side of part 4.3 along the length of the part 4.6 screws, the optical alignment of the pyrometer sensing head can be controlled.

<u>D) FINAL OPTICAL TRAIN ASSEMBLY AND ALIGNMENT</u>

1. The pyrometer comes pre-calibrated from the factory. The instrument instruction manual should be thoroughly read and understood. The pyrometer camera should be pre-focused at 50" in the instrument shop by following the instructions in the manual.

2. Connect all of the optical train equipment to the gasifier as shown in Figure 1<u>. Great care must be taken not to scratch any of the optical parts</u>. Only well-trained and properly qualified instrumentation personnel should perform this work. Proper placement of the flange rings and tightening of the bolts should provide a very good first order optical alignment of the system.

Final optical alignment will be done during preheat when the reaction chamber walls are glowing red hot.

3. Make all of the connections for the purge systems, safety shutdown system and the instrument air system. All connections in the primary purge stream, secondary purge stream and safety shutdown systems should be leak tested with nitrogen up to 1500 psi, if available. If not, leak test with the highest pressure available. Follow good plant practice.

4. During the first preheat period, in which the pyrometer is operated, the purge systems should be operated as discussed in Section 2. When the gasifier gets hot enough for the walls to glow, make the final optical alignment of the system by adjusting the three screws on the optical alignment ring until the image of the circular reticle on the camera eyepiece is located in the center of the sight tube opening. The pyrometer system is now ready for operation.

Appendix D

Controller Programming – Block Diagram and Description, Panel Diagram

PYROMETER PURGE CONTROL PROGRAM

This appendix describes the purge control program for the pyrometer system by giving an overview of each subroutine in the program. Figure 18 is a block flow diagram of the program that shows the interelationship among the subroutines (See Figure 2 for valve and instrument nonmenclature).

MAIN: This program, "MAIN", contains the subroutines that control the Nitrogen Purge to the Optical Pyrometer.

SUBROUTINES:

INIT: This subroutine will close all the pyrometer block valves and set the pyrometer pressure and flow valves to 50%. If all the valves are closed and the control valves initialized, then it de-energizes init-step. This tells the program that the initialization step is complete and the program will NOT perform this step on the next scan unless prompted by the operator

PREHEAT: This Subroutine opens BV-8A, reads the gasifier pressure and opens the appropriate block valves, BV-1 or BV-2. When BV-1 or BV-2 are open, BV-14 will open. It enters the set point in FCV_4 and unlatches the enable bit when the parameters are satisfied.

STARTUP: This Subroutine prepares the pyrometer for startup. It Opens BV_2 and sets FCV_4 set point to a high flow rate.

NORMAL: This subroutine sets FCV_4 flow rate to a “normal” flow rate. This flow rate is set once the gasifier reaches the desired pressure.

PULSE: The subroutine provides a pulse of nitrogen to purge the sight tube of any blockage. BV_14 is closed to allow the blockage to heat up. PCV_4 and FCV_4 are opened manually to increase backpressure. When the timer times out BV_14 will open causing a blast of nitrogen to clear the blockage. The subroutine will place PCV_4 and FCV_4 back into Auto mode and it will set the set points to "NORMAL"

COOLDOWN: This subroutine sets the pressure and flow during gasifier cool down.

MANUAL: This subroutine enables the operator to manually open and close all pyrometer block valves.

CTRL PANEL: This subroutine determines the state of all the pyrometer block valves and sets the appropriate light on at the panel. It also scales the pressure and flow inputs to the indicators on the panel.

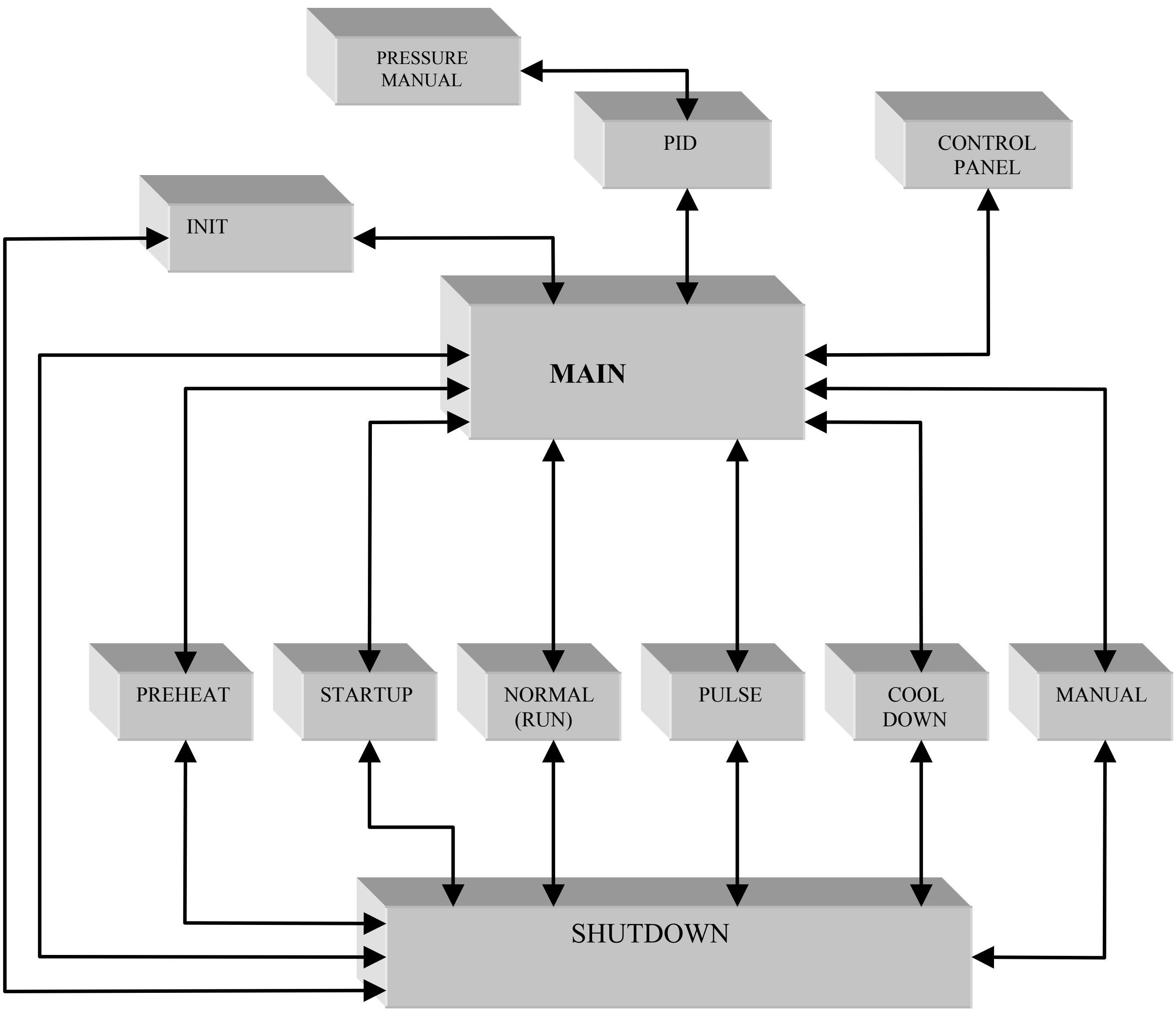
PID: This subroutine scales the input variables for comparisons. It scales the inputs and outputs for the PID blocks. It contains the PID blocks for PCV_4 and FCV_4 control.

PRESS_MAN: This subroutine will allow PCV_4 to be in a semi manual control. The program will set the output to the valve to keep the pressure at a desired value.

The following figures show the PLC block diagram, and the panel and wiring diagrams for the cabinet containing the PLC.

Figure 19

PYROMETER BLOCK DIAGHRAM



Panel Diagrams

Figure 20 – PLC Panel Layout

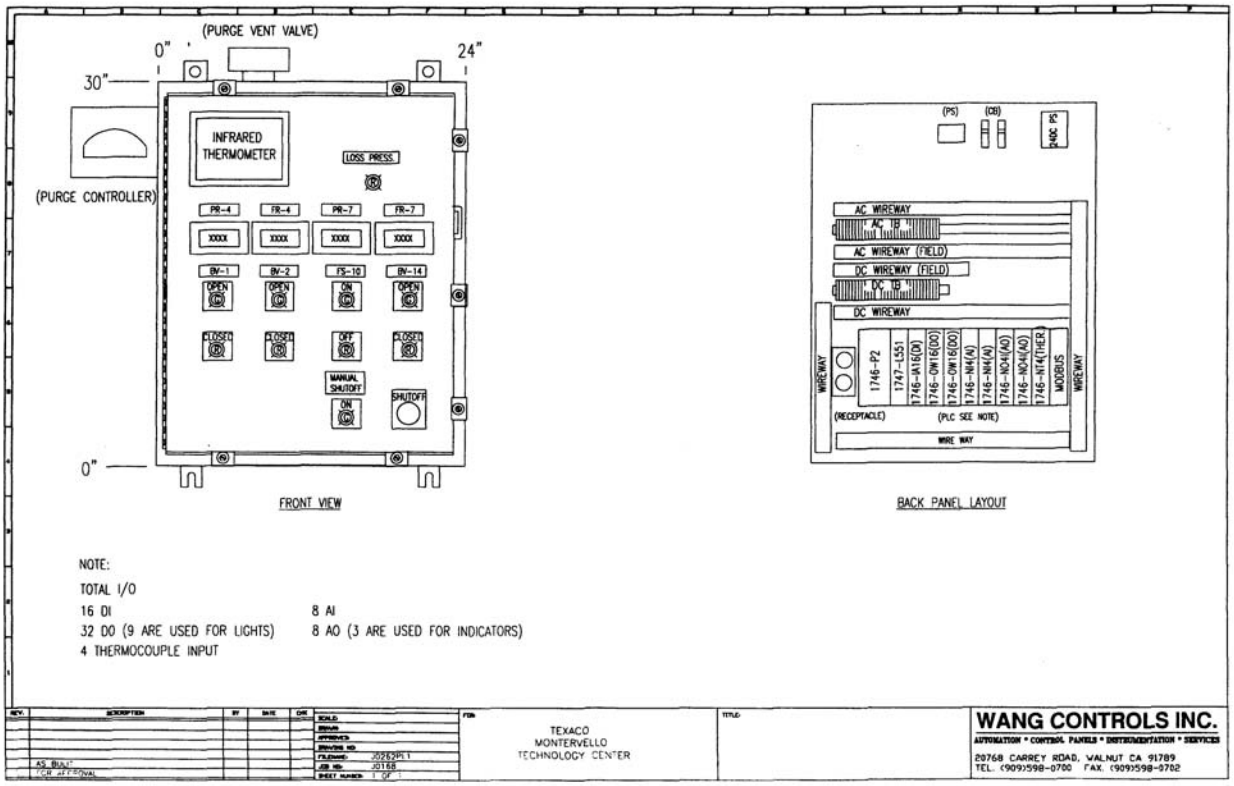


Figure 21 – Electrical Layout

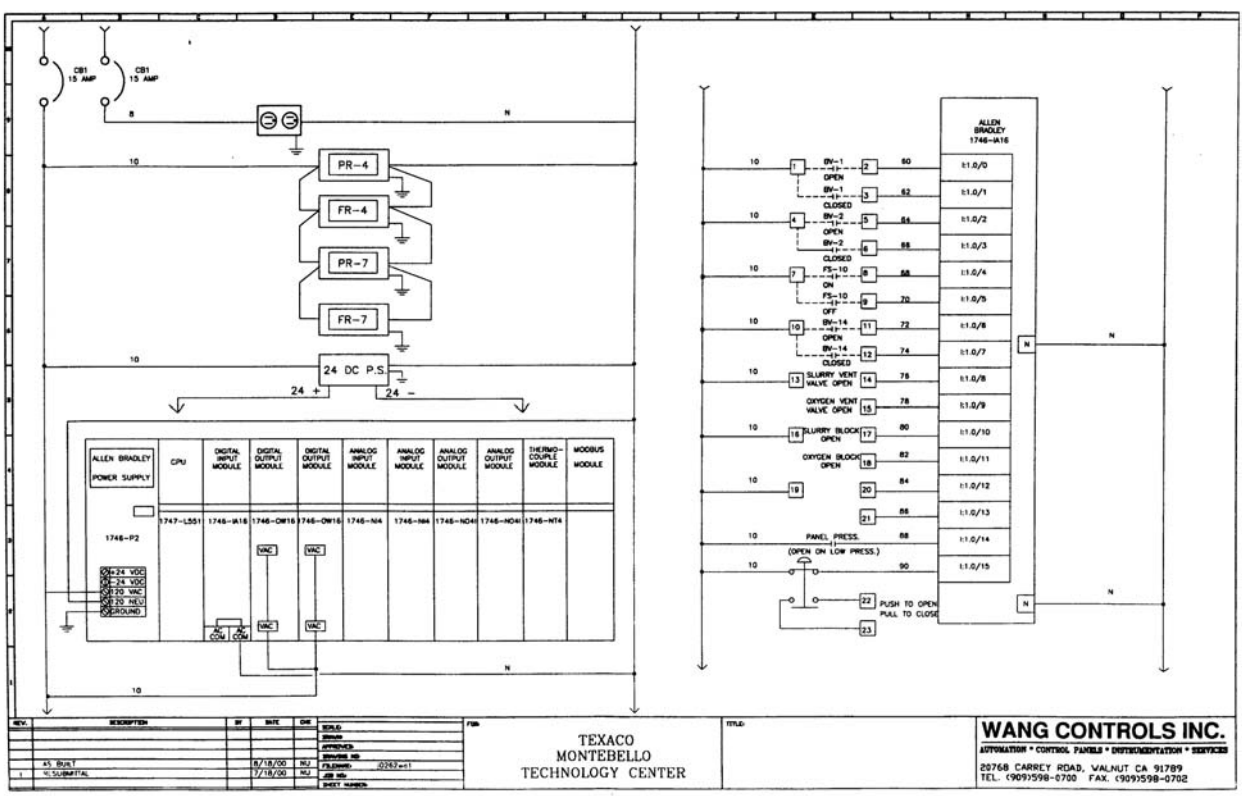


Figure 22 – PLC Connections - 1

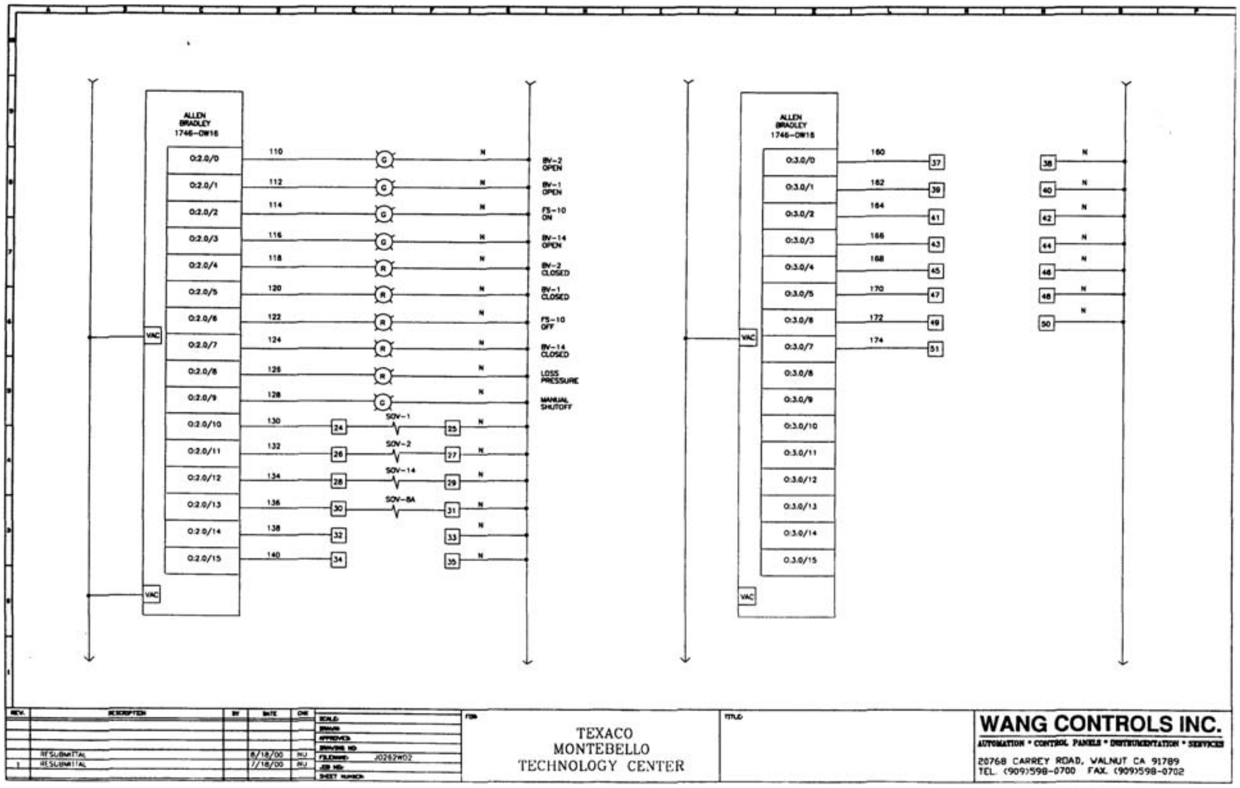


Figure 23 – PLC Connections - 2

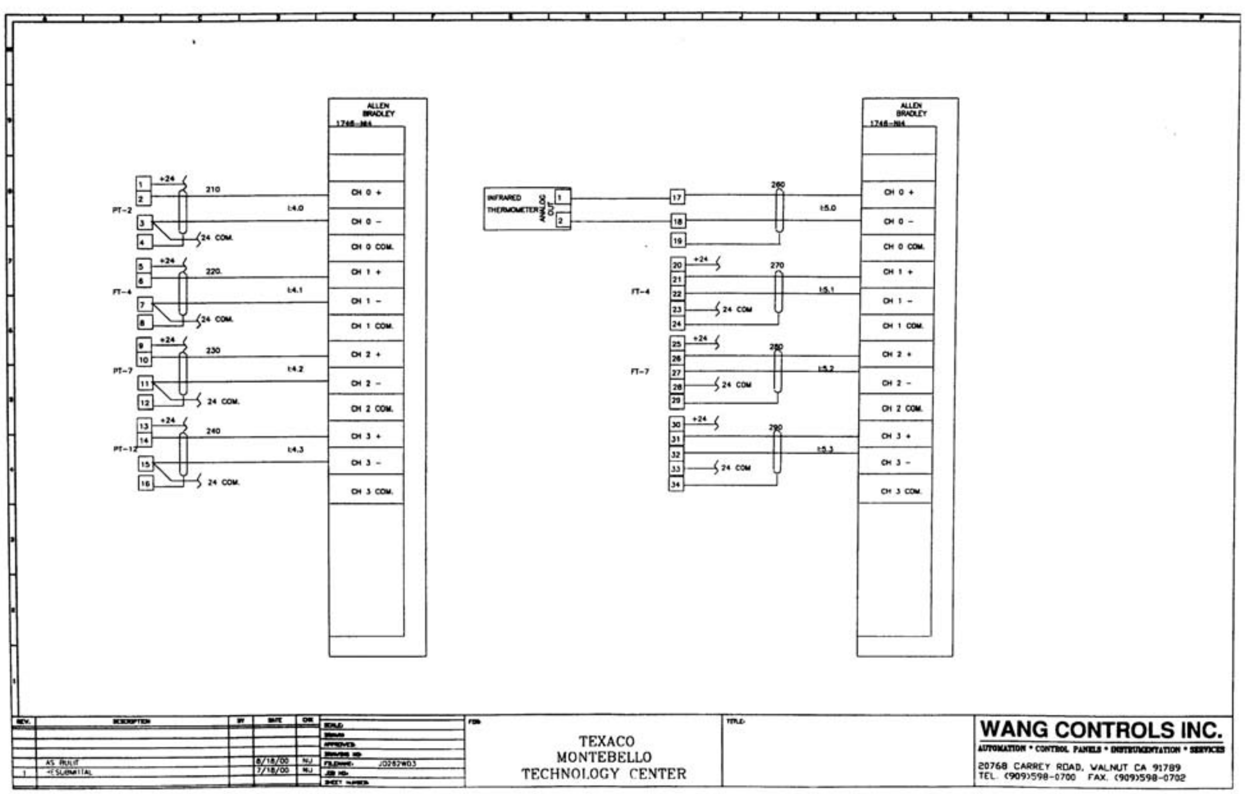


Figure 24 – PLC Connections - 3

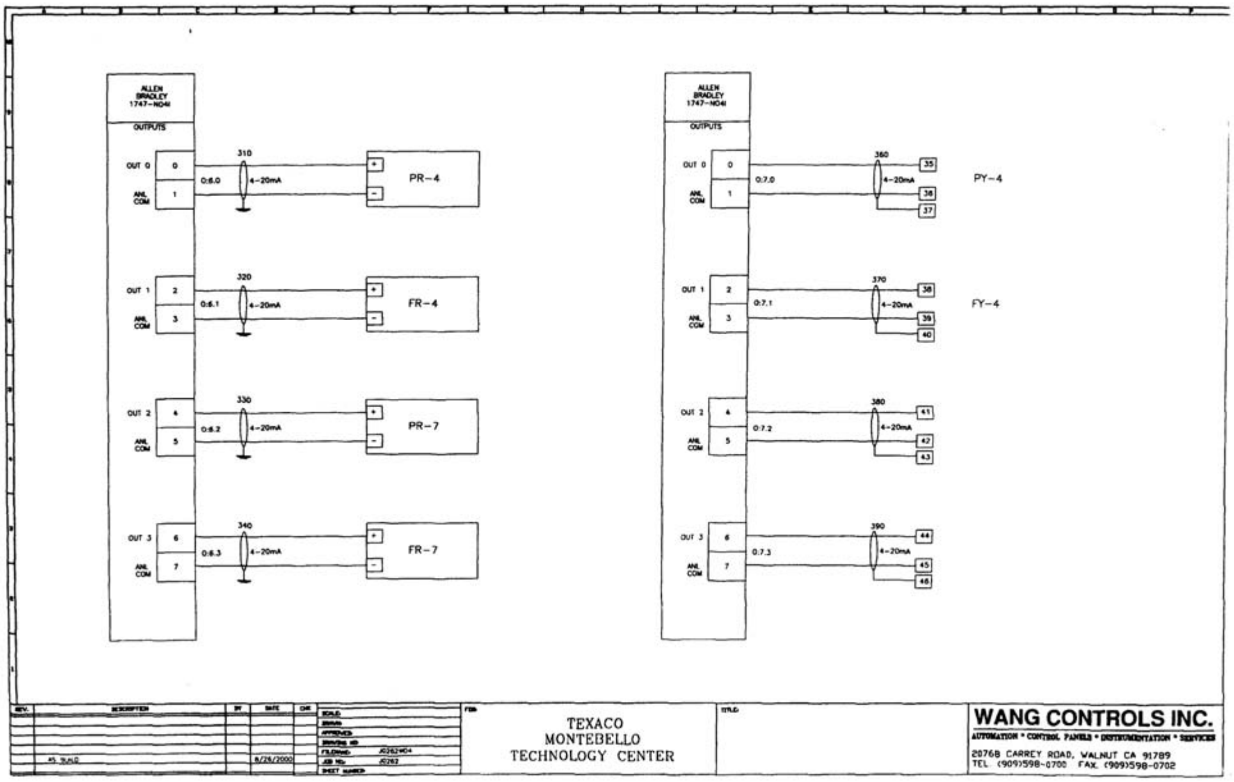
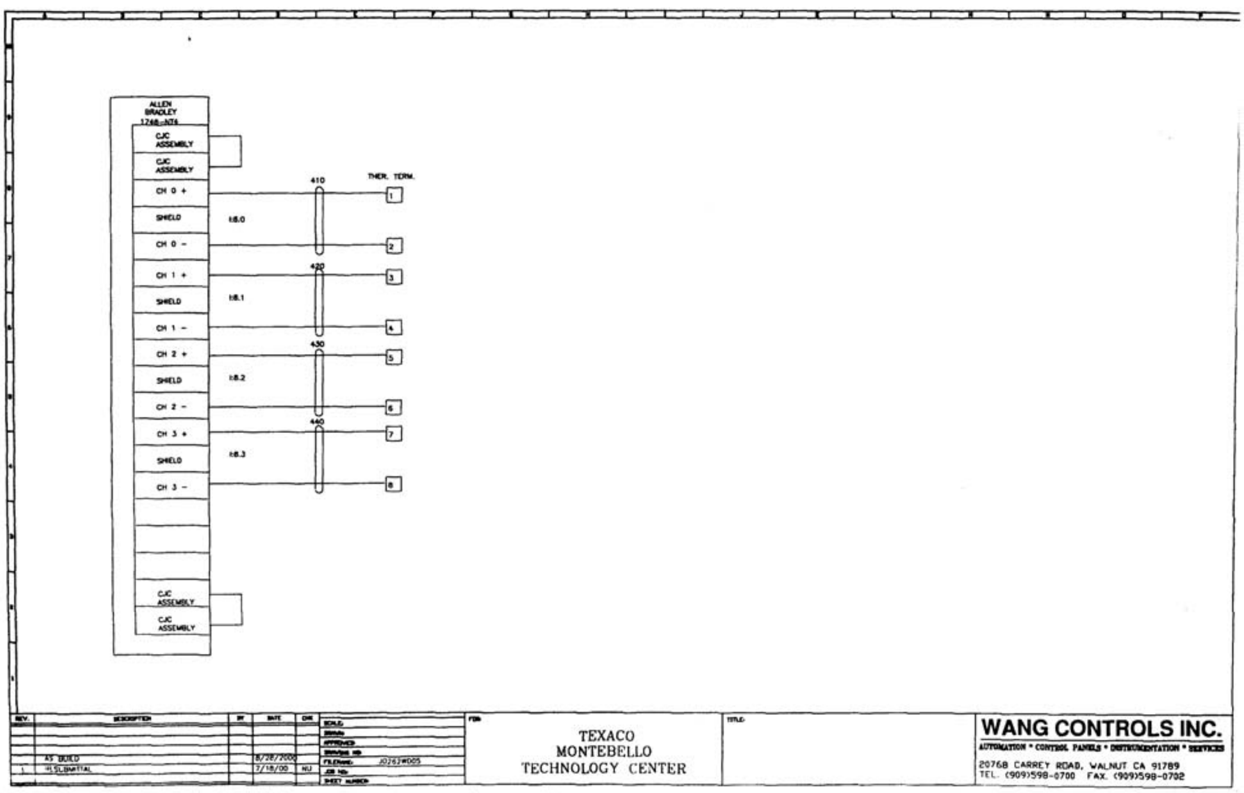


Figure 25 – Connections - 4



Appendix E

UNDER REVIEW – DRAFT COPY

FIELD TESTING OF A TEXACO INFRARED RATIO PYROMETER SYSTEM FOR THE MEASUREMENT OF GASIFIER REACTION CHAMBER TEMPERATURE

a Statement of Work to extend the work of
U.S. Department of Energy
Federal Energy Technology Center
Program Solicitation No. DE-FC26-99FT40684

by
Texaco Inc.
Montebello Technology Center
329 North Durfee Avenue
South El Monte, California 91733

March 29, 2001

1. Introduction

This Statement of Work (Work) is seeking an extension to Cooperative Agreement No. DE-PS26-99FT40565 (Agreement) between the U.S. Department of Energy (DOE) and Texaco Inc. (Texaco) for the design, fabrication and bench testing of a Texaco Infrared Optical Pyrometer System (System). Under the Work, the System would be installed and field-tested at a commercial coal gasification site for a period of six calendar months. The successful completion of such commercial testing should serve as a key milestone in demonstrating the viability of using the System for measuring gasifier reaction chamber temperatures in commercial gasifiers.

2. Background Information

Reliable measurement of gasifier reaction chamber temperature is important for the proper operation of slagging, entrained-flow gasification processes. In an effort to meet this need, Texaco developed and successfully tested an infrared ratio pyrometer system at its Montebello Technology Center (MTC) in the 1980s. The results of this work showed that such a system has a faster response time than both thermocouples and inferential techniques using syngas methane measurements, and provided reliable temperature measurements for longer periods of time when compared to thermocouples.

Based upon the earlier work done at MTC, Texaco entered into the Agreement with the DOE to design, fabricate, and bench test the System.

The tasks under the Agreement included:

Task 1 – Detailed system design and specifications. Drawings, equipment specifications, and design philosophy were reviewed and updated as needed.

Task 2 – Procurement – All required materials were procured.

Task 3 – Fabrication – Customized parts were fabricated as per Task 1.

Task 4 - Assembly and Bench Testing – All materials from Task 2 and Task 3 were assembled and mechanically tested.

Task 5 – Controller Programming and Testing – The control system was programmed and tested in conjunction with the equipment tested in Task 4.

Task 6 – Field Test Planning – Cost estimates to install and operate the system were provided and verbal agreement to host a field test of the System was obtained from one potential site.

A schematic diagram depicting the System is shown in Figure 1. Gasifier temperature is measured using a dual wavelength optical pyrometer camera. The pyrometer camera sites into the gasifier through a specially designed optical site path that also serves to isolate the pyrometer from gasifier pressure.

3. Statement of Work

The purpose of the Work is to extend the scope of work under the Agreement to include the actual field testing of the System in a commercial coal gasification plant. Subject to the mutual agreement of the parties, we propose to conduct all field tests using the coal gasifier located at Tampa Electric Company's Polk Power Station (hereinafter, Test Site). A successful commercial field test of the System would provide reliability and longevity information that is needed to market the System to other plants. DOE funding of the Work would help mitigate the financial risk to the Test Site. By offsetting the Test Site's cost, the Test Site would be more willing to implement the risk of testing of the System.

Following is a list of the new tasks to be completed pursuant to the Work. Several tasks are interdependent of each other and are contingent on factors out of Texaco's control. If the completion of any task is not attained resulting in no field testing of the System, then the last completed task would be considered the final task of the Work. The Agreement would be considered completed and no further requirement of Texaco is needed other than a final report.

Task 6.1 – Test Site Agreement – A Test Site Agreement concerning the installation and testing of the System must be signed and in effect between Texaco and the proposed Test Site prior to any additional work of the System at the Test Site. Texaco shall have no obligation to perform any of the tasks outlined herein unless and until Texaco and the proposed Test Site facility come to terms and enter into such Test Site Agreement pursuant to which the proposed Test Site undertakes to perform, at its gasification facility, the testing obligations contained therein.

Task 6.2 – Packing and Transportation of the System to Test Site - The Programmable Logic Controller (PLC) panel, control panel, pyrometer and associated equipment would be specially packed and crated. The crates would be transported to the Test Site via road transportation. Once on site, the System would be unpacked and checked for damage. To protect the System from the elements, the System would be stored in an enclosed building until installation.

Task 6.3 – Mechanical Installation – The Test Site facility would select and prepare a flanged nozzle on the side wall of the gasifier to accommodate the System. Modifications would also be made to the gasifier structure in the neighborhood of the selected nozzle to allow installation and operational access to the System. Except for the pyrometer camera, the shutdown valve, and associated spool pieces, major System components would be installed, including the makeup of all required interconnections for instrument air, low-pressure nitrogen, and high-pressure nitrogen between the various components of the System.

Task 6.4 – Electrical and Instrumentation Installation – The Test Site facility would run lines to connect the System to the headers for instrument air, low-pressure nitrogen, and high-pressure nitrogen, as well as the electrical lines, including running all instrument cables between the System and Test Site facility’s control room.

Task 6.5 - Distributed Control System Integration – The pyrometer PLC system would be integrated into the Test Site facility's Distributive Control System (DCS) system. New control screens would be created and tested. Programming would be done to allow data collected via the DCS to be historized. This work would require close coordination between Texaco and the Test Site facility.

Task 6.6 - Training – Texaco would provide operations and maintenance training and procedures for the System to the Test Site facility's personnel.

Task 6.7 – Final Installation and Start-up – The pyrometer camera, shutdown valve, and associated spool pieces would be installed, leak checked, and the System would be activated. Initial trouble shoot testing during commercial operation would be performed. The actual date of this task would be subject to Test Site facility approval. If the Test Site has not allowed start-up of the System by the end of calendar year 2001, the completion of Task 6.7 would be considered not attainable and Tasks 6.8 and 6.9 would be omitted.

Task 6.8 – Monitor Commercial Operations – The commercial field test of the System would last six calendar months. Texaco would provide technical support throughout the field test, including up to thirty personnel days of on-site assistance. Data only pertaining to the pyrometer temperature and thermocouple temperature would be recorded for analysis by Texaco. The Cooperative Agreement would require the Test Site facility to record data pertaining to the pyrometer temperature and thermocouple temperature during the field test.

Task 6.9 – Pyrometer System Performance Evaluation Report – Prior to commencing any testing Texaco shall submit a TEST Plan, for comment, outlining the tests to be performed and results anticipated. After completion of the field test, Texaco would compile a report for the DOE describing the results of the field tests, including conclusions and recommendations. Data to be included in the report would include:

- Delta System Temperature vs. Gasifier Thermocouple Temperature
- On-stream time of the System as a percentage of total gasifier run time during the field test
- A summary of key System problems encountered in the use of the System during the field test

No other data pertaining to the gasifier's operation or performance would be provided. Either Texaco and /or the Department of Energy could report the results publicly through a publication and/or presentation.

Proposed Time Schedule

FY 2001 to 2002 ⇒ TASK 6.X	Q3 (4/01-06/01)			Q4 (7/01-9/01)			Q1 (10/01-12/01)			Q2 (1/02-12/02)		
6.1 – Cooperative Agreement	X											
6.2 – Packing and Transportation of the System to Test Site	X											
6.3 – Mechanical Installation	X	X										
6.4 – Electrical and Instrumentation Installation	X	X										
6.5 – Distributed Control System Integration		X										
6.6 – Training			X									
6.7 - Final Installation and Start-up*			X	X								
6.8 – Monitor Commercial Operations			X	X	X	X	X	X	X			
6.9 – Pyrometer System Evaluation								X	X	X		

* Actual date of final installation and start-up is dependent on the Test Site facility operations

4. Cost estimate

The cost estimates for the field testing of the System were developed jointly by the Test Site facility and Texaco personnel.

Task 6.1 – Test Site Agreement No Cost

Task 6.2 – Packing and Transportation of the System to Test Site
Labor - Packing $ 500
Material - Packing $1000

Transportation		$3000
Unpacking		<u>$ 500</u>
	Total	$5000

Task 6.3 – Mechanical Installation

Material – Hanger Support		$2000
Material – Platform Steel and Piping		$5000
Material – Miscellaneous (Tbg, etc)		$1000
Labor		<u>$13,000</u>
	Total	$21,000

Task 6.4 – Electrical and Instrumentation Installation

Material – Cable		$2000
Material – Conduit		$2000
Material – Support of Conduit		$1000
Material – Miscellaneous		$ 500
Labor		<u>$25,000</u>
	Total	$30,500

Task 6.5- Distributed Control System Integration

Material – PLC Card – 50 points		$2000
Material - Miscellaneous		$ 500
Labor – Program DCS Screens		$6000
Labor – Test PLC and DCS interactions		$5000
Travel Expenses		<u>$3000</u>
	Total	$16,500

Task 6.6 – Training

Material – Booklets and Copying		$ 200
Labor – Texaco Preparation Work		$2500
Labor – Texaco Facilitation of Class		$4500
Labor – Site Personnel Time in Class		$2500
Travel Expenses		<u>$4000</u>
	Total	$13,700

Task 6.7 – Final Installation and Start-up

Material – Block valve and Misc Items		$3500
Labor – Texaco Start-up Team		$18,000
Labor – Site Personnel Start-up Team		$3000
Travel Expenses		<u>$9000</u>
	Total	$33,500

Task 6.8 – Monitor Commercial Operations – 5 Trips

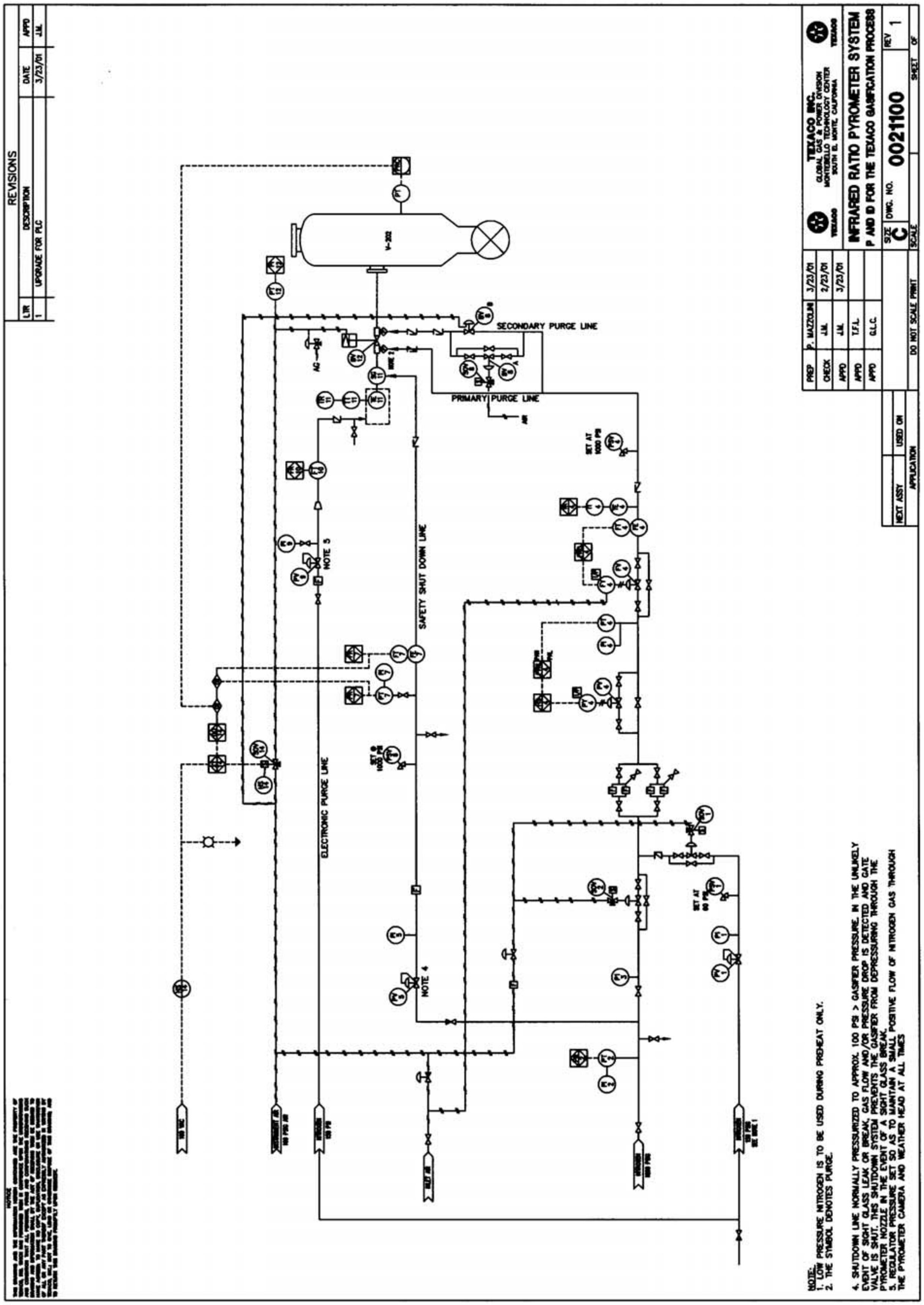
Material – Parts as needed		$1000
Labor – Texaco Personnel		$10,000
Labor – Site Personnel		$2000
Travel Expenses		<u>$7000</u>
	Total	$20,000

Task 6.9 – Pyrometer System Performance Evaluation Report

Labor – Final Meeting		$4000
Labor – Report Writing		$5500
Labor – Review and Disposition		$1000
Disposition of Equipment		$6000
Travel Expenses		$2000
	Total	$22,500

Grand Total	$158,700
DOE 80 %	$126,960
Texaco 20%	$ 31,740

Figure 1


REVISIONS
UPGRADE FOR PLC
3/23/01
TEXACO INC.
INFRARED RATIO PYROMETER SYSTEM
P AND ID FOR THE TEXACO GASIFICATION PROCESS
0021100
DO NOT SCALE PRINT
V-202
SECONDARY PURGE LINE
PRIMARY PURGE LINE
SAFETY SHUT DOWN LINE
ELECTRONIC PURGE LINE
NOTE 4
NOTE 5
NOTE:
1. LOW PRESSURE NITROGEN IS TO BE USED DURING PREHEAT ONLY.
2. THE SYMBOL DENOTES PURGE.

March 29, 2001

James Watts
Department Of Energy
626 Cochrans Mills Road
Bldg 922 Room 327
Pittsburgh, PA 15236

RE: Statement of Work – Field Testing Texaco Ratio Pyrometer
DE-FC26-99FT40684

Dear Mr. Watts,

Enclosed is the Statement of Work to extend the Department of Energy's Project DE-FC26-99FT40684. Under this extension, field testing of a Texaco infrared ratio pyrometer system for the measurement of gasifier reaction chamber temperature would occur.

Texaco infrared ratio pyrometer system was successfully operated at the Montebello Technology Center facilities in the 1980s, but in order for the equipment to gain commercial acceptance, a successful commercial demonstration is required. Texaco is requesting that the Department of Energy accept the enclosed Statement of Work to help mitigate a test site's financial risk of testing the Texaco infrared ratio pyrometer system.

In the Statement of Work, a list of tasks to be executed is shown. Several of these tasks are interdependent and contingent on factors outside of Texaco's control. In the event that the completion of these tasks cannot be attained, the last completed task would be considered the final task in the Statement of Work. Texaco would then provide a final report, and the Department of Energy's Project DE-FC26-99FT40684 would be complete with no further obligation by Texaco.

Texaco has approved its share of the proposed funding in the event the extension is granted.

If the Department of Energy accepts the Statement of Work, please so indicate by providing to Texaco a modified Notice of Financial Assistance Award of DE-FC26-99FT40684. If there are any questions, please contact James Mudra at 562-908-7380.

Sincerely,

Gary Chapman
Manager, Technology Asset Management

JM/

Enclosure (Statement of Work)