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**FURNACE FLAME/TUBE ANALYSIS PROPOSAL
FOR**

Hydrogen Reforming Furnaces

The information contained in this proposal is intended to detail the Canty method for temperature analysis as well as describe the features of the system, with respect to hardware and software, that make it unique for high temperature applications. After reviewing the proposal one should be familiar with the following capabilities of the Canty High Temperature Vision systems:

1. Temperature analysis capacity for all areas of the image, not just single point.
Multiple zone capability for user customization of analysis.
2. Flame detection and size measurement
3. Detection of tube movement and ability for software to automatically move measurement zones as tubes distort.
4. Camera design requires no cooling of the internal lenses. Cleaning gas not required either in a clean, hydrogen atmosphere. This saves on consumption of air and the life of the lens is not reliant on an air supply.
5. EXP system rating available – Class 1, Div 1 B,C,D
EEx d IIC T6
6. OPC data output
7. Administrator/Operator software structure

Furnace Tube Temperature Specification

- I. Introduction
- II. Scope of Proposal
 - A. Required Performance
 - 1. View Burners for flame existence/quality
 - 2. View Tubes for Temp/Trend Analysis
 - B. Process Conditions
 - C. Cauty Experience
 - D. Imaging Process/Benefits
 - 1. Multiple analysis zones
 - 2. Full zone analysis, not single point
 - 3. Real Time Trending, Historical data
 - E. Furnace Model w/Camera views
- III. Equipment
 - A. Hardware Design Features
 - B. Software Design Features
 - C. Utilities
 - D. Installation
- IV. Calibration Procedure
- V. Project Proposal
 - A. Equipment Itemization
 - B. System Schematic
 - C. Installation
 - 1. Customer Requirements
 - a. Nozzles
 - b. Wiring
 - c. Bench Test
 - d. Utilities
 - e. Installation
 - 2. Cauty Requirements
 - D. Proposal Summary
- VI. Appendix 1 – E20 Calibration
- VII. Appendix 2 – Tube Temperature with test Results
- VIII. Appendix 3 – Flame Monitoring with Results
- IX. Appendix 4 - High Temperature Camera Manual

I. Introduction

This proposal addresses scope and details for a vision monitoring system intended for installation in a hydrocarbon reforming furnace. Documentation herein describes the Canty system and its design and operating features, proposal for installation to meet customer needs for monitoring and the calibration methods used for the on line measurement.

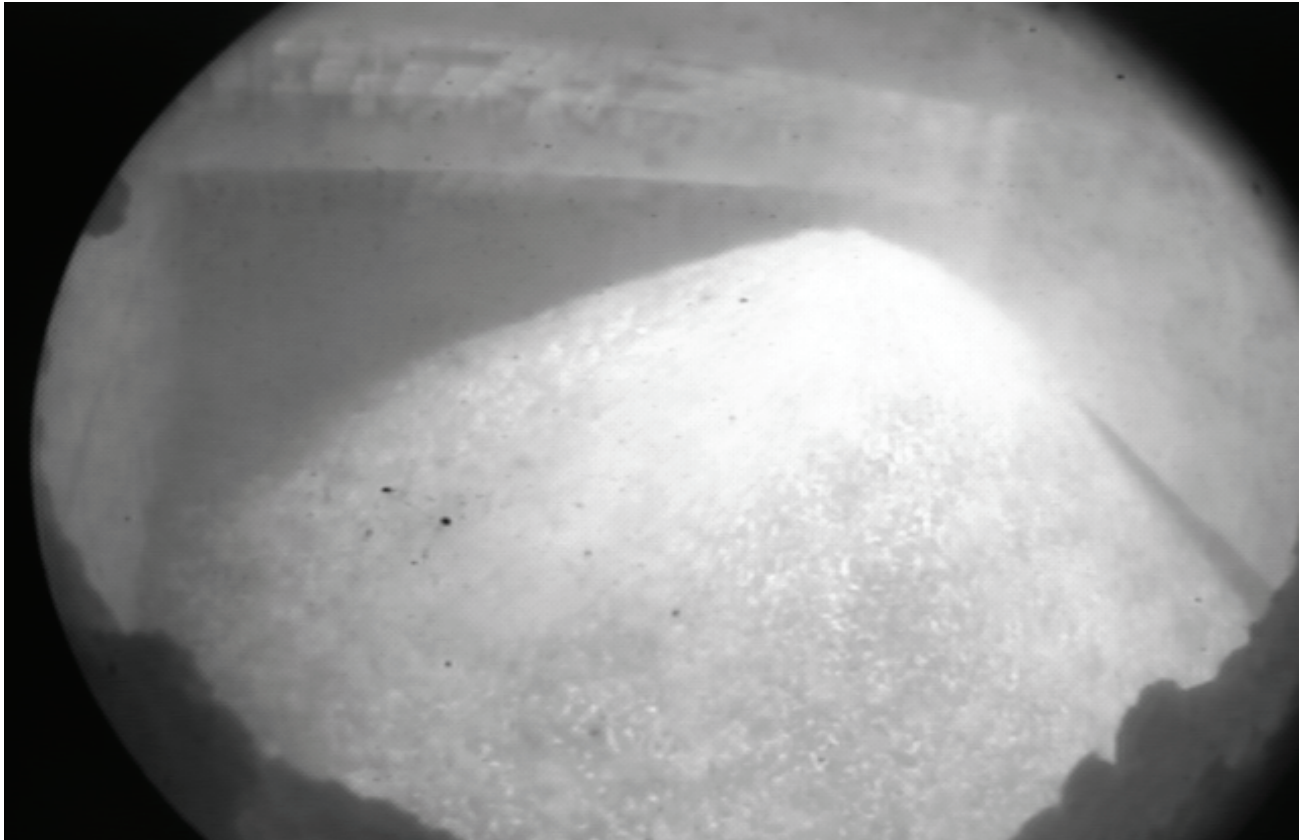
II. Scope of Proposal

A. Required Performance

1. The primary goal is to be able to monitor the burner performance to detect flame as a minimum and possibly flame quality.
2. In addition it is also desired to be able to monitor tube temperature in the lower half of the furnace and see trends as operations proceed.

B. Process conditions are expected to be approximately 2000 F with a maximum of 2200 F. Temperature at the refractory wall is likely to be ~1800 F, but could see excursions to 2200 F. The furnace burns hydrogen and is therefore expected to be quite clean without the need for any cleaning air to protect the camera view from airborne particulate.

C. Canty Experience – JM Canty has long been a provider of high temperature vision systems for industry. The unique design does not rely on cooling air to maintain the integrity of the system. Components exposed to the severe process conditions are intended to survive on their own unlike other systems which can be destroyed when an interruption to the air supply occurs. The electronic housing is separated from the process side insertion lens by a fused glass, hermetically sealed window preventing any migration of hot, process gasses out of the chamber. This design follows Canty's long engineering philosophy of designing in maximum durability and safety fostered many years ago when a large part of the business was dedicated to the design of pressure vessels for human occupancy (ASME PVHO) and associated devices such as lighting and camera systems for these vessels. Canty also has experience in designing systems for vessels containing lethal products, which like pvho vessels, require 100% containment of the internal atmosphere. Images are included showing past installations for reference.



Lime Cooler Box



Incinerator Flame

D. Imaging Process and Benefits

1. Multiple Analysis Zones - Analysis by vision has some interesting benefits in monitoring tube performance. Unlike traditional point and shoot systems, the zone of analysis is decided by the operator. The zone can cover as much or little of the tube in the view as desired. The data then collected can be filtered and analyzed to best describe the process performance of the tube. For instance, threshold settings can be used to trigger alarms when hot spots occur.

All portions of the screen view can be zoned and monitored, so for a bank of tubes in the view, each can have an analysis zone(s) placed on it. For more detailed information, a single tube can be covered by multiple zones in order to get more resolute information in the axial direction.

It is also possible to monitor tube distortion with the Canty system. During the analysis cycle, the location of the tube can be tracked from its original position. Tube movement can indicate variant conditions inside the furnace and tracking and storing the information for historical reference can improve furnace performance. With this feature, the temperature measurement zones can be moved as the tubes move in order to maintain best accuracy.

2. Full Zone Analysis – all information within the analysis zone is used to provide output data. Data can be averaged for mean temperature sorted for hot and cold spots or both. Location information is available as well so the information can be further analyzed by the operator.

3. Real Time Trending / Historical Data

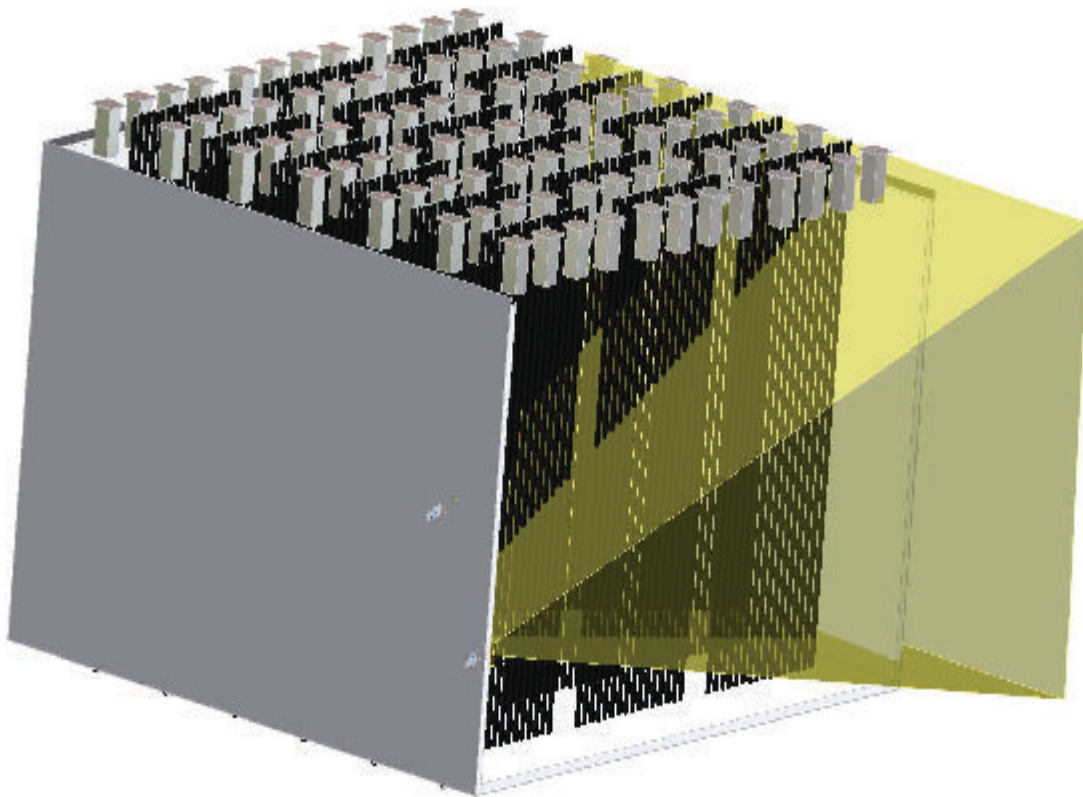
Since the vision system remains fix mounted to the furnace and always viewing the process, results are real time. Analysis points remain the same so software can then trend data over time to provide insight on performance and possible degradation. This data can also be stored for future reference and historical record.

E. Furnace Model – the following model is provided to better describe the camera views and positions to accomplish the monitoring of all tube and burners. It will be provided as a separate file so you can view through your 3D CAD program. The included view here shows a cut away of the furnace fully exposing a line of burners and a line of tubes. The upper camera views a half row of burners on the opposite end of the furnace. The lower camera views a half row of tubes on the opposite end of the furnace. Cameras are positioned for best perspective of their intended targets. Cameras selected are all Canty 12” HighTemp Insertion models.

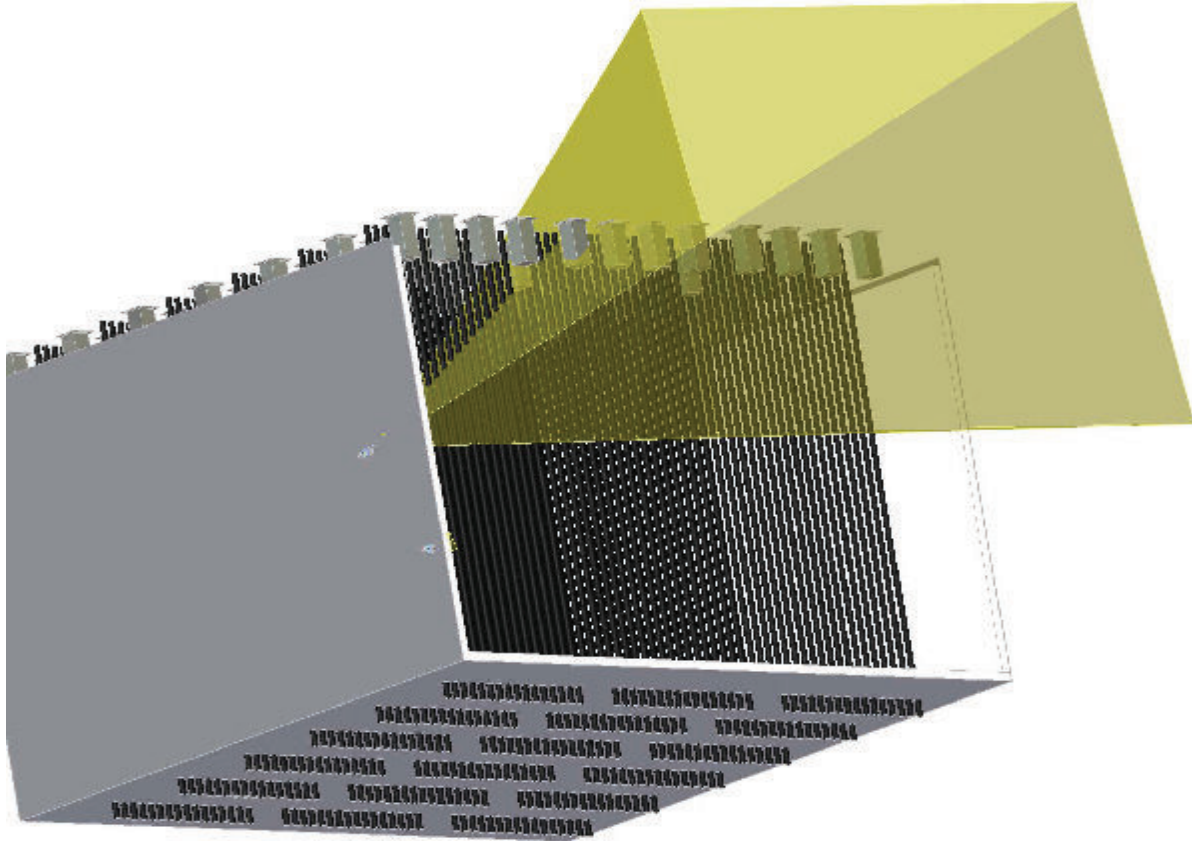
Burners: 7 rows x 2 cameras per row = 14 cameras
Tubes: 6 rows x 2 cameras per row = 12 cameras

Total: 26 cameras per furnace.

The following models show an iso view of the tubes and burners and how cameras mounted at one end of a row will see each. It is from these layouts that the total number of cameras to be used has been determined.



Iso View of Furnace Interior – Gold shaded area indicates view of tubes.



Iso

View of Furnace Interior – Gold shaded area indicates view of burners.

III. Equipment

The following equipment is anticipated in order to fulfill the performance requirements:

- Canty 12" High Temp Cameras
- Canty Vector Processors w/software.

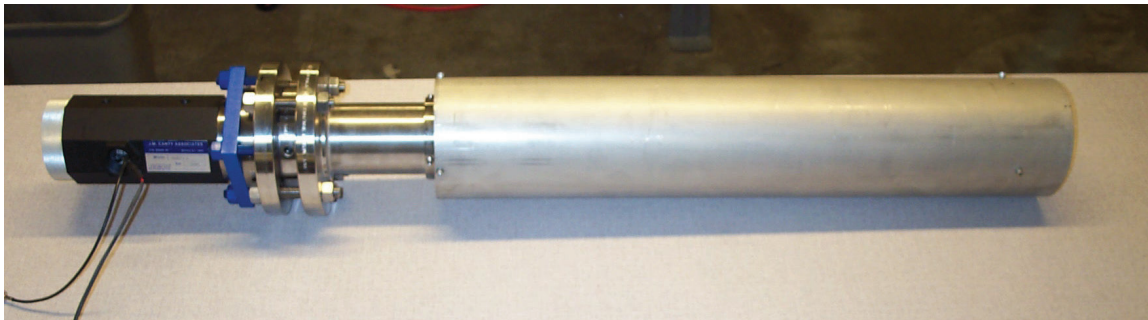
A. Design

The design of the camera system is unique in that it's internally exposed lens assemblies are **designed to survive without cooling air**. When installed properly, the combination of system materials and heat transfer coefficients at the camera tip limit heat transfer to the system and allow it to run hot without chance of damage. This feature, when system is installed in a clean, gas burning environment, does not disrupt the temperature or air balances of the furnace because no cooling air is being introduced to the furnace.

In addition, the design includes a disposable, quartz shield which protects the process exposed lenses from direct contact with the internal atmosphere. Should any particulate contact the system, the quartz shield is there to protect the optical lenses. Replacement of the protective quartz shield is inexpensive. Replacement of damaged lenses is very expensive and so the Canty design guards against that possibility.

Internally, the system is a two piece assembly consisting of the internal insertion lens and the external camera package. As mentioned earlier in this

document, Canty employs a fused glass window as part of the electronic housing package. This has a dual purpose; First the camera housing assembly is a separate entity which carries WP and EXP ratings. Secondly, the camera housing bolts to the internal lens system and transmits the optical rays through the fused glass window to the CCD. This mounting also creates a hermetic barrier between the process and the electronic housing thereby preventing migration of hot, process gasses outside the pressure boundary of the system.



High Temp Camera Assembly

Finally, the camera electronics come with a full array of controls that allow it to be optimized to the software function to achieve accurate, consistent data output. For reference, the High Temp Camera data sheet is included with this proposal.

B. Software Design Features

Canty software engineers continually work to improve software algorithms to be able to gather more information from the video images captured. As a leader in the industry, Canty also participates with others to share knowledge and develop monitoring systems that better serve the needs of the furnace operators. In that regard Canty consults with groups such as Prosensus Inc and Laurentian University on various issues relating to hardware and software. These activities enable us to have a broad view of the industry and to better prepare our product for the services operators desire most.

With respect to design, the Canty software is fully flexible in analyzing any portion of the captured image. Multiple analysis zones can be drawn to monitor discreet areas of the view and each zone can run it's own particular algorithm depending on need. The benefit here is that multiple tubes can be continually surveyed for changes and trends. The analysis data is also not single point, but is comprised of all the data points in the analysis zone. By choosing proper software filters various information can be obtained from the full array of data such as hot or cold spots. This data can also be archived in total or as snap shots at determined increments of time. The on screen data output can also be updated in the short or near term and can thus be used to judge what is happening in the furnace over time with just a glance at the screen. For instance, using the histogram feature with a 1x daily output a long term trend can be presented on screen in real time.

C. Utilities

Required utilities to operate the Canty camera system are as follows:

- Electrical: 120 VAC, 60 Hz, < 1 A
- Electronic Housing Air (If needed): 8 SCFM max, clean, dry, oil free air (~40 psi at housing).
- Cleaning Air – Not needed for Hydrogen fuel furnace.

D. Installation

The system installation is an integral part of the design. It is not hard to do, however it must be done correctly to optimize the system's performance.

Canty can advise on installation preparations. In short, the primary considerations are as follows:

- Install cameras through refractory with a snug fit as shown in the following excerpt from the installation manual. Lens should sit back from the inside refractory surface as far as possible without causing tunneling of the view.
- Make sure installed nozzles are aimed at the area of interest in the furnace so the view is optimal.
- Make sure any air supply is clean, dry and oil free. Canty supplies an FRL with 5 micron filter to ensure this, however good source air will allow the filter to run for long periods without clogging.

INSTALLATION INSTRUCTIONS

Insertion High Temperature Vision Systems

If the high temperature vision system features an insertion of any length , please reference this section for mounting details. If the camera purchased has no insertion lens, skip this section and proceed to 3D.

3A) WALL MOUNT TUBE INSTALLATION

If your camera system includes a Canty wall mount tube, the system is factory assembled and aligned. A typical camera assembly is shown in Figure 7. Typical welding installations are shown in figs 1 and 2. The unit does not have to be disassembled for welding if it is properly protected. The camera system must be protected from hot weld spattering on any of its parts. All warranties will be void if any spatter is found on any of the components.

• Prepping

- The wall mount tube has a nominal 3.5" outside diameter. A mounting hole must be made in the vessel\refractory where the unit is to be mounted. The hole must be slightly larger than the O.D. of the wall mount tube and machined at the desired angle to match the ideal line of sight for the camera. The mounting hole must have

an unobstructed path from the flange to the inner wall of the chamber. The depth of the hole **cannot be shorter** than the length of the mounting tube.

- After machining, be sure to repair any refractory that has been damaged.

- Welding

- The wall mount tube must be inserted to the correct depth into the door or refractory wall. See figures 1 and 2 below for optimum installation tips. *The wall mount tube must be welded at a depth so as not to protrude into the flame, and should be mounted flush with the inside wall of tank, pipe or vessel . If the wall mount tube is too short, or is not welded in deep enough, you will see "tunneling" on the video picture.* (Be sure the spray tube does not protrude into the flame). It may be up to 2" shorter without any loss in picture quality.

- The required weld is typically a 3/16" fillet weld. Consult your plant specifications for the type of weld required for the application.

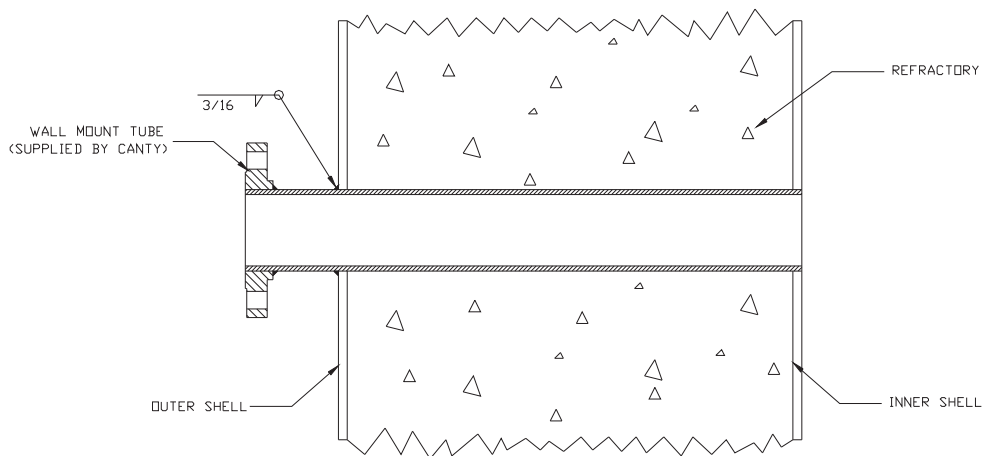


Fig. 1 Wall Mount Tube Welding Detail - Perpendicular Mount

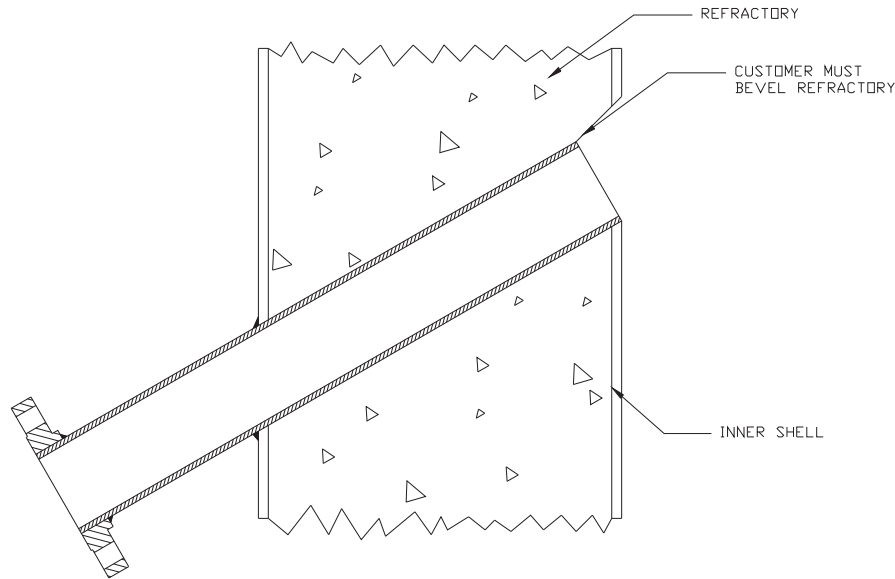


Fig. 2 Wall Mount Tube Welding Detail - Angled Mount (D9169)
 Note: Refractory must be beveled to prevent tunneling of image

IV. Calibration

Calibration of the vision system is via in situ comparison. Once installed, the vision characteristics of the system will not change. At this point, the calibration curve can be created by comparing readings of the vision system to readings of a calibrated IR device or installed thermocouple. The software will then extrapolate a calibration curve that will remain unchanged. The test method which correlates a vision system to E20 requirements is included for reference as an appendix.

The calibration will not change as long as the installation does not change. A calibration device will be included so the CCD package can be changed out without changing calibration of the entire system.

V. Project Proposal

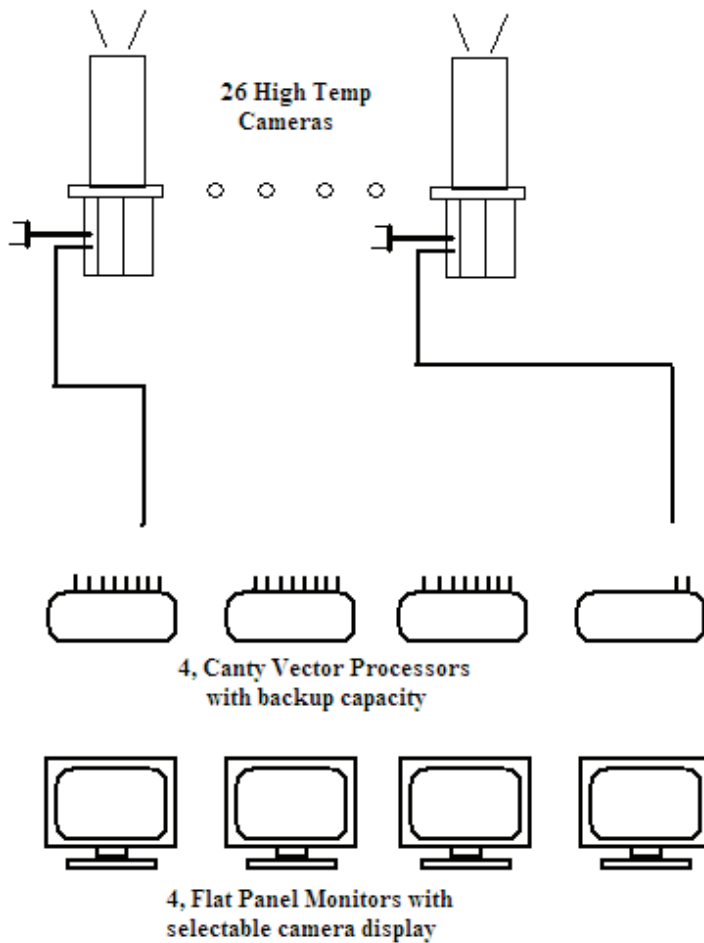
A. Equipment

Canty proposes a two tiered camera installation to cover the desired range of view. The upper camera installations will mount just under the burner flame projection and will look up at a slight angle to view the flames. In order to cover all the burners in a row, two cameras per row are proposed ($7 \text{ rows} \times 2 = 14$ Burner cameras). The view of a burner camera is illustrated in the Furnace Models included previously in this document.

The lower camera installations will view the tubes between the furnace elevations of $\sim 23'$ and $\sim 42'$. Again, see the Furnace Models included earlier in this document. In The furnace design depicted, there are 6 rows of tubes and 2 cameras per row are proposed for viewing. Total = 12 tube cameras.

Canty will also provide four (4) Vector computer systems for video analysis. System will be set up so that each of 3 computers can analyze 8 cameras each with a 4th system analyzing 2 cameras and acting as a back up for any one of the other three. Likewise, any of the other three will be able to take on the 2 cameras of the 4th unit should it be removed from service for maintenance.

B. System Schematic



C. Installation Responsibilities

1. Customer

a. Nozzle Attachment- The camera mounting nozzles supplied by Canty must be installed per the installation manual (see previous section III,D). It is also important that the nozzles be correctly aimed so the cameras can see the intended points of interest. Canty can assist in this endeavor and has already included draft camera/view layouts in this proposal.

The nozzles are to be welded into the furnace skin and fit snugly within the refractory. The camera system then slides into the mounting nozzle and fits properly and optimizes operation.

b. Wiring – the camera systems come with power supply units that must be positioned and wired for power. Video cable runs back to the control room are also required for each camera.

The Vector systems and monitors will reside in a control room environment. Both plug into wall outlets. Canty recommends a UPS system for the Vectors in order to avoid surges and system shutdown from the full operational condition.

c. Utilities -

d. Inspection and Bench Testing – When the systems are received they must be bench tested prior to installation to assure system integrity and focus after shipment. It is easier to make adjustments prior to installation within a controlled environment. The manual will instruct on set up and check out.

e. Installation – After the previous steps are completed the camera is ready to install. Follow the recommendations in the manual to complete the hook up. If furnace is operational, air hookups should be made and operational prior to camera installation. For hydrogen or natural gas fired furnaces, only air to the electronic housing may be needed. Ambient temperatures may be such that no cooling air is needed for the housing. Supply it to start and reduce as possible. It is best to keep the internal temperature of the housing under 110 F for normal operation.

2. Canty Responsibilities

a. Training – primary service Canty supplies on site is after the installation and hook up of the video system. Canty technician sets up and optimizes the software and trains operator personnel on how to effectively use the system. Depending on the physical installation, Canty technician may also make recommendations on installation modifications upon inspection.

b. Installation – Canty can also provide technical help on site to assist installation by supervising and training personnel on proper installation and maintenance.

c. Post installation- Canty provides technical phone assistance for a period of 1 yr. software licenses are renewable yearly after that.

D. Proposal Summary

The following equipment and services are required to complete the installation for this project. All camera models are identical which will simplify support and maintenance.

1. Equipment

Qty 26, VSHDE76C1 – S-3FL150-12INS

Qty 4, VCC5500-LIC

Qty 4, Flat Panel monitor

- 2. Start Up Assistance** – 5 days on site to assist in software set up and training to integrate and operate the entire system.

3. Recommended Spare Parts

The following list details the recommended spare parts to assist in maintaining the system.

- a. 26, Quartz shields
- b. 4, Quartz shield retainers
- c. 2, Ethernet camera modules
- d. 8, Housing o-rings
- e. 16, Graphoil gaskets

Appendix 1. E20 Calibration Routine.

This appendix details Cauty tests conducted to verify repeatability of camera system calibrations. It meets the requirements of the ASTM E20 specification for thermal measuring devices.

Scope:

This method covers temperature measurement by visual imaging systems and includes the following parameters that comprise total system operation:

Equipment Calibration

Repeatability

Response time

Warm up time

Drift

Software

Use:

The method described herein is established to allow valid use of vision systems for temperature measurement in the visual range of the spectrum. Vision systems can detect temperature changes based on intensity of emitted radiation as well as color composition of emitted radiation over the visual portion of the spectrum. For instance, as an object reaches approximately 1000 F it starts to emit a dull, red glow. As the object temperature increases it emits a brighter red and eventually a brighter orange and white color. As the intensity of emitted radiation increases, the detected intensity registered by the CCD increases which can be correlated to temperature vision CCD systems are capable of separating the Red, Green and Blue components of the input to the chip thus allowing a correlation to the temperature of the emitting source. Starting at approximately 1000 F, many substances (grey bodies) emit a faint red color that, with increasing temperature, becomes a brighter red that then changes to shades of orange and then to white. As these colors change in correlation to the body's temperature the CCD device response also changes in a way that can be correlated to the temperature of the body. In addition, RGB systems can be used that mimic the concept of the two color pyrometer; the red and green response curves can be compared to determine temperature. The red curve can also be used by itself as a temperature indicator.

It is important to note that it is preferred that these systems are installed in a permanent, fixed way and view essentially the same process or image field. Calibration in most cases is installation specific. It is also important that image field intensities do not vary widely from time to time. This is generally not the case in an industrial setting, however it can occur and can be a cause for abnormal readings if calibration does not address. Lenses for temperature measurement systems should be narrow angle with preference that the lens just encompasses the area of measurement. It must also be noted that heavy oxide build up, or skin buildup on molten pools, must be avoided as they can mask the product or process temperature.

Lastly, the accuracy of visual measurement systems is based on that of the devices used for calibration (see ASTM Section 14, Vol 14.03).

Equipment:**Imaging device:**

A CCD camera device is the imaging device to be used. All CCD devices have a baseline gain function. Devices used must have a gain selection capability and this must be turned off to achieve minimum image gain.

Lens:

Selection of the lens must accommodate the application geometry. Lens should not be wider in view angle than required to encompass the area or process to be measured. This reduces the likelihood that external radiation sources can influence the CCD.

Camera/Lens Housing:

The housing for the CCD and lens must be maintained in the operating range of the CCD which is generally 0 F – 120 F.

It is recommended that the housing be fitted with a spray ring when operating in dusty atmospheres to prevent product build up on the lens that can interfere with system operation. As an alternative, a frequent PM plan should be instituted to handle any dusting issues.

Reference Temperature Source:

A target capable of generating heat that causes radiation emission in the visual range.

Reference Temperature Measurement Device:

A calibrated thermal device (Thermocouple, RTD etc...)

Data Analysis Capability:

Software to compute temperature from image.

Physical Test Set Up:

The system should be set up as shown below with camera/lens viewing the selected Reference Source.

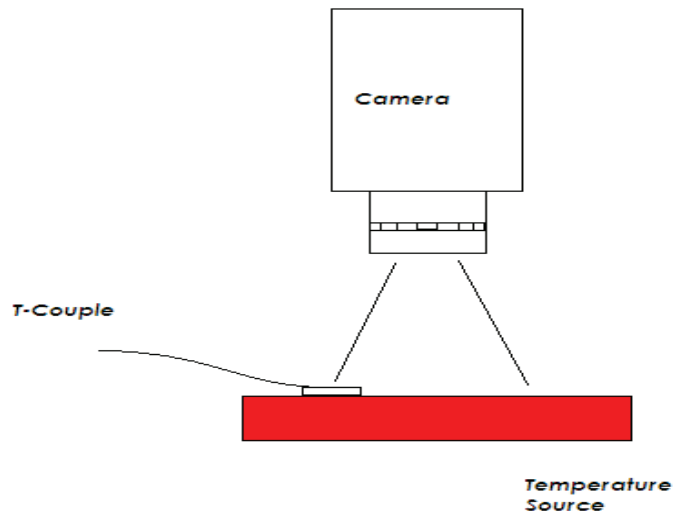


FIG 1. Test Equipment Configuration



FIG 2. Images of target at various temperatures

Parameters to control during the test:

- Internal housing temperature ± 1 C
- Reference source – must be insulated so set point temperature is constant.
- Power to camera – regulate within 1%
- Camera settings – all remain constant and noted in test documentation
- Lens settings – all remain constant and noted in test documentation
- Locate the thermocouple immediately adjacent to the point of measurement

It is important to note that during the testing as described in any category below, the position of the camera with respect to the target must be constant. Ambient lighting conditions must also remain constant for valid results.

Testing:

Warm Up Test:

- a. This method sets out the steps for determining warm up period for the CCD device.
- b. Set Reference Source temperature to a value in the mid range of the span. Allow to stabilize as required. Power camera and take readings every minute and note the time to achieve a stable reading ± 2 F for 5 minutes duration.

Calibration Stabilization:

- a. From a cold start, with camera off for 1 hour in controlled ambient atmosphere (± 1 C), aim camera at stabilized reference target and turn system on. Record temperature every minute until system readings are stable. System is uncalibrated at this point. Duration of warm up must be at least time length determined for warm up test. Once readings are stable proceed with calibration.
- b. To set instrument initially and confirm repeatability and accuracy, place camera and Reference Source in a dark area. Prior to energizing the Reference Source, take a base intensity reading from the camera. Allow reading to stabilize to ± 1 grey scale values. Set Reference Source temperature to 1000 F and energize. Allow reference to reach a stable 1000 F ± 2 F. At this point begin taking temperature readings with the camera/software. Measurement must be stable to ± 2 F.
- c. In approximately 25 degree intervals, increase the temperature of the target and take readings as in (b) above until camera range is exhausted.

Note:

In the field, the above testing will be carried out in the same manner in the installed configuration. To obtain greatest camera range, it is best to set the camera shutter to the low end of the expected scale. By doing this higher temperatures will create greater radiation into the CCD and brighten the image and a full range of the CCD will be useable for maximum temperature range at the particular settings.

Response Time:

- a. This method details steps to determine response time of CCD device when already in the warmed up condition.
- b. Warm up camera to its operational ready state. Make sure camera is targeted at the Reference Source. Place a barrier between the CCD and the source so no input radiation gets to the CCD. Set Reference Source temperature to mid range of the span and allow to stabilize. When stabilized, remove the barrier and record the time to reach a stable temperature reading ± 2 F.

Repeat 5 times from same initial reading.

Repeatability:

- a. This method details the testing for repeatability of the same temperature measurement over a long period of time and in between camera power cycles.
- b. Set Reference Source temperature to the mid range of the expected span. Allow source to stabilize as required (dependent upon source). At the same time power the camera and allow to warm up. Record temperature of Source. Repeat this test 6 times allowing 1 hr CCD cool down in between tests.

Drift:

- a. This method details testing to determine long term drift of instrument over an extended period of operation.
- b. Power Supply – Use regulated power supply for CCD. Maintain voltage at +/- 1%
- c. Power Reference Source and camera CCD and allow both to stabilize. After this point is reached, record temperature of Source and temperature reading by the vision system each hour for 8 hrs. Repeat this test once per month for the duration of the warranty period or the suggested maintenance period. Use same Source temperature each day for testing. Leave camera powered in between test cycles.
- d. Measure drift by comparing standard deviation to +/- 2 F accuracy. Deviation of less than 1.4 is acceptable. If drift becomes greater than +/- 2 F note this test time for system assessment.

Appendix 2 – Tube Temperature with Test Results

Tube Temperature Measurement by Vision

by Thomas Canty, P.E. and Keith DeMonstoy
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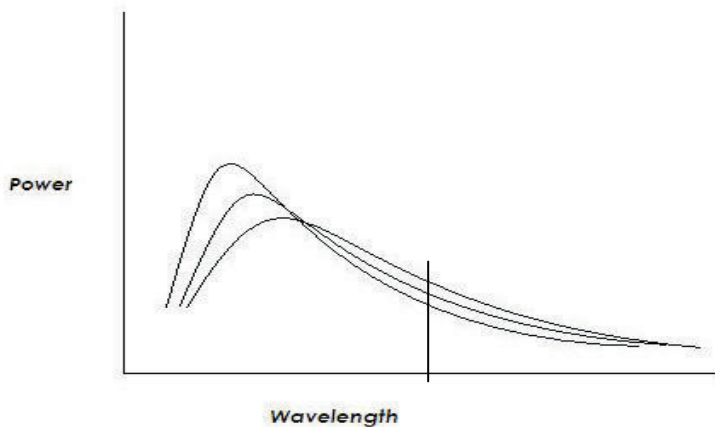
Abstract:

This presentation is intended to provide insight into non contact temperature analysis by vision and how it compares to other non contact technologies as well as traditional contact methods. Vision methods offer expanded instrument capacity as well as flexibility in monitoring the process due to the operator view of the process it provides and the many options available for data analysis.

Non contact means of temperature indication are primarily intended to provide relief from deterioration of traditional contact methods (i.e. thermocouple's etc...), costs of installation and maintenance. Optimum operation of Hydrogen furnaces, Ethylene furnaces and power boilers relies primarily on control of tube temperature to yield best energy efficiency and reliability of the process. It is also critical that hot spots be detected along the tube length in order to prevent an upset condition that will bring the boiler down for repair.

The basic theory is based on the radiative emissions of a body at temperature – as the body temperature increases, the radiation curve shifts towards the shorter wavelengths and that is why as a body heats up the eye cannot detect it until it reaches 1000F which is the approximate visible point where emitted radiation is dark red in color. As the temperature increases, the color graduates to bright red, then orange then toward white.

A pyrometer functions by measuring a narrow band of wavelength intensity and comparing it to the intensity of a black body to determine the temperature. From the graph below it can be seen that if a single wavelength is monitored the intensity of that measurement changes as the body temperature changes (curve shifts) which then corresponds to a different temperature on the calibration scale.



The same is true of a camera system measuring the increasing intensity of an object as it radiates from approx 1000 F (dim, dark red color) on up the temperature scale to 3000+ F for instance which would be a bright white. From the graph above one can see that as color goes from red toward white the peak intensity is always increasing and it is the measure of this intensity which indicates the object temperature. Using an RGB camera the measurement can also be made by monitoring the individual color components of the signal impinging on the chip. For industrial uses, the measurement of intensity usually suffices.

Traditional Technology

Standard instrumentation used in industry include thermocouple type devices (contact) and thermal imaging and pyrometer systems (non contact). In severe temperatures and atmospheres, the contact devices deteriorate quickly and provide gradually less reliable information leaving the operator running blind. They also create a discontinuity on the surface they are welded to which, in the case of a furnace tube, can lead to premature tube failure.

Non contact systems have difficulties with calibration drift and emissivity adjustments to account for the fact that many items being measured are not black body emitters. In addition, these technologies are single point measurement systems and are best used as hand held devices which can be difficult to use and provide subjective measurement results based on operator preferences for targeting.

Vision Technology

Vision technology offers several benefits these other technologies do not. The visual aspect of the system allows the operator to view the process and confirm the readings received. It also allows flexibility to set up measurement zones on screen at any time to assess any or all areas of the process in view should a change be required. Since vision systems are generally fixed installations, an added benefit is that the information is taken from the same process points and features within a given measurement zone at all times which means there is no error in sighting of the instrument.

The vision system is also unique in that it does not suffer calibration drift as almost all instruments do. Once the calibration is set the readings repeat themselves within a couple degrees F. The calibration is based on thermocouple or pyrometer readings initially, however after that calibration is finished it does not have to be redone in the future as long as the system remains in it's location.

Process history and performance can also be best documented by a vision system. First off, the camera can analyze any area of process that is within the systems view. This affords the operator the capability of viewing many points of interest instead of just single point temperature readings. As an example, if the system is monitoring a tube bank it can assess the temperature of the tubes for the full length of view. If there is a local flow problem in a tube it will become overheated in one section. The camera can locate that section and indicate it's temperature rise over the rest of the tube or adjacent tubes. This information allows the tube location to be identified as well as the position in the tube that has encountered the upset condition. Over time this historical data, recorded in video or still image format by the control software, may be significant in improving the process. In addition to the ability to monitor the full area of the view, the full area of view can also be segmented into multiple zones of measurement, i.e. each tube having it's own measurement zone for automated process control capabilities. This capability allows the tube to be operated at optimum efficiency since the addition of excess heat can be avoided thereby reducing energy draw to operate the furnace.

System Demonstration

Run Video Here - <http://www.jmcanty.com/video.html>

Following are typical images of a metal rod heated in the near IR range and into the visible range. The first image shows the rod at 850 F which is imaged by the IR capabilities of the system. Also shown on this image are typical measurement zones. As can be seen, these can have any size or direction at the will of the operator and allows measurement of any area in the field of view. The second image shows the rod as it reaches 1000 F. Obviously the higher intensity radiation in the visual range creates an appropriate response by the CCD chip.

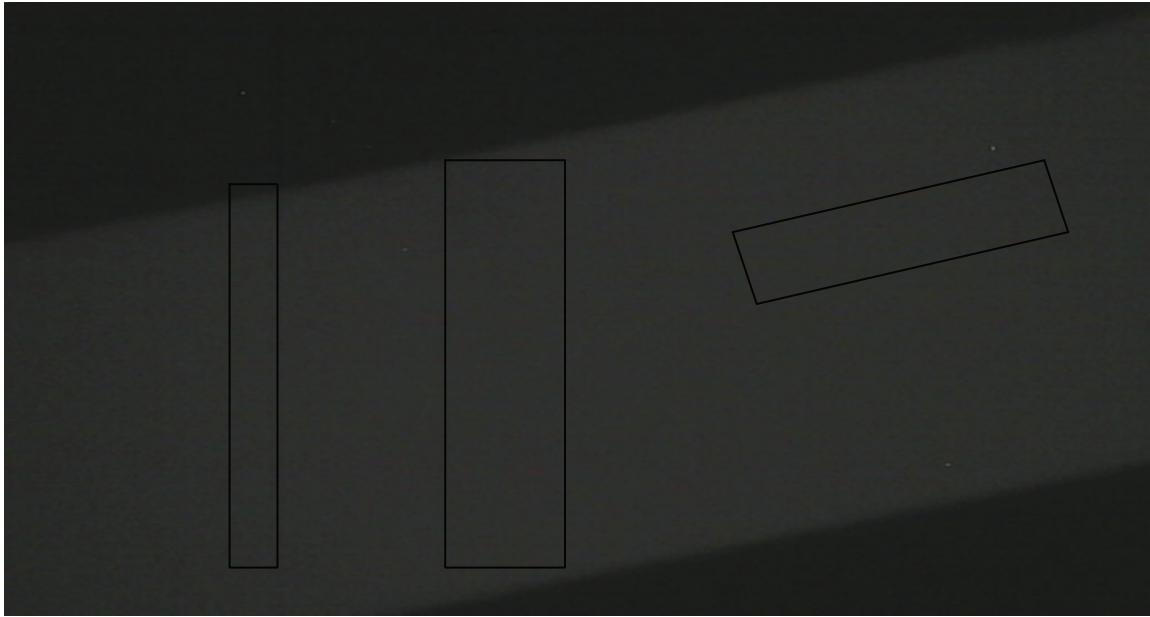


Image of element at 850 F

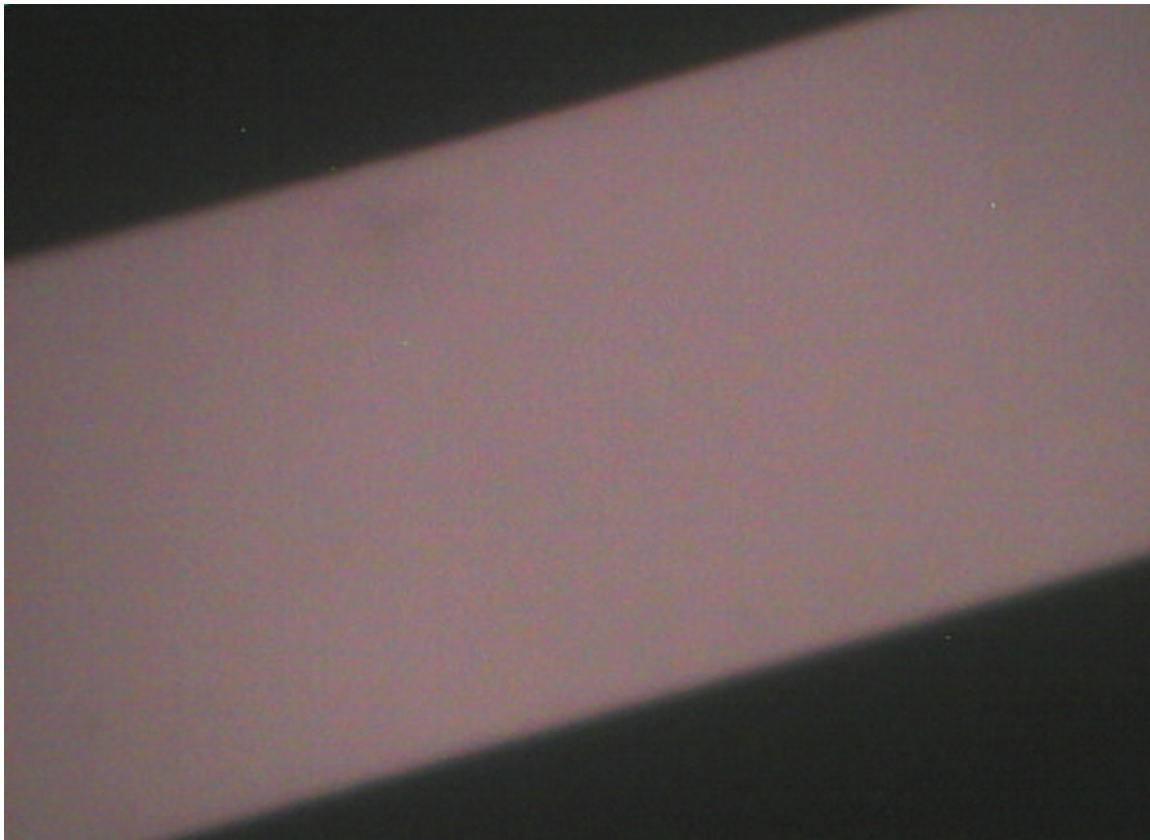
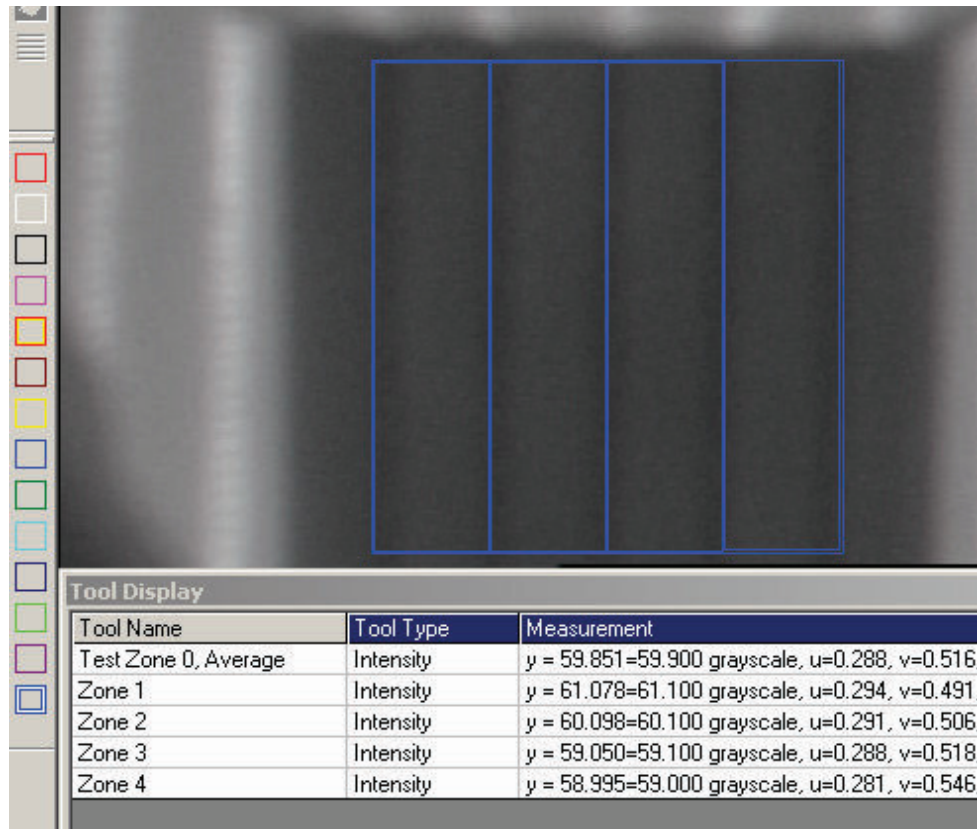


Image of Element at 1000 F

Performance on Tube Array

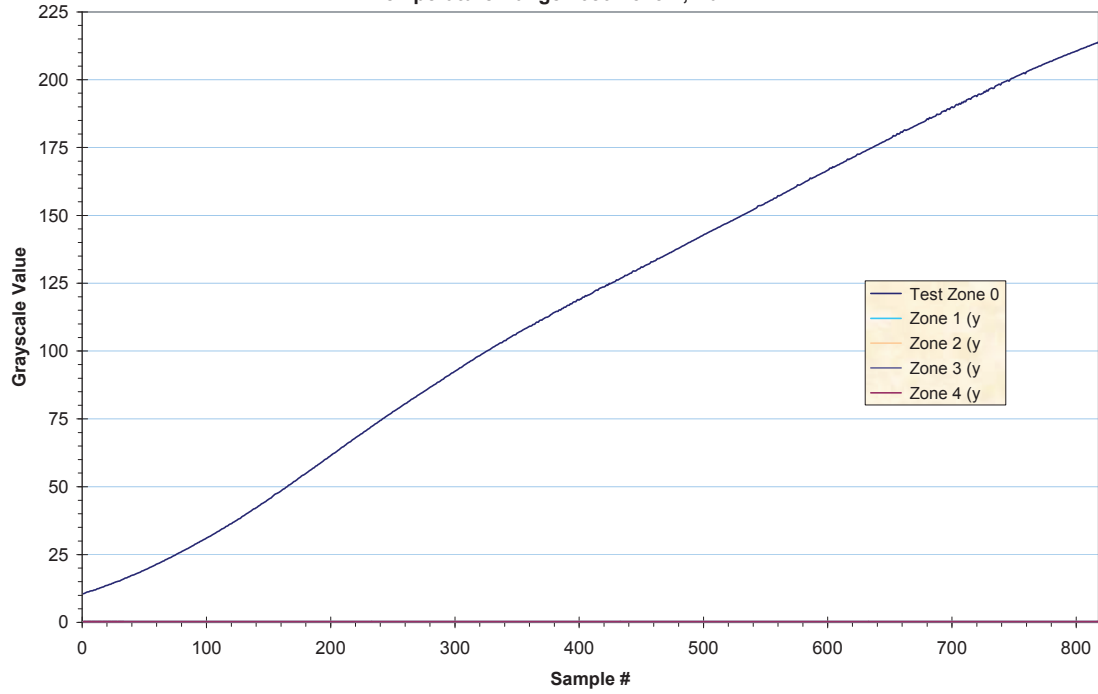
The following shows an image of a tube array with four measurement zones configured on 4 of the tubes. The measurement readings are indicated in the table at the bottom of the image and are listed in gray scale values. All measurements are within two percent of each other.



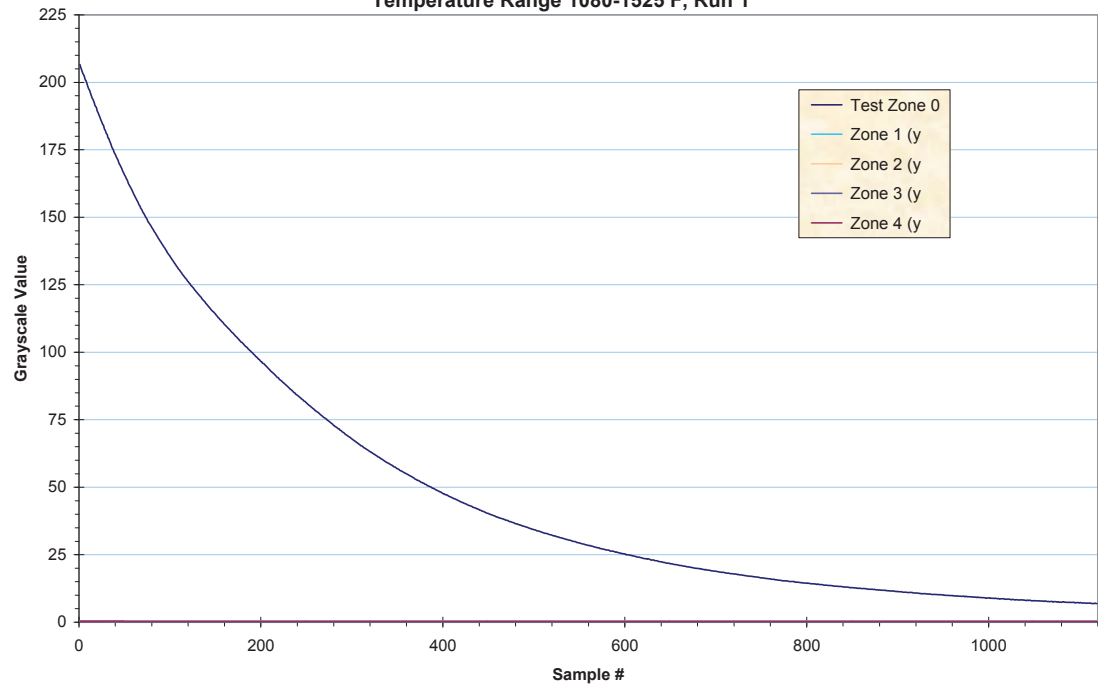
As thermal loads are fluctuated up and down the following graphs track those changes. The cooling cycles are left to natural convection and thus are not linear in nature. For comparison, a second heating cycle is included to demonstrate the repeatability of the vision system which meets the testing requirements of ASTM E20 for calibration and accuracy of temperature measurement devices.

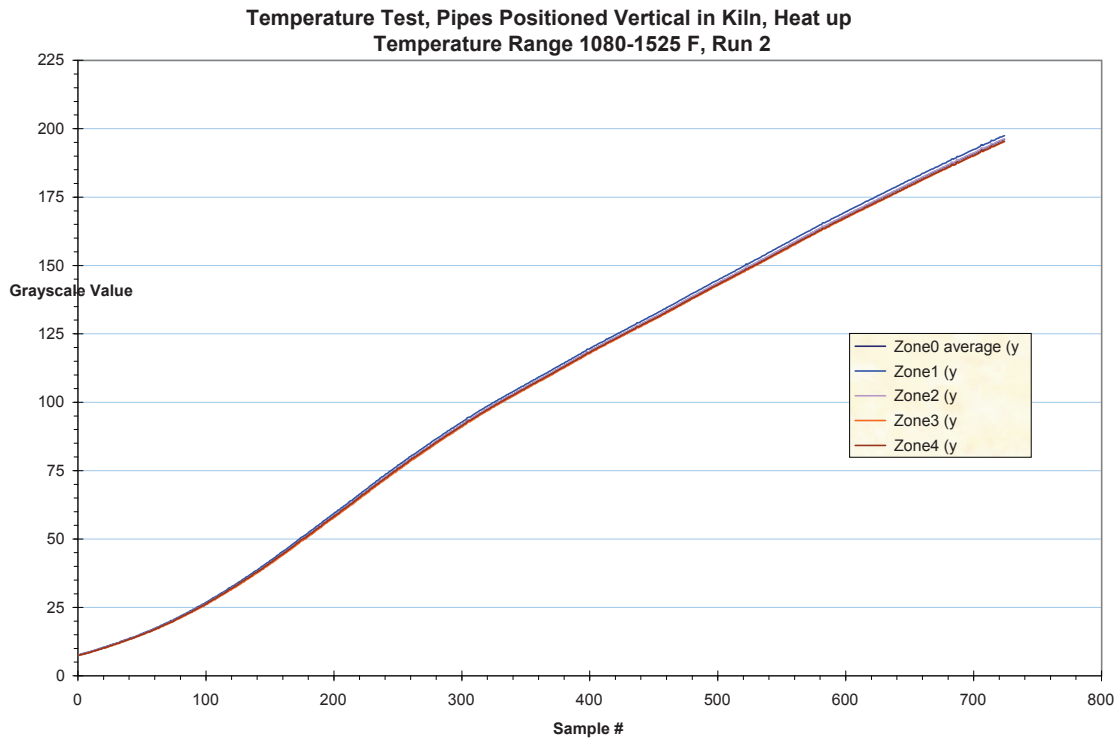
For the following curves, the vertical scale is gray scale intensity which is measured 0 – 255 (pitch black to bright white). The hotter the tube, the higher, or more intense, the gray scale reading. This value in process would be calibrated to the temperature. The horizontal scale is the image number, or time.

Temperature Test, Pipes Positioned Vertical in Kiln, Heat up
Temperature Range 1080-1525 F, Run 1



Temperature Test, Pipes Positioned Vertical in Kiln, Cool Down
Temperature Range 1080-1525 F, Run 1





System Components:

The equipment that comprises the vision system required includes a High Temperature Camera and a computer/software package designed to analyze temperature. The camera must be able to survive high temperature environments and maintain a clean lens system. Depending on fuel source and purity of the furnace atmosphere, air for cleaning may or may not be required. Canty's design places a protective quartz shield in front of the lens system and conducts air for cleaning past that lens which prevents foreign particulate from contacting and sticking to the quartz shield. Should air be lost, the shield may coat over, however that can be removed and replaced with another – the lens components are unharmed.

Typical Camera - <http://www.jmcanty.com/overview/P.Process%20Vision/A7355.PDF>

The power of the software is critical in performance of the system. Having the analysis capability alone may not be enough as typical high temperature processes often exhibit viewing difficulties that can cause for false readings. The ability of the software to “intelligently” analyze the images is required to get good results. For instance, if there is smoke in a process view occasionally it can falsely lower the temperature readings. The software must be able to recognize this and discount those readings.

Appendix 3 – Flame Monitoring Typical System Data

Report: Flame Analysis in Rotary Kiln

Purpose: To assist operations in monitoring flame size and quality with the intent of providing optimum kiln conditions for processing contents.

System:

The Flame analysis system is comprised of a Canty High Temperature Camera unit along with Vector processor for image analysis. Systems can also be provided with Ethernet cameras for connection direct to in place LAN systems. The Canty hardware/software is described in detail at the following locations:

High Temperature Camera:

<http://jmcanty.com/Products/TempCameraTemperatureMeasurement/TA7355-1.pdf>

Vector Image Processor:

<http://jmcanty.com/Products/Vector/TA9562-1.pdf>

The Camera system is designed to withstand the rigors of extreme environments and is used in boilers of all kinds, kilns, annealing ovens and glass furnaces. The software takes the process image and digitizes it so it can be processed. Canty provides many available image filters and outputs to allow the operator to set the system up to extract specific and multiple pieces of information at the same time to allow proper control of the system. For instance, intensity or color detection can be used to monitor flame temperature. Threshold analyses can be used to determine the size of the flame and the size of various temperature zones in a flame if they are visible. In addition, it may also be possible to monitor the product in the kiln or furnace at the same time. The software allows many features to be monitored simultaneously and allows the operator to set the feature conditions that will trigger alarm anywhere on the screen or only in specific areas of the screen.

The following images show a view inside a rotary kiln looking down toward the flame. The product is visible as well in the view. The image following the “live” shot show the flame digitized and the output details the flame size in square pixels which in process would be equated to square inches or some other value system that indicates to the operator flame status. The analysis shown here detects the flame as a particle with size and shape characteristics. It can also be detected simply as a count of pixels above the threshold limit. The image is an array of pixels with intensity of 1-255. The software analysis of these images detects pixels in the view that are 246 grey scale values or higher which filters out only the flame from detection as can be seen in the digitized image. The images shown here are black and white, however the same software system will allow analysis of color in RGB and Yuv. Color can sometimes give a more qualitative analysis of the flame temperature.



Figure 1, Flame Monitor, Kiln1 pink box shows Particle Size analysis region



Figure 2, flame detect at threshold of 246, min particle 400 pixels

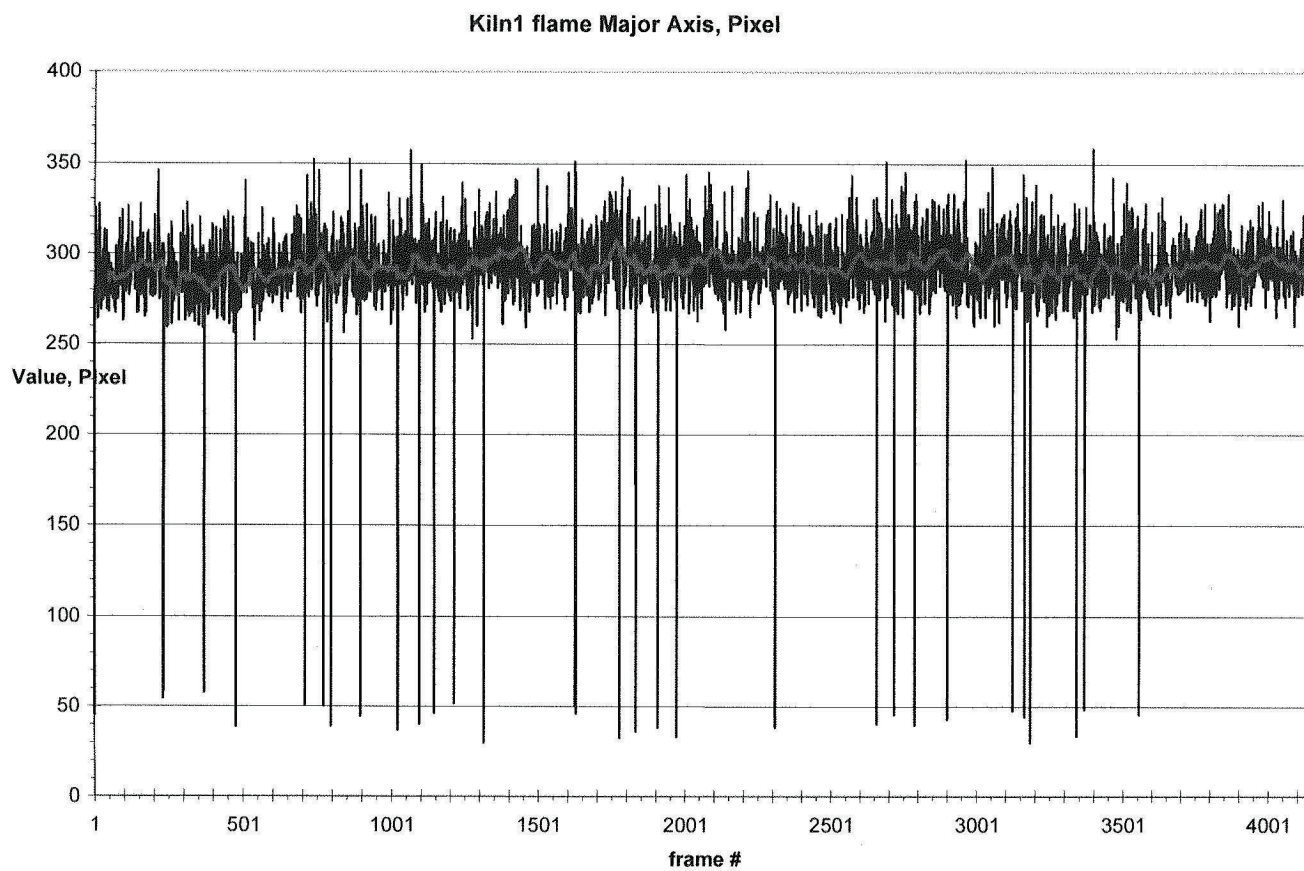


Figure 3, flame detect major axis shows about 1% small flame regions greater than 400 pixel
Average Major Axis near 285 pixel

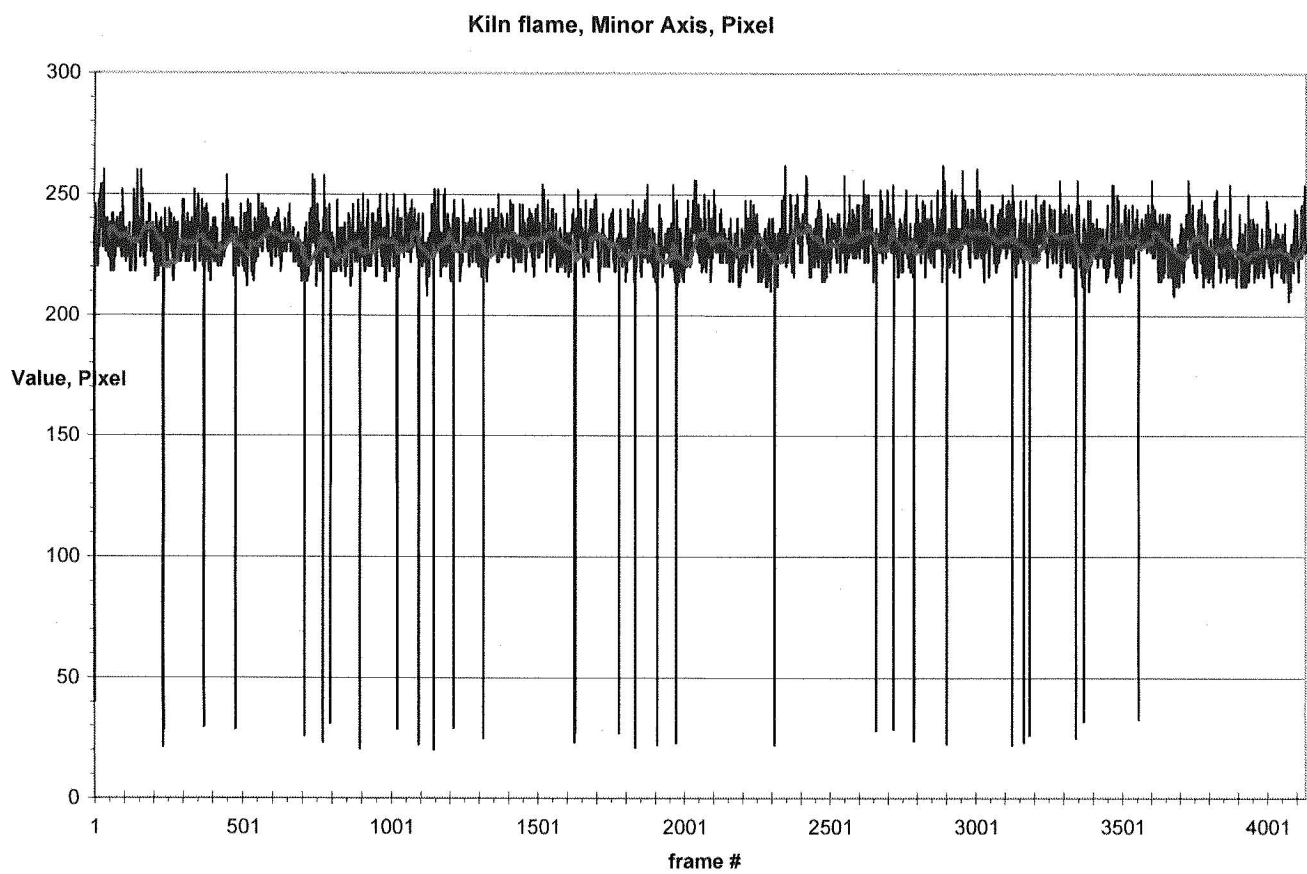
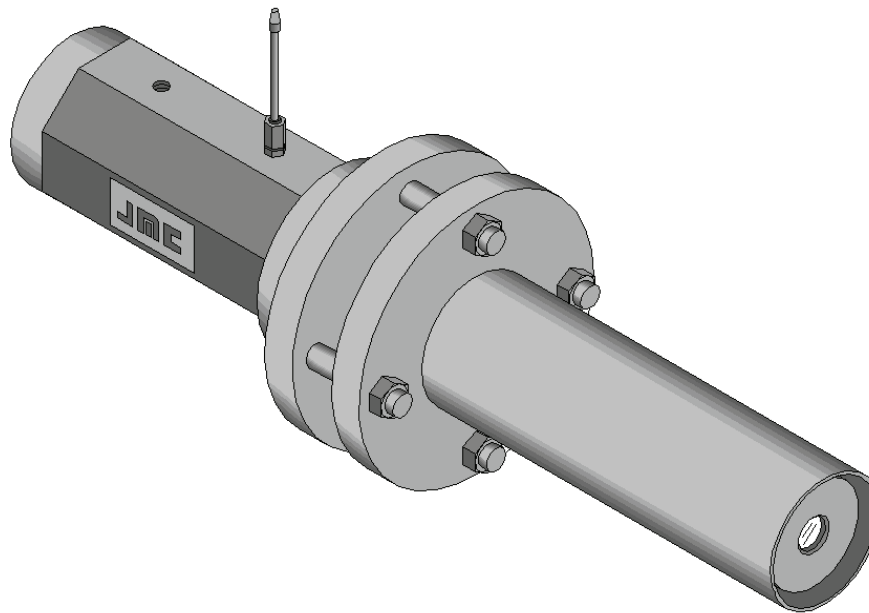


Figure 4, flame detect minor axis shows about 1% small flame regions greater than 400 pixel

Average Minor Axis near 235 pixel

High Temperature Insertion Vision Systems

Installation, Operation & Maintenance Manual



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*JM Canty International, Ltd.
Ballycoolin Business Park
Blanchardstown
Dublin, 15 Ireland*

1) UNPACKING

Inspect the shipping carton(s) immediately upon receipt for evidence of mishandling or damage during transit. Depending on the condition of the shipping carton, proceed as follows:

NO APPARENT DAMAGE

If there is no apparent damage to your cartons,

- Carefully unpack all cartons, while examining for any damages that may not have been initially noted.
- Examine each item for possible damage. Examine glass surfaces for gouges, cracks or chips. Note that small scratches do not necessarily degrade picture quality. Examine any threads that may be present for burrs or nicks. Check entire shipment for evidence of damage. If all equipment is free of damage, proceed to Section 2 for bench testing instructions. This will help identify any hidden damage before the unit is put into service.

VISIBLE DAMAGE

- If any or all of the containers show signs of damage during shipping, please open the carton(s) in the presence of a representative from the shipping company. If this is not possible, please contact a representative from the shipping company immediately and arrange for an on-site insurance claim inspection. **Do NOT attempt to repair or install damaged equipment.**
- Arrange through the shipping company to have the equipment inspected for insurance purposes, and decide to repair or replace damaged equipment.
- Do not return any material to CANTY without first obtaining a RMA (Return Material Authorization) number from the factory. Please call or write to the address on the last page of this manual. Request a RMA number immediately. No shipments will be accepted without a RMA number.
- Repackage the damaged item(s) and place in its original shipping material or a secure container, and ship prepaid to the factory.

2) BENCHTOP TESTING YOUR SYSTEM PRIOR TO INSTALLATION

It is important to test your camera prior to installation to verify the unit is fully operational. This will facilitate any focusing or troubleshooting steps that must be taken. On a stable bench top, provide power to your camera system and verify the video picture is properly focused for the correct distance as required by your application. Reference section 4 for wiring details. Unless noted otherwise, all cameras are factory focused and tested for viewing approximately 1-30' from the

camera. **Please verify the camera is fully operational and properly focused before installing.**

3) INSTALLATION INSTRUCTIONS

A) WALL MOUNT TUBE INSTALLATION

If your camera system includes a Canty wall mount tube, the system is factory assembled and aligned. A typical camera assembly is shown in Figure 7. Typical welding installations are shown in figs 1 and 2. The unit does not have to be disassembled for welding if it is properly protected. The camera system must be protected from hot weld spattering on any of its parts. All warranties will be void if any spatter is found on any of the components.

- Prepping

- The wall mount tube has a nominal 3.5" outside diameter. A mounting hole must be made in the vessel\refractory where the unit is to be mounted. The hole must be slightly larger than the O.D. of the wall mount tube and machined at the desired angle to match the ideal line of sight for the camera. The mounting hole must have an unobstructed path from the flange to the inner wall of the chamber. The depth of the hole **cannot be shorter** than the length of the mounting tube.

- After machining, be sure to repair any refractory that has been damaged.

- Welding

- The wall mount tube must be inserted to the correct depth into the door or refractory wall. See figures 1 and 2 below for optimum installation tips. *The wall mount tube must be welded at a depth so as not to protrude into the flame, and should be mounted flush with the inside wall of tank, pipe or vessel . If the wall mount tube is too short, or is not welded in deep enough, you will see "tunneling" on the video picture.* (Be sure the spray tube does not protrude into the flame). It may be up to 2" shorter without any loss in picture quality.

- The required weld is typically a 3/16" fillet weld. Consult your plant specifications for the type of weld required for the application.

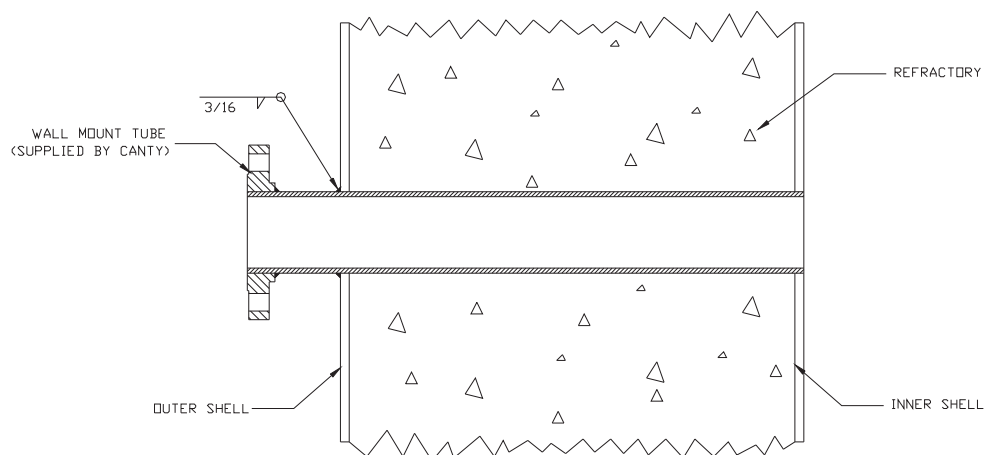


Fig. 1 Wall Mount Tube Welding Detail - Perpendicular Mount

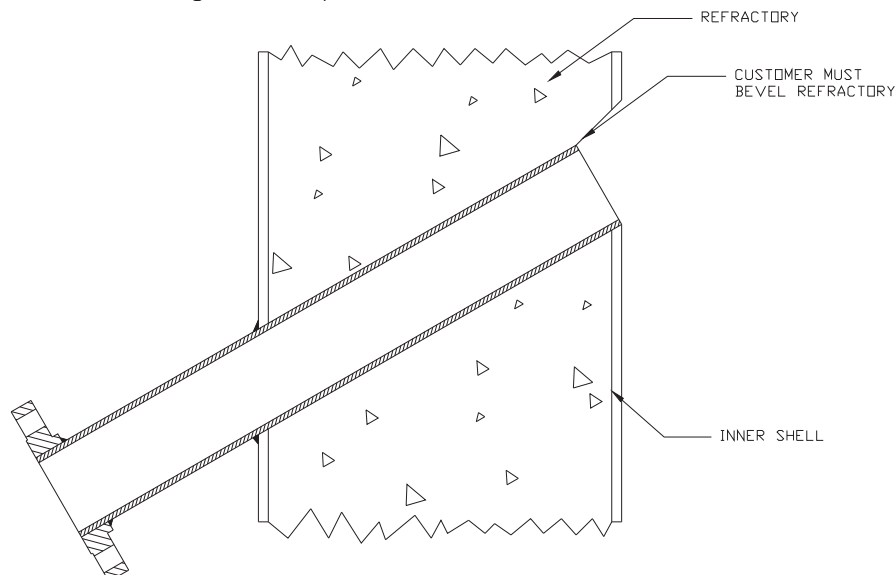


Fig. 2 Wall Mount Tube Welding Detail - Angled Mount (D9169)

Note: Refractory must be beveled to prevent tunneling of image

USING A CANTY SUPPLIED WALL MOUNT TUBE

If using a Cauty wall mount tube, all required studs, nuts, etc are provided by Cauty. There are no additional items required to mount your camera. The standard Cauty wall mount tube features a 3", 150 ANSI flange connection. Customers may also order a custom flange which retrofits non-ANSI mounting connections.

USING AN EXISTING OR CUSTOMER SUPPLIED MOUNT TUBE

If using an existing or customer supplied wall mount tube, verify the mounting hole has an unobstructed path (3" - 3.5") diameter from the flange to the inner wall of the chamber. The depth of the hole **should not be shorter** than the length of the spray tube. (Be sure the spray tube does not protrude into the flame). It may be up to 2" shorter without any loss in picture quality.

The customer must supply studs and nuts to hold the camera and spray tube to the customer's mount. Stud length must be $\geq (3" + \text{the depth of the tapped holes in the customer's studpad or the flange thickness} + \text{the thickness of a second mounting nut})$.

B) ASSEMBLY AND ALIGNMENT

If your camera was welded in without disassembling, there is no further assembly required. Proceed to section 4. If your camera was disassembled during

the installation process, or a customer supplied wall mount tube is used, the following steps are required:

- Be sure to bench top test your unit as previously recommended before continuing.
- Place a gasket over the spray tube as shown in Fig. 7. Place another gasket over the camera insertion as shown on the drawing. Insert the camera insertion tube into the spray tube. This assembly may then be placed into the nozzle. A side view would show the following stack: the vessel mount, gasket, spray tube, gasket, camera front flange.
- The mounting bolts should be torqued down while viewing the live camera image on your video monitor. Be sure to check for alignment. If the spray tube is not concentric, the picture will show a black ring around the outside of the image. If this occurs, the spray tube will need to be realigned/centered with the camera. For a 3", 150# flange the **recommended bolt torque is 360 in lb.**

C) AIR CONNECTIONS - SPRAY TUBE, COOLING TUBE

Note: Air supply to both spray tube and cooling tube must be instrument quality air only. The presence of oil in supplied air can irreparably damage the CCD camera and/or coat optical lenses, resulting in a severely degraded image. Canty recommends an oil removal (coalescing) filter, 0.5 micron, with regulator. The cooling tube requires 12 SCFM. The spray tube requires 15 SCFM.

• SPRAY TUBE

The spray tube is provided with a 1/4" NPT female connection in the OD of the flange to provide air to the quartz shield. The air purge is used to prevent ash or soot build-up on the quartz lens, which could degrade your picture quality. This will also keep the lens from oil coating if it is mounted in a oil spray type burner. The suggested air flow through the spray ring is 800 scfh. For oil fire boilers or similar applications, the pressure may need to be increased, depending on the application. The actual flow rate may be adjusted depending upon the application.

With a proper installation, if air is lost during service *the lens will not be damaged*. However, the quartz dust shield may need to be cleaned if the picture degrades. The quartz dust shield may be cleaned with any commercial glass cleaner or lacquer thinner. Reference section 5 for details.

• COOLING TUBE

The camera housing is provided with a cooling tube to maximize the cooling effects of the incoming air. The specifications for the cooling tube are shown in figure 3. The cooling tube is provided with a 1/8" NPT male air inlet fitting. A 1/4" NPT female air exhaust port is provided on the camera housing. The exhaust air must be routed by the customer in a manner consistent with N.E.C. and plant requirements.

Note: For explosion proof / flame proof systems, the hot air exit must be used with the appropriate purge control system to meet the requirements of the application. A cooling tube does not meet explosion proof / flame proof requirements without a purge control system.

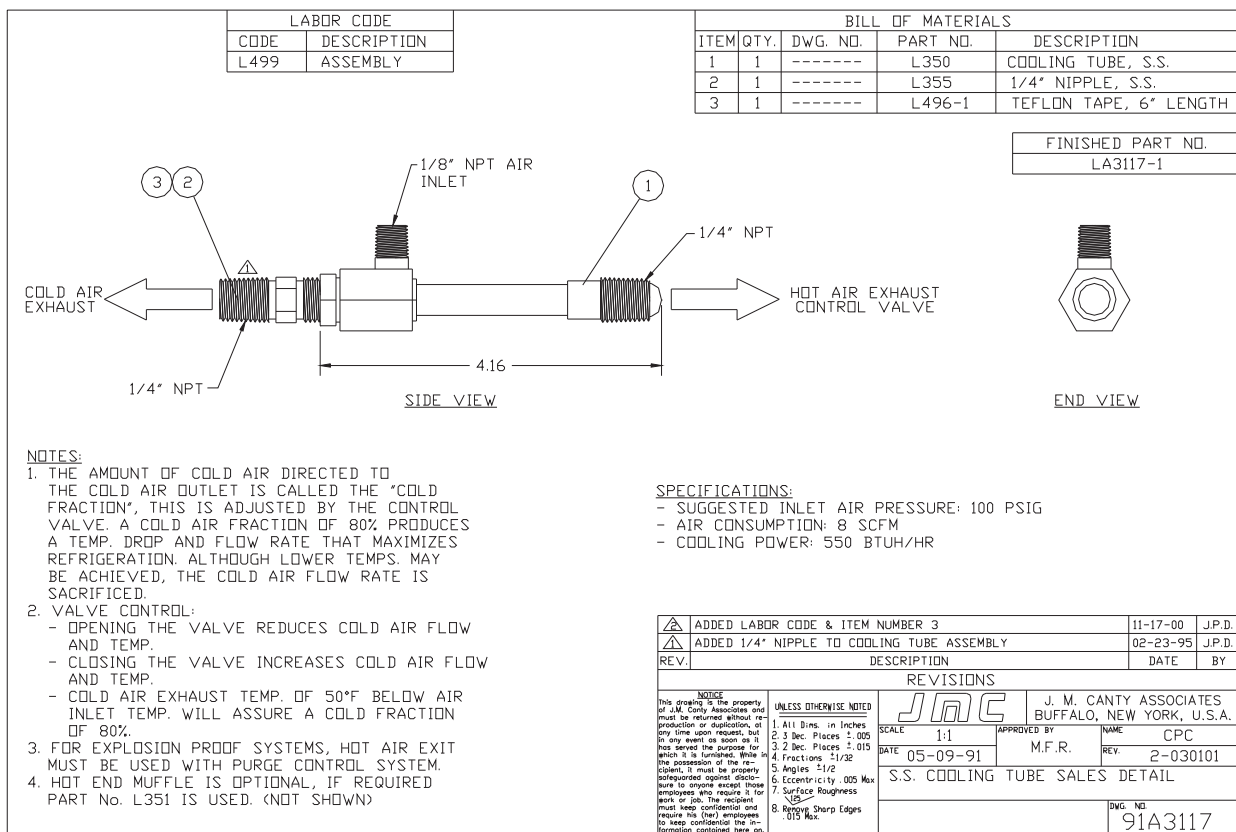


Fig. 3 - Cooling Tube Detail

4) PROVIDING POWER TO THE SYSTEM

To supply power to the camera, locate the two power wires exiting the camera housing through a 1" NPT wire inlet (the third wire will be a coaxial cable for obtaining a video picture). These pigtails are to be used to supply power to the camera, and obtain a video output signal.

The camera 12VDC input power pigtail cable is provided with a 2 pole quick connect termination. Please reference the applicable section below for power supply wiring details.

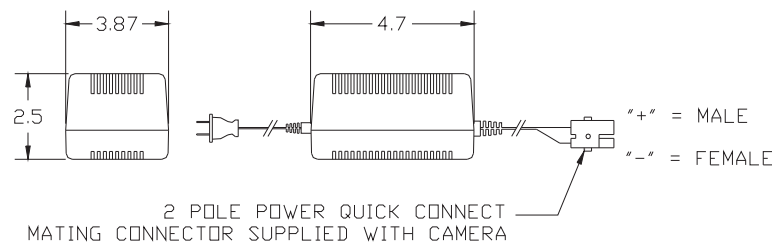
Connect user supplied coaxial cable from the coaxial cable pigtail of the camera to the monitor or Vector System. Canty recommends the use of RG 59-U coaxial cable only. **Cable must be suitable for CCTV applications. Do not substitute MATV, CATV cable.**

Camera Power Supplies

Canty offers three basic types of camera power supplies: standard (non WP or EXP), weather proof and explosion proof. Please reference the figures below for details on the power supply purchased with your system.

Standard (non WP or EXP) Power Supply

The standard Canty power supply is provided in a desk-mounted enclosure. The non weather proof or explosion proof housing can also be mounted in a customer-supplied enclosure for an additional degree of protection. 120V AC and



240V AC input models are available.

Fig. 4 Standard (non WP, EXP) Camera Power Supply (D9169)

Weather proof Power Supply

The weather proof power supply is available in 120V AC and 240V AC input models (120 V AC model is shown below). The power supply features a NEMA 4X fiberglass enclosure and a regulated 12 V DC, .8A output. The enclosure includes two weather proof cable strain reliefs.

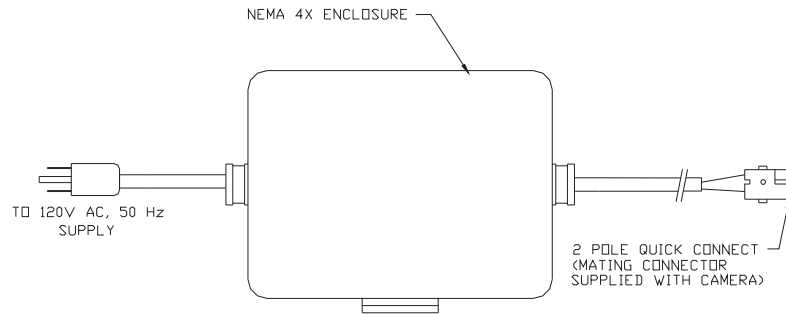
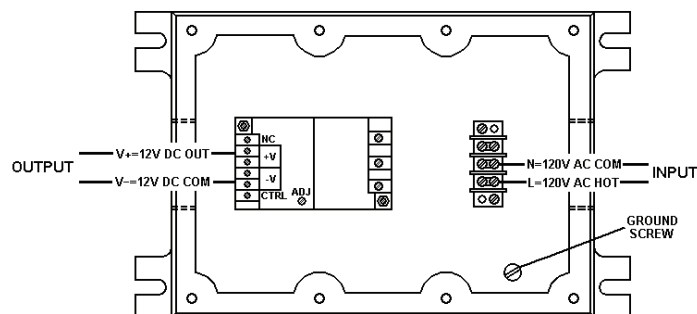


Fig. 5 Weather Proof Camera Power Supply - Simplified Diagram (D9169)

Explosion Proof Power Supply

The Cauty explosion proof power supply is currently available for 120V AC models only. The power supply features an explosion proof housing and regulated 12 V DC, .8A output regulator. The enclosure provides two wire inlets for input, output power cable wiring. The customer is responsible for wiring 120V AC power to



PSU, 12VDC output from PSU to camera pigtailed power connections.

Fig. 6 Explosion Proof Camera Power Supply - Top View, Cover Removed (D9169)

5) MAINTENANCE

Your High Temperature Vision System is virtually maintenance free. Your process may require periodic cleaning of your Vision System. You can use general purpose mild cleaners to clean the housing as needed. The housing is constructed of anodized aluminum. Avoid washing with materials which may corroded the housing.

The glass dust shield may be cleaned periodically. Avoid scratching or gouging the glass lens. Scratches or gouges may degrade the quality of your video picture.

REPLACEMENT PARTS:

<u>NUMBER REQ'D</u>	<u>PART NUMBER</u>	<u>DESCRIPTION</u>
1	VA4548-1500DA	QUARTZ DUST SHIELD

QUARTZ SHIELD REPLACEMENT:

Reference Figure 7 for details.

To change the quartz dust shield (item 26), simply remove the three S.S. set screws (item 16) located in the quartz retainer (item 19). Be careful the quartz does not fall out while removing the retainer! Visually inspect all components to see if oxidation has caused any damage. If all parts seem in functional condition, verify the quartz is clean, and replace the 3/8"-16 S.S. set screws (be sure to tighten evenly so the set screws all end up the same depth and the retainer does not get deformed). Do not leave any exposed threads on the quartz retainer OD. They will oxidize and will not loosen. When the set screws are completely tightened, the quartz shield must still have the freedom to move slightly.

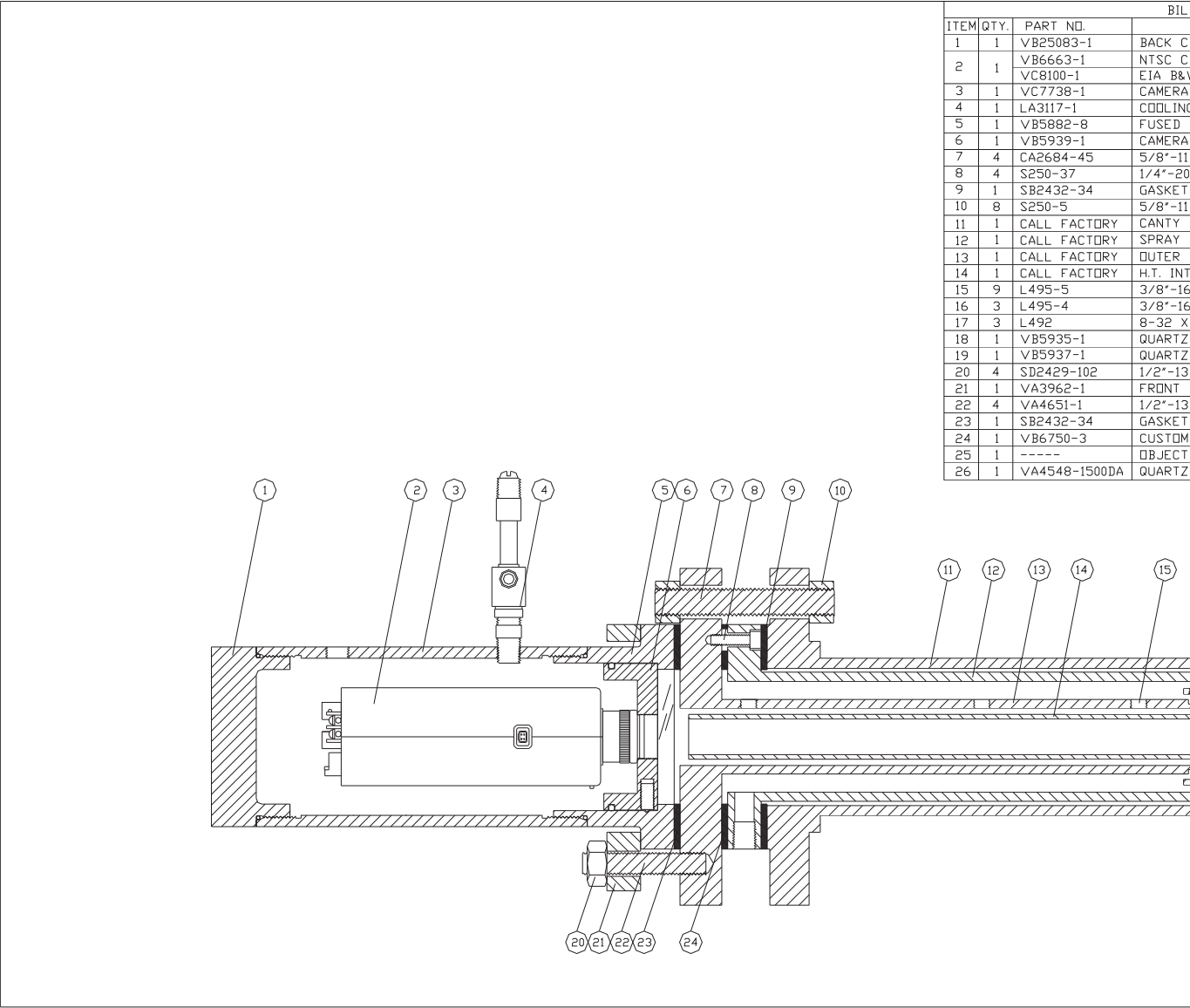


Fig. 7 - Bill of Materials - Typical HT Camera System (D9169)

TROUBLESHOOTING TIPS

No Picture On The Video Monitor

- Is your video monitor turned on?
- Is your camera power supply turned on?
- Is the correct polarity and output voltage present to power the camera ?
- Is the filament in the in-line fuse (in the camera pigtailed power wires) ruptured?
- Is there sufficient light to illuminate the area to be monitored?
- Is your coaxial cabling run too long? If yes - consider a video amplifier.
- Is there an open circuit in the coaxial cable?

Picture Is Blurry

- Verify the camera is focused for the correct distance from the lens. Adjust focus as required. Note: Unless specified otherwise - camera is factory focused for a viewing distance (from the camera) of approximately 1 - 30'.
- Is there a coating of process material on the quartz shield?

Please consult the factory for additional troubleshooting tips.

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