Field Test of the Flame Quality Indicator

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ABSTRACT

The flame quality indicator concept was developed at BNL specifically to monitor the brightness of the flame in a small oil burner and to provide a "call for service" notification when the brightness has changed from its setpoint, either high or low. In prior development work BNL has explored the response of this system to operational upsets such as excess air changes, fouled atomizer nozzles, poor fuel quality, etc. Insight Technologies, Inc. and Honeywell, Inc. have licensed this technology from the U.S. Department of Energy and have been cooperating to develop product offerings which meet industry needs with an optimal combination of function and price.

Honeywell has recently completed the development of the Flame Quality Monitor (FQM or Honeywell QS7100F). This is a small module which connects via a serial cable to the burners primary operating control. Primary advantages of this approach are simplicity, cost, and ease of installation. Call-for-service conditions are output in the form of front panel indicator lights and contact closure which can trigger a range of external communication options. Under this project a field test was conducted of the FQM in cooperation with service organizations in Virginia, Pennsylvania, New Jersey, New York, and Connecticut. At total of 83 field sites were included. At each site the FQM was installed in parallel with another embodiment of this concept - the Insight AFQI. The AFQI incorporates a modem and provides the ability to provide detailed information on the trends in the flame quality over the course of the two year test period. The test site population was comprised of 79.5% boilers, 13.7% warm air furnaces, and 6.8% water heaters. Nearly all were of residential size – with firing rates ranging from 0.6 gallons of oil per hour to 1.25.

During the course of the test program the monitoring equipment successfully identified problems including: plugged fuel lines, fouled nozzles, collapsed combustion chambers, and poor fuel pump cut-off. Service organizations can use these early indications to reduce problems and service costs. There were also some "call-for-service" indications for which problems were not identified. The test program also showed that monitoring of the flame can provide information on burner run times and this can be used to estimate current oversize factors and to determine actual fuel usage, enabling more efficient fuel delivery procedures.

ACKNOWLEDGEMENTS

This work was sponsored by the U.S. Department of Energy. We would like to thank our project manager, Steven Cooke from DOE's National Energy Technology Laboratory (NETL) and also Esher Kweller from DOE's Office of Energy Efficiency and Renewable Energy for their very helpful guidance, support, and encouragement.

This project would not have been possible without tremendous support and cooperation from the service organizations which so enthusiastically agreed to participate. This clearly demonstrates that this industry is forward thinking and very willing to help introduce new technologies which can improve efficiency and operations. All specific participants are listed in the report.

We would like to acknowledge also the support and assistance received from all of the participants in the three team members, BNL, Insight Technologies, Inc. and Honeywell, Inc. Specifically, this includes:

Yusuf Celebi, BNL, engineering and field test support
George Wei, BNL, engineering and monitoring equipment organization
Doug Davis, Insight, management and AFQI engineering support
Michael Rossi, Insight, hardware and software development
David de Jong, Insight, project web site development
Amy Melcher and John Sawina, Honeywell, hardware and software development

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1. INTRODUCTION

This field test has been managed by Insight Technologies, Inc., under contract to the U.S. Department of Energy, National Energy Technology Laboratory. Insight has been supported in these tests by Brookhaven National Laboratory (BNL) and Honeywell International. The flame quality indicator technology was originally developed at BNL and patented by the U.S. Department of Energy. Insight Technologies and Honeywell are licensees of this technology.

The objective of this project was to conduct a two year field test of the Flame Quality Monitor (FQM) currently under development by Honeywell with technical assistance provided by Insight Technologies. The Flame Quality Monitor is a system which optically monitors the quality of a flame in an oil-fired heating appliance and signals the service organization when the quality of the flame has degraded to the point where service is required. For the homeowner, benefits include increased efficiency as conditions which lead to heat exchanger fouling are detected early, improved reliability as problems are corrected before the system stops providing heat, and avoidance of situations where combustion products spill from the heating appliance into the residence. For service organizations the system will provide greater customer satisfaction, and reduced service costs.

The FQM system uses a photocell sensor in combination with a microprocessor based primary control to monitor the flame. Drift of the signal more than a predetermined amount from a setpoint triggers a service call. The service organization can be notified either using a local alarm or link to an alarm system.

Background of the Flame Quality Indicator Technology

Honeywell has been involved in the development of controls for use in oil-fired equipment since the late 1800's. As production processes have moved forward to new technology platforms, Honeywell has provided upgraded performance and features in new series of control offerings.

As early as the 1920's and 1930's, flame sensing was accomplished with a bimetallic sensor which was placed into the equipment flue and interfaced with electro-mechanical logic circuits to rely on the temperature of the flue gas to provide indication of the combustion process.

The next step in the evolution occurred in the 1970's when a cadmium sulfide flame sensor, that changed resistance when exposed to light, was introduced into the market. This new technology was combined with the same basic electro-mechanical logic circuits to provide a control that would react to the combustion process through the visual light emitted from the combustion process. This control technology has proven to be exceedingly reliable overall and continues to be the control of choice for a majority of controls installed in the marketplace today.

During the early 1980's, electronic microprocessor technology was introduced to the oil-fired equipment marketplace in the commercial application areas where cost was not as much of a factor. This new technology continued to use the same cadmium sulfide flame sensor in many of the applications. Some small improvements in flame monitoring were made, but the controls continued basically, to look for "flame / no-flame" status of the combustion process.

Beginning in the late 1980's, Brookhaven National Laboratory initiated a program to identify practical sensor concepts which could monitor changes in the performance of an oil burner over time. The goal was to design a very inexpensive system which could lead to burners being serviced before heat exchanger fouling occurs, thereby reducing efficiency of the oil-fired appliance. Many technical approaches were explored in this work including: semiconductor CO sensors, zirconium oxide oxygen sensors, flue temperature, heat exchanger pressure drop, flame spectral emission peaks, and two-color flame temperature measurements. While many of these approaches are interesting and may offer better performance, the simple Cad Cell (broad band, flame brightness) was selected for further development work. The Cad Cell has the advantages of low cost, it is widely used, and exhibits good sensitivity to flame quality changes. Additional information on the BNL background work can be found in References 1 and 6.

Flame Quality Basics

The cadmium sulfide flame detector is sensitive to the changes in emission of visible/near-IR light from the oil burner flame and can be used to indicate changes in the combustion process. The amount of light incident on the Cad Cell depends upon flame temperature, flame soot concentration, and flame length. Changes in the flame can affect these factors. Low excess air, for example, can lead to a long flame, with high soot concentration, and more light to the Cad Cell. However, this information is hidden by a number of variables in the appliance and application. The ability to separate the flame quality information from the appliance / application conditions is the basics of the Brookhaven National Laboratory development.

One of the largest variables is the effect of combustion variation with the length of the burner "on" cycle time. As has been reported in earlier Brookhaven Laboratory reports on Flame Quality, the cadmium cell resistance continues to change over a continuous run period of the oil-fired appliance. In the implementation of this concept, this factor is overcome by selecting a warm-up period sufficient to provide a more stable combustion process, then use the same time period each time a comparison is made.

The next variable is the natural tendency of a flame to modulate its intensity or "flicker" over a very short time period making instantaneous readings subject to significant error.

Finally, there are the variables that occur in the application that cause transient changes in the combustion process, but do not actually indicate a change in the combustion process requiring service. These variables can be strong wind loads causing draft changes, voltage dips causing pump pressure changes, and many other temporary variations in the combustion process. This is overcome by some filtering and by defining an acceptable range of variation from the initial reading and a required number of occurrences of readings outside of the acceptable range.

Implementation of FQI Technology

In the early to mid 1990's a number of companies field-tested the flame quality concept in different product offerings. All of these products required that the burner be retrofit with an additional cadmium sulfide flame detector necessitating a fair amount of additional wiring be added to the appliance. The installation of a second "cad cell" sensor required disassembly of the burner during installation of the flame quality system and had the potential to change the burner airflow design. Additionally, the low volume opportunity drove the total cost of installation beyond a level that a majority of the contractors found acceptable. Insight Technologies was arguably the most widely known and distributed offering of this generation control.

In the mid 1990's Honeywell began development of a microprocessor based oil primary control as the next level of proven control technology. Introduced in 1999, this control was provided with a communications connection that allows for the field connection of other equipment to enhance the performance of the control and installed equipment. This "data port" provided a more cost effective opportunity to implement the Brookhaven Flame Quality algorithm.

Honeywell and Insight Technologies identified an opportunity to leverage the field and application experience that Insight Technologies had gained through their development of the Flame Quality Indicator with Honeywell's manufacturing and oil primary knowledge to move the Flame Quality Indicator technology to a more cost effective platform.

The design concept was to use the Honeywell oil primary control data port to provide the Cad Cell information to a new Flame Quality mechanical platform based on the Insight current product, but did not require the addition of a Cad Cell, power connection, or extensive wiring to the appliance.

The many improvements in the algorithm, to address burner "on" cycle time, short cycles, flame signal stability and others, would all be incorporated into the new Flame Quality Monitor.

The Flame Quality Monitor (FQM) is connected to the Honeywell oil primary control by a simple wire harness with a plug connector on each end (see Figure 1-1). Thus, installation can be made in a few minutes without any disruption to the appliance. In this first of several planned implementations of this technology, the FQM provides a simple contact closure to the dealers choice of alarm options, battery powered, 24 Volt powered alarms, home security systems, etc.

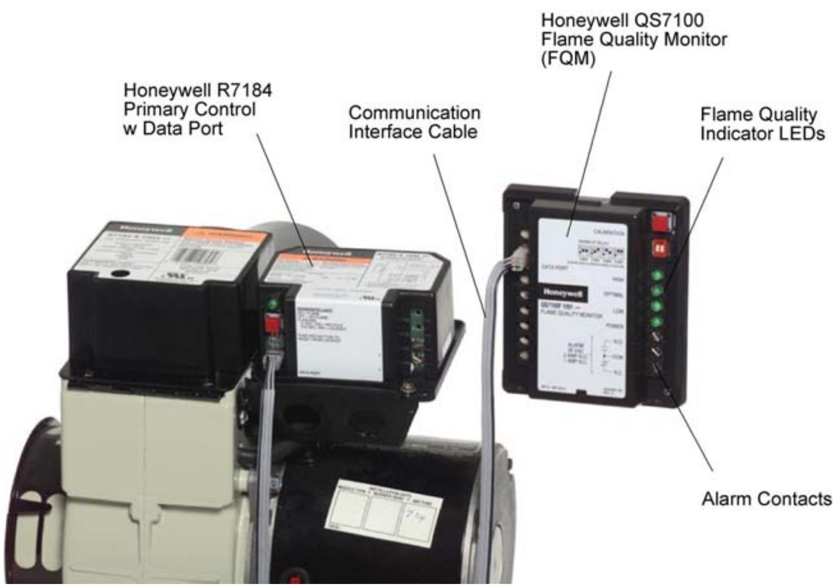

Figure 1-1 Photo of Honeywell Flame Quality Monitor connected to the Honeywell R7184 microprocessor based primary control

After the connections are made, the installer selects the appropriate warm-up period for the particular installation conditions, then the burner is adjusted and checked for CO_2, stack temperature and smoke number to assure that the appliance is operating optimally. The "calibration" button is pushed and the appliance allowed to run for the warm-up period. At the end of the warm-up period, the FQM takes a series of readings to determine an appropriate value for the Cad Cell resistance and records the initial reading into memory. Each subsequent cycle that exceeds the selected warm-up period results in an additional series of readings being compared to the initial reading. If a reading exceeds the allowable variation, and there have been a sufficient number of these "out-of-range" readings to warrant service, the alarm is triggered. The complete installation and operating instructions for the Honeywell FQM are included in the Appendix.

In summary, although the basic concept of monitoring cad cell resistance, and using that information to provide a measure of change in flame quality was developed by BNL, the actual Honeywell implementation has improved the concept in six important ways:

1. The amount of "warm-up" delay is field selectable by the service technician.
2. The cad cell resistance is measured using a unique algorithm, not a single reading.
3. The determination of "need for adjustment" is determined through an additional algorithm, not a single reading.
4. The installation is a simple connection between the oil primary and flame quality controls with no additional hardware installation requirements.
5. A separate cad cell is not required.
6. An additional power supply is not needed.

2. TEST PROGRAM

The objectives of this program were to evaluate the technical performance of the FQM in the field and to quantify the benefits that this technology provides to the service organizations. The technical approach planned was to identify service organizations which would participate, provide training to them, support their installation efforts as needed, monitor the flame quality signals remotely for the two year period, respond to poor flame quality indications as quickly and comprehensively as possible, and document problems identified and false alarms. A total of 100 sites were originally planned with some distribution over the main parts of the U.S. which have a large population of oil-heated homes. As originally conceived the host sites would be managed locally by volunteer oil companies which typically provide both fuel and service. The list of participating organizations and locations is provided in the next section of the report. The response from these organizations in terms of willingness to participate was excellent.

As discussed in the previous section, the Honeywell FQM was the main focus of this test program. The FQM provides only contact closure and a local light signal when a flame quality problem has developed. The Insight Advanced Flame Quality Indicator was used in tandem with the FQM to provide an additional capability to monitor combustion data from all test sites remotely via the Internet. The AFQI also monitors FQM alarm status as well as Cad Cell and stack temperature sensor inputs. With this configuration, sensor data is collected and automatically uploaded to Insight's Web server via a telephone connection. The data, received by a proprietary gateway application, is stored in a SQL Server database and processed to provide run-time information including: alarm status, flame signal, stack temperature, cumulative run-time, number of burner cycles, and run-time per cycle.

Insight's monitoring website displays historical burner data in graphic format that quickly indicates cycling patterns, onset of combustion problems and trends associated with degradation of combustion. The monitoring website also provides the capability to automatically send alarm notifications via e-mail whenever the flame signal exceeds a high or low limit.

The test sites monitored by the AFQI required installation of an additional cad cell and 9VDC wall-type transformer power supply. A data logger was used to record ambient room temperature at a number of test sites.

Figure 2-1 shows the overall monitoring plan. When a flame quality alarm occurs on the FQM unit, the FQM alarm contacts close. These are connected to the AFQI which provides information to the web server that an FQM alarm has occurred. In addition the AFQI provides information to the web server on the flame quality signal it measures, the exhaust gas temperature, and the run time information.

To make the installations at the home test sites easier, the FQM and AFQI were both mounted on a metal plate with magnetic back mounts, and pre-wired as much as possible in advance. A photo of this setup and all other equipment installed at the test homes is included here as Figure 2-2.

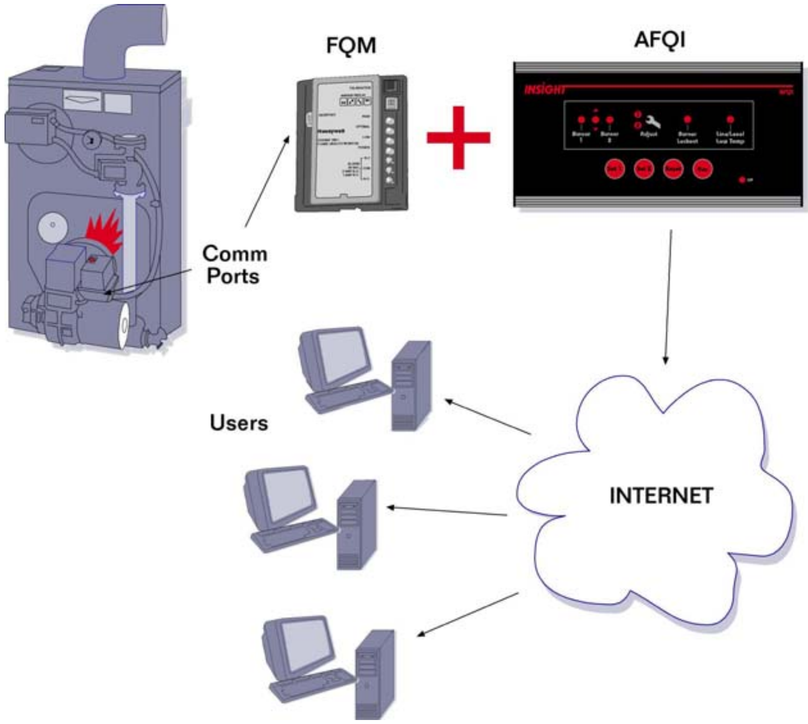

Figure 2-1 Overall monitoring arrangement

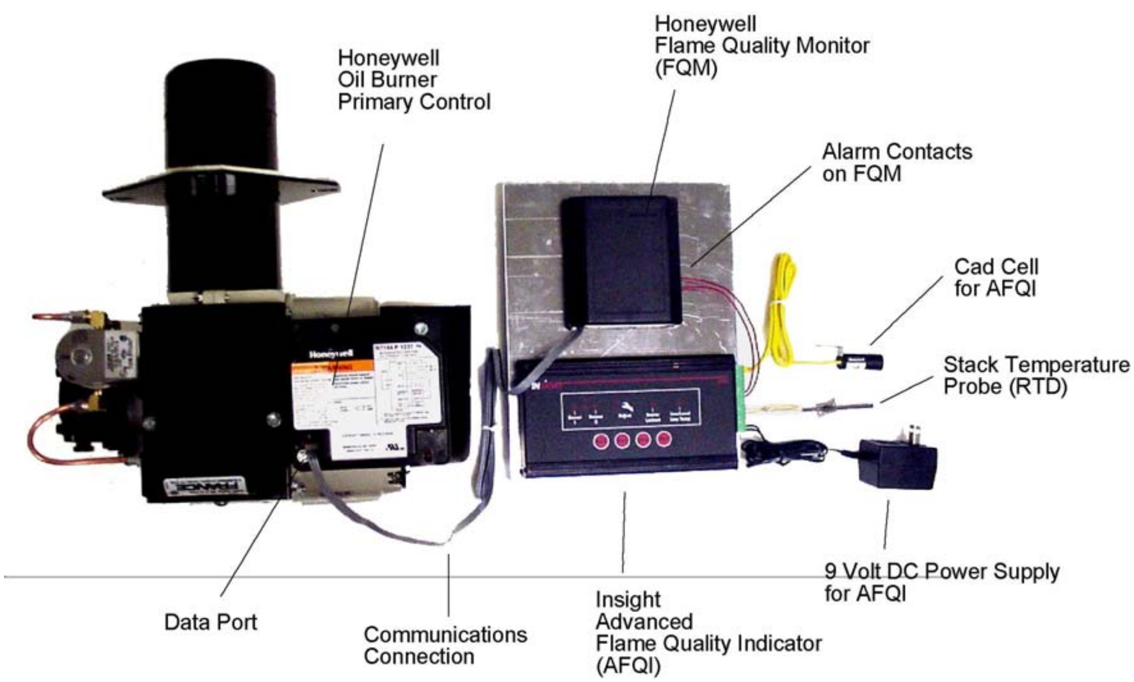

Figure 2-2 Components assembled for the field test at each site

For each participating organization a one day training seminar was provided. This typically involved the service manager and one or two technicians who were to be involved with the project. This usually included one or two installations with the BNL representative. Each organization was provided with a project binder which included:

- A 10 step, "quick start" guide to the equipment installation
- A Test Plan
- Contact information (phone numbers etc.) for support
- FQM, AFQI, R7184 installation instructions
- Wiring diagrams
- Data sheets for each site

The Test Plan was particularly important as it defined the roles of each participant, the site selection criteria, and the project steps in detail. This test plan and all of the materials in the project binder are included in the appendix to this report.

3. RESULTS

Field Test Participants

To develop a representative set of homes for this field test assistance was sought from service companies in several states in which oil heat is strong. The objective was to get a diverse set of climates and conditions. The response from the organizations approached was very positive. Some organizations approached early in the program installed 10-20 units. Others which joined the project later installed just a few. The participating service organizations are listed below in order of number of units installed (with highest installed number first) are as follows:

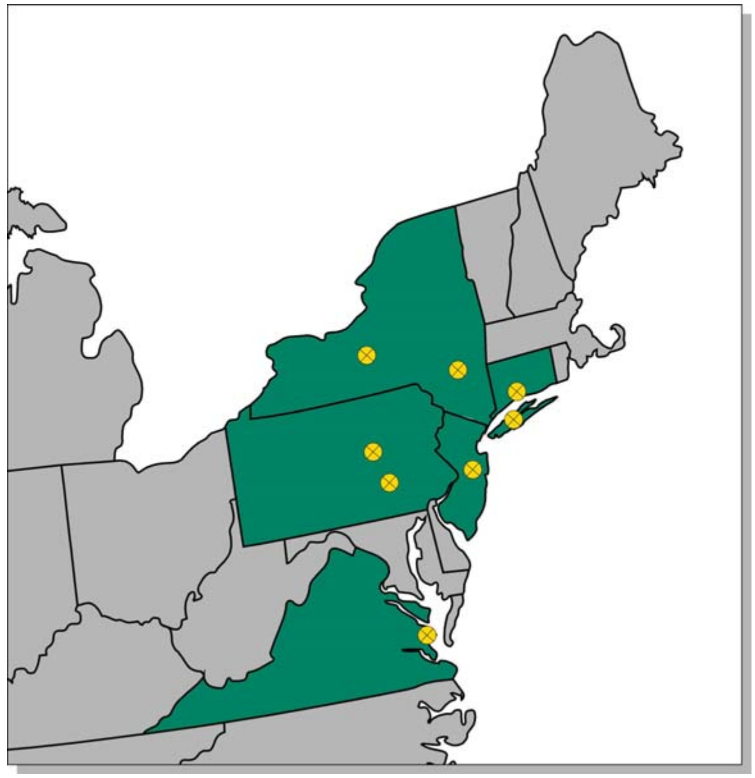

Figure 3-1 Locations of test sites

E.T. Lawson, Virginia
Santa Fuels, Connecticut
V.R. Boltz, Pennsylvania
Heritage Energy, New York (Catskill Region)
Agway Energy Products, New York (Finger Lake Region)
Sico, Pennsylvania
Griffin Energy, New York (Long Island)

In addition to these units several were installed in homes of BNL families and several were installed at Long Island facilities of the U.S. National Park Service including the Fire Island Lighthouse. Several units were also installed by Energy Kinetics, Inc. in New Jersey. Figure 3-1 illustrates the locations included in the project.

Table 3-1 shows the distribution of units by major region. Also provided in this Table is the approximate design temperature for the test region. This is included simply to show that the regions covered a range of climate. Table 3-2 shows the breakdown of the test units by appliance type. Clearly the test population set is heavily dominated by boilers. The burners included are nearly all conventional, modern, retention head types. One unit in the test population included a very old non-retention burner. In two cases, the burners were prototype, high-performance, retention head burners undergoing preliminary field tests by one manufacturer. The service organizations participating decided to include both the new burner and the FQM at the same site.

In normal operation, the AFQI makes a call to the Insight web server on a regular basis to provide information about the AFQI signal, the status of alarms, the burner run-time and cycling data. The time period for the call can be programmed, but once daily was the timing typically used in this study. In some cases more frequent calls were set. The participating organizations could view the status of their units on the Insight web page using a unique user name and password. When alarms occurred, the planned procedure was for the service organization to visit the site, document the condition of the burner, check the alarm status of the FQM, and to correct any burner malfunctions found. Upon completion of this procedure, the FQM and AFQI were reset.

Table 3-1. Distribution Of Test Units By Major Region.

Location:	Sites - % of total	Winter Design Temperature (F)
Virginia	31.6	21
Pennsylvania	23.7	2
Southern Connecticut	19.7	8
Long Island	13.2	7
Upstate New York	9.2	0
New Jersey	2.6	9

Table 3-2. Distribution of Units By Appliance Type

Appliance Type	Sites – % of Total
Boilers	79.5
Furnace	13.7
Water Heater	6.8

Results

For every site, the results analysis included a review of service history during the test period, flame quality signal trends from the AFQI, and the AFQI and FQM alarms that occurred. A set of outcome codes have been established and have been assigned to the test sites. These are listed in Table 3-3. For outcome codes which are listed as "justified" – there was either an alarm or not depending on the case but the performance of the burner over the test period was such that that outcome was the correct one. For cases which are described as unresolved reason – the outcome was not seen as the correct one, for example there was no alarm but a burner problem did develop. These are listed as unresolved because in many cases the burners were serviced to restore proper operation to the test homes but insufficient data was taken at the time to fully diagnose the reason for the alarm or no-alarm outcome.

Table 3-3. Outcome Codes

1. No AFQI Alarms, justified
2. No AFQI Alarms, unresolved reason
3. No FQM Alarms, justified
4. No FQM Alarms, unresolved reason
5. AFQI Low, justified
6. AFQI High, justified
7. AFQI Low Alarm, unresolved reason
8. AFQI High Alarm, unresolved reason
9. FQM Low, justified
10. FQM High, justified
11. FQM Low Alarm, unresolved reason
12. FQM High Alarm, unresolved reason
13. FQM unknown, justified
14. FQM unknown, unresolved reason
15. Monitoring equipment problems
16. Extraordinary boiler/furnace equipment problems
17. Insufficient feedback on site problem
18. Equipment not correctly calibrated
19. Strong signal fluctuations
20. Monitoring equipment not reset during service call

At some of the sites service was required during the test program and the AFQI and FQMs needed to be reset. In these cases, the test period may be divided into two parts and separate outcome codes may be assigned for each test period.

In addition to the outcome codes, a set of Fault Codes were planned based on the type of problem which occurred at the sites. As might be expected, most of the problems observed are fuel system related: fouled nozzles, plugged fuel lines and filters, and fuel pump problems. The Fault Codes are listed in Table 3-4.

Table 3-4. Fault Codes

1. Fuel line block
2. Fuel pump failure
3. High smoke
4. Nozzle fouled / failed
5. Collapsed chamber
6. Blocked chimney
7. Rough starts
8. Ran out of fuel
9. Other

At the beginning of the project participating organizations were invited to include sites in the program which have some history of problems. While some were certainly in this category, the population set typically included a mix of sites including service organization facilities, homes of service technicians and other people directly associated with the service organizations, and typical customers.

When alarms occurred, efforts were made to identify the causes. However, in some cases either the unit was serviced before the cause could be established or no clear cause for the alarm could be identified. In looking for a cause for an alarm, the first test is a basic combustion test in steady state and in many cases this will identify the presence of a problem. In a significant number of the test sites, however, the problem was traced to a malfunction with either ignition or cutoff, which leads to head coking and fuel deposits in the burner air tube. While these malfunctions lead to alarms they don't always show up as problems in steady state combustion performance. In the results analysis every effort was made to resolve as many of the indicated alarms as possible.

Throughout the test project, numerous burner malfunctions were clearly identified when FQM alarms were logged. Some examples include:

Example 1 - The AFQI flame signal data indicated sharp fluctuations at this site from day to day, well out of the acceptable operating range. The problem was traced to a crack in an underground oil tank that allowed water inflow. The tank was replaced and the problem corrected.

Example 2 - Shortly after a fuel delivery, the AFQI reported flame signal data that started drifting rapidly out-of-range. Within a week, an alarm condition was indicated by the FQM. Upon inspection of the site, a very high pump suction pressure was measured and it was found that the oil line and filter were blocked with sludge. While under high pump vacuum, air was being drawn into the fuel line and nozzle assembly leading to: after-drip, oil vapor drifting back into the burner air tube, and nozzle coking. Even under these conditions, the burner continued to operate. The situation was corrected and the AFQI subsequently reported the flame signal returned to normal.

Example 3 - This site monitored a cast iron boiler with a history of soot-up problems which was a concern to the service organization. Over a period of several months, the AFQI signal was observed to be drifting toward the out-of-range limit. BNL staff along with a service technician visited this site. Upon inspecting the site, the FQM was observed to be in an alarm mode. On shutdown, the burner was observed to rumble lightly, indicating poor shut-off. Steady state combustion performance was determined to be acceptable. The service technician observed the flue openings were heavily sooted and that the unit was heading rapidly for another problem. The heat exchanger was cleaned and the fuel pump replaced which greatly improved shut-off performance. The FQM system was credited with preventing a serious repeat problem at this customer site.

Example 4 – An alarm was noted at one site where a boiler was being monitored. The service company did not respond when alarm notification was received. Several days later they received a call that heavy smoke was observed from the chimney. When the service technician arrived the refractory combustion chamber was found to have collapsed. The boiler was replaced.

Example 5 – One site had monitoring equipment on both a boiler and a water heater and both units had flame signals which were very steady for months. Suddenly, one morning an alarm was reported on both units at about 5 AM. At about 8 AM the homeowner called in, reporting that he had run out of oil (this was a "will-call" account).

Figure 3-2 shows the trend in flame quality signal over time for a properly operating unit as displayed on the Insight web site. Figure 3-3 shows the trend in the FQI signal for a boiler which operated very well over a one year portion of the test period. The project ended at the end of the period shown. Measurements at this site at the beginning and end of the period showed essentially the same performance. Figure 3-4 shows the flame signal trend for a burner which developed a blocked fuel filter shutdown.

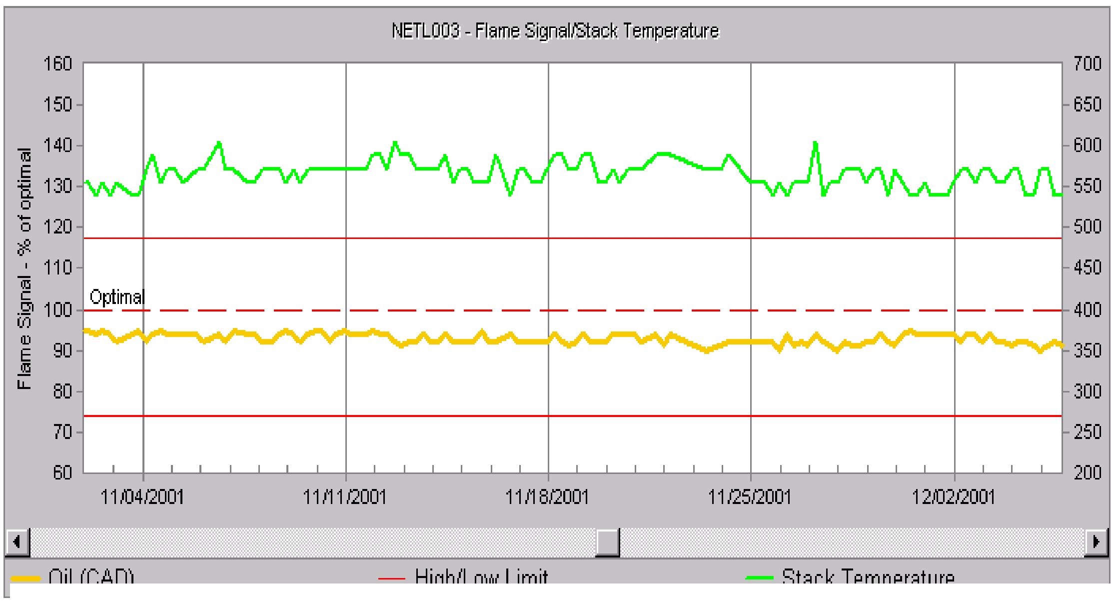

Figure 3-2: Example of signal trends in a properly operating boiler. Graphic is reproduced from the Insight web site. The lower line (yellow) represents flame quality signal and the upper (green) is flue gas temperature.

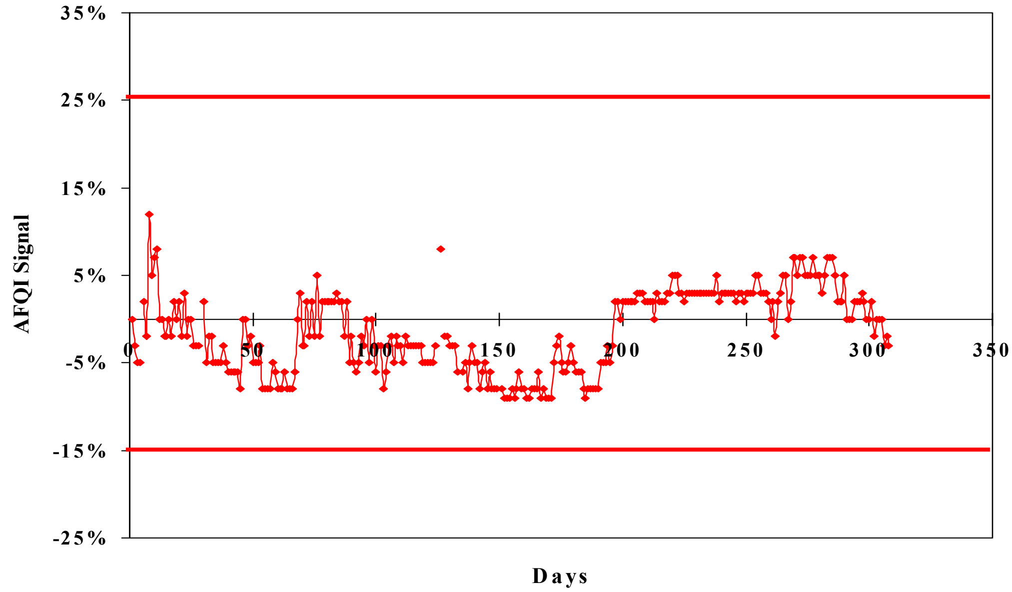

Figure 3-3 Long term trend in the FQI signal for a site which had no problems over the test period. The red lines in this figure show the upper and lower limits.

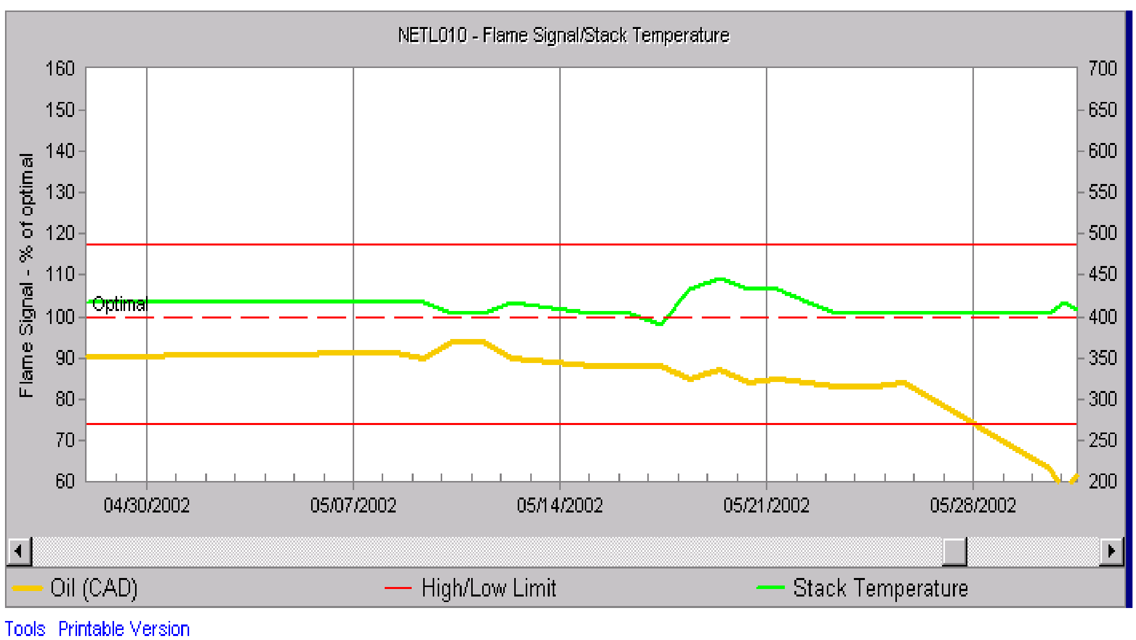

Figure 3-4: Example of flame quality trend in the case of a burner problem. Fouling of the fuel line filter caused this alarm which led to a burner shutdown.

Figure 3-5 shows the results of the outcome analysis for the test sites. These results represent a careful review of the signal trends, alarms, host organization service records, and site visit notes for each home included in the project. For some of the outcome codes defined there simply were no results in that category. The high number of occurrences of outcome code 15 is a reflection of a modem problem which occurred early in the program. This was resolved but led to some loss of time in the project. The time period over which units were in the test homes ranged from 6 to 18 months. Some of the test sites were excluded from the outcome analysis simply because there was poor feedback of information concerning the service history over the test period.

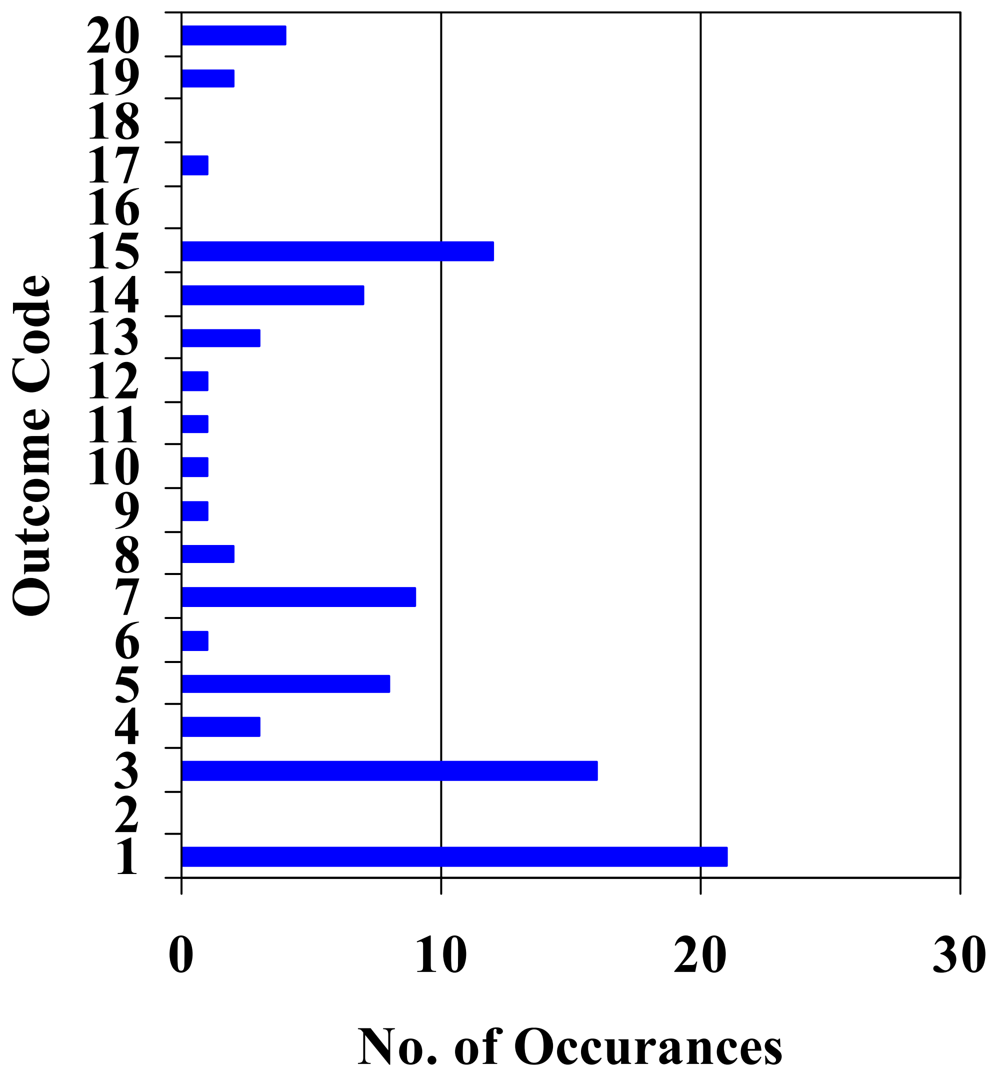

Figure 3-5. Results of outcome analysis for test sites.

From Figure 3-5, the most frequent outcome codes are 1 and 3 and these indicate the cases where the burners ran well and there were no alarms over the test period. Cases where there were alarms found and these were found to be justified (burner problem was found) included outcome codes 5,6,9,10, and 13 and there were a significant number of these. Many of the FQM alarms are in category 13, indicating that it is unknown if the alarm was a high or low signal. The reason for this is the way in which the FQM alarms were communicated. An FQM alarm results in closed contacts to the AFQI which puts a note on the web site that there is an alarm without providing information on high or low signal. The service technician visiting the site needs to run the unit, as is, and determine the alarm state. In many cases this step was simply not done. The number of justified FQM alarms is somewhat lower than the AFQI alarms and, again, this is largely due to the monitoring protocol. In most cases, an FQM alarm would show up on the web site as a single event, while the AFQI alarms would be repeated daily. In some cases, the FQM alarms would not receive as much attention from the service organizations. Some adjustments were made in the monitoring protocols through the test period and the way in which the FQM alarms were signaled differed somewhat from site to site.

From the outcome chart in Figure 3-5, it is clear that there were a significant number of alarms which were not resolved and could be considered "false alarms". For many of these cases there was a service visit and some basic combustion measurements were made indicating steady state performance was acceptable. Because these sites were customer homes, detailed monitoring to provide better understanding of the situation was not considered practical. In some of these cases rough starts were noted but not resolved. At one of these sites the boiler was known to be in poor condition and in need of replacement but the homeowner was not willing to make this investment at present (rental property). In another case the flame quality signal fluctuated strongly and the reasons for this were not resolved. For sites such as these, some of the problems which could lead to unresolved or "false" alarms may include:

1. Poor ignition and periodic flow of combustion products back into the flame tube, leading to fouling of sensor and air tube surfaces. Fouling on the air tube surfaces can lead to less reflected light getting to the sensor cell.
2. Air leaks in the fuel line;
3. Water in the system;
4. Inconsistent fuel pump operation;
5. Movement of the sensor cell.

The faults actually observed during the project included many of those listed in Table 3-4. Fuel system problems were certainly the most common specifically; fuel line blockage, nozzle fouling, and fuel pump failure. There were no cases of chimney blockage found and no cases in which excess air changed due to fouling of the fan inlet. One area of uncertainty in the analysis of project results is the supply of air to the burners. In some cases the burner air supply may have been more restrictive, due to the closing of doors and windows, after the setup team left the sites. This could contribute to unresolved changes in the signals.

Beyond flame quality measurement, the project results provide interesting information on field operating conditions. The Insight database provides cumulative run-time and number of burner cycles which proved to be very useful. From this data, the average burner "on" time, cycling rate, and if the nozzle size is known, daily fuel consumption can be calculated.

Figure 3-6 shows daily run times and number of cycles for a boiler with a tankless coil in the winter. Figure 3-7 shows the same information for the same boiler in the summer.

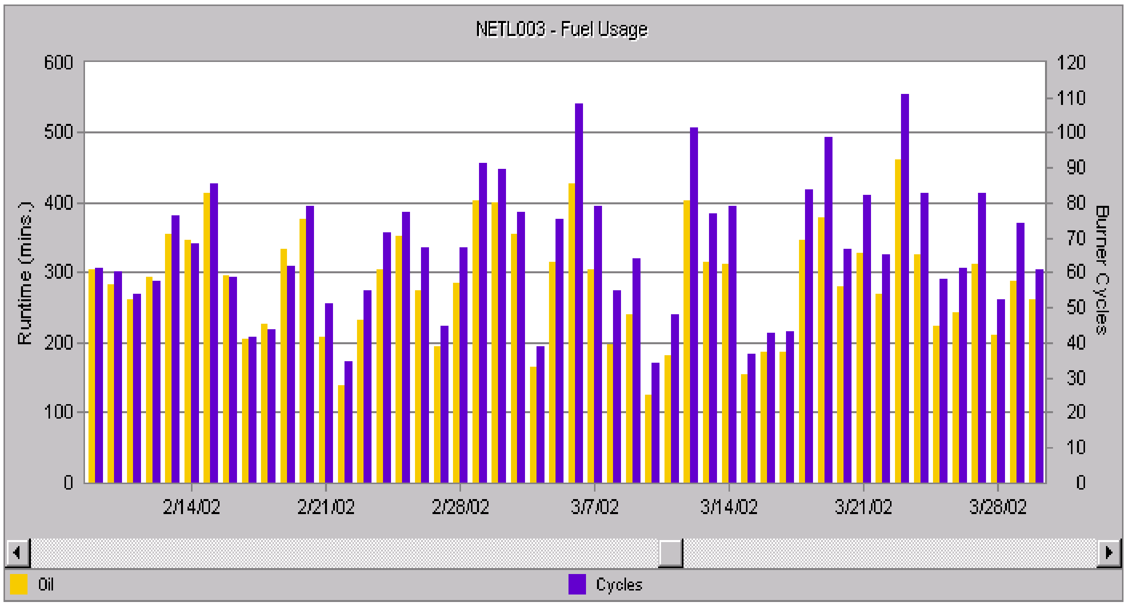

Figure 3-6: Example graphic from Insight monitoring web site. Run-time (light/yellow bars) and number of cycles (dark/blue bars) per day during winter.

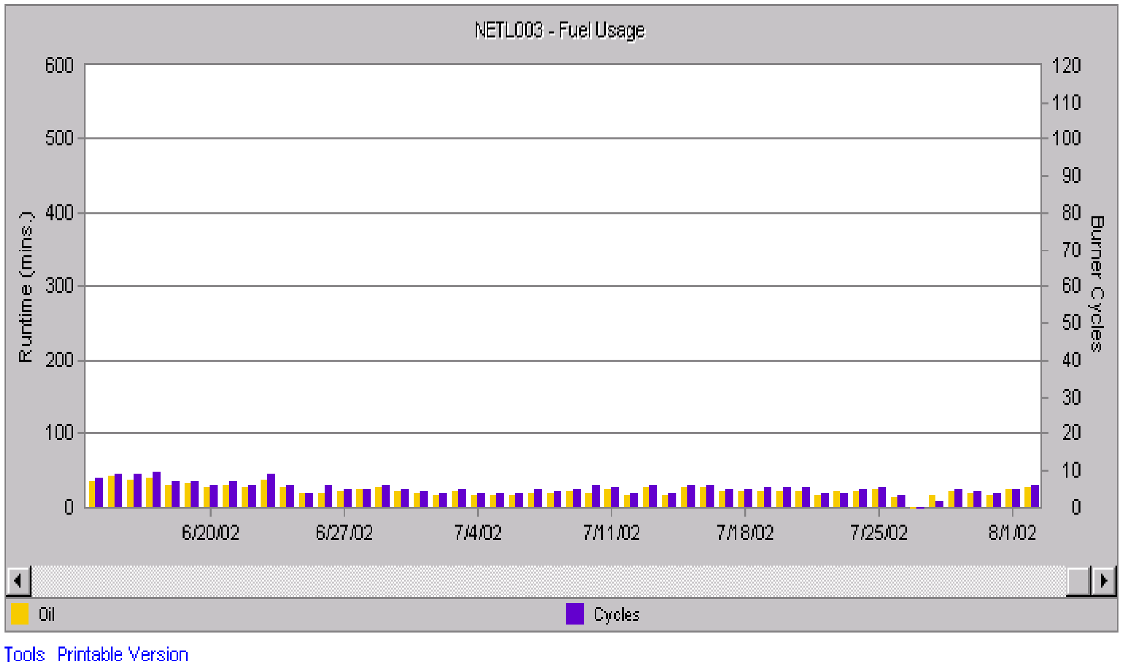

Figure 3-7: Example graphic from the Insight monitoring web site. Run-time and cycles per day during summer. Boiler with a domestic hot water coil but very light domestic hot water load.

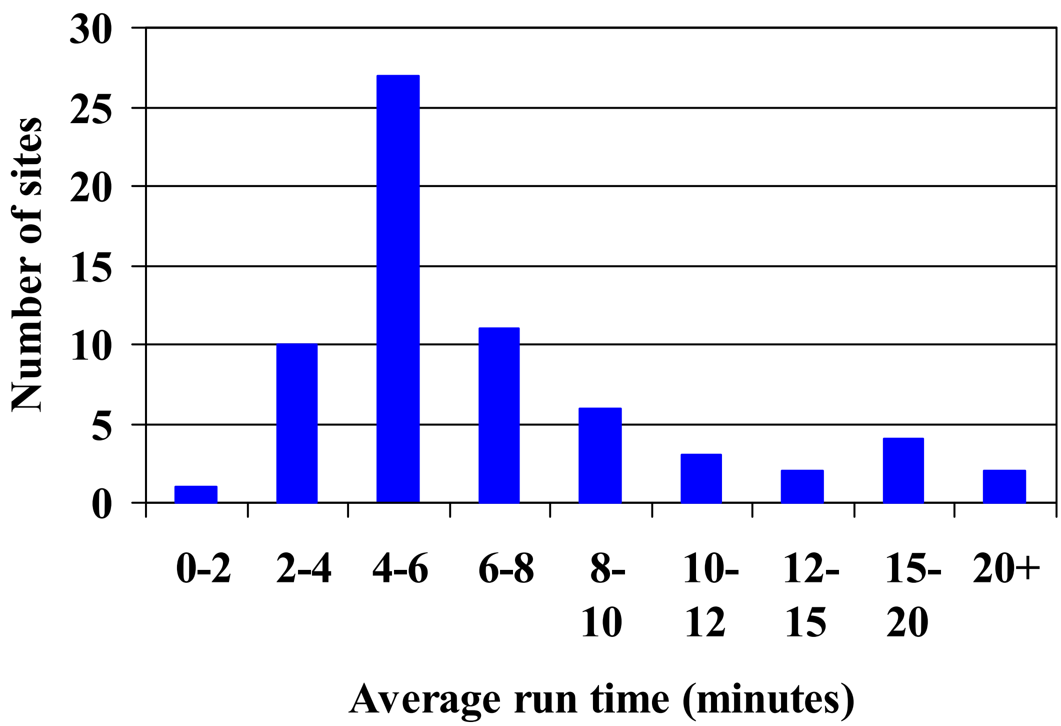

Figure 3-8: Distribution of average run-times for all units

For any site the average burner run-time can be found by simply dividing the total run-time by the total number of cycles. Figure 3-8 shows the distribution of average run-times for all units. The mean of all these run-times is 5.5 minutes.

Another interesting analysis involves examination of how cycling rate and run-time vary with outdoor temperature. In the analysis, the number of degree days assigned to each day can be used as a measure of the average outdoor temperature and this information is available from either local weather services or the participating service organization. Degree days are counted from midnight to midnight and the AFQIs call at different times during the day. Because of this, the approach being used is to analyze run-time and cycle data for a 24 hour period over a two day period, during which the average outdoor temperature was very steady. The 24 hour period might be for example, 10 AM one day to 10 AM the next, depending upon when the AFQI called. The degree days per day value for the two adjacent days was applied to that time period.

Figure 3-9 shows results in the form of Run-time vs. Degree Days for some selected sites with a linear fit-line through each data set. For every tested location there is a "design outdoor temperature". Design outdoor temperature is the outdoor temperature upon which residential heat load calculations are based. From the design temperature there is a corresponding number of degree days per day. By extrapolating the run-time trend line to the design point, the amount of time that the burner would run on the "design day" can be determined. This number, represented in hours, is divided by 24 to determine the oversize factor for the heating appliance. For the units shown, the oversize factor is typically 2. This information can be combined with firing rate and combustion efficiency to get a measure of the actual heat load for the house on the design day and aid in sizing replacement equipment.

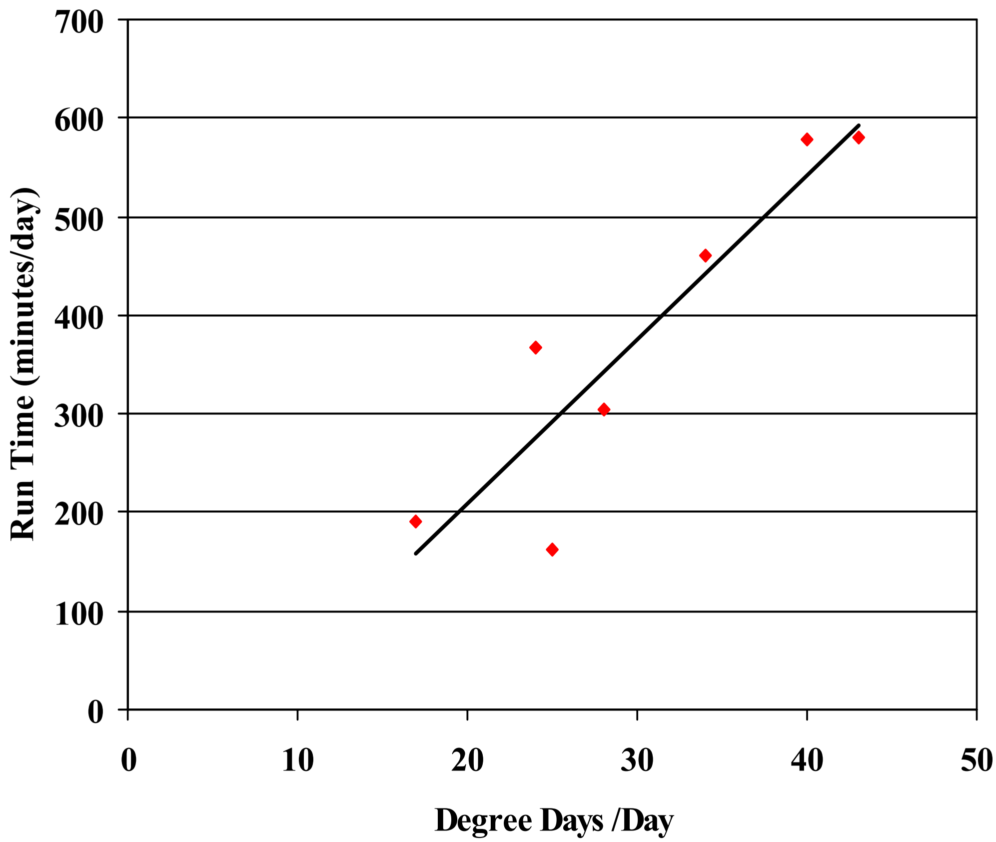

Figure 3-9: Example results from the monitoring web site. Run-time as a function of outdoor temperature

Figure 3-10 shows an example of the variation of average run-time per day with outdoor

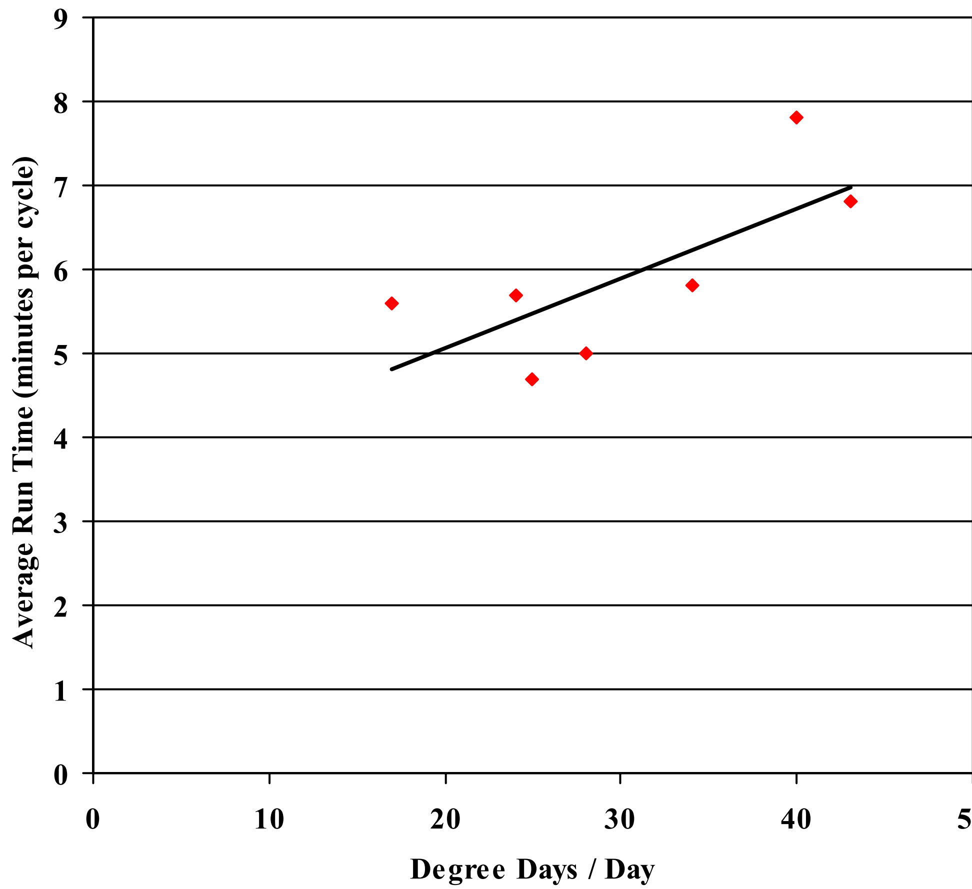

Figure 3-10: Example results from monitoring web site. Effect of outdoor air temperature on average run-time per cycle

temperature. It might be expected that the average run-time increases as the weather gets colder and heat demand increases. For some of the sites, a small increase in average run-time is observed under the coldest conditions although in others, the average run-time is fairly constant over the year. This implies that the run-time is limited not by outdoor temperature but by the capacity of the system to transfer heat from the boiler or furnace to the indoor space. Achieving longer run times (less frequent cycling) would require a higher ratio of distribution capacity to firing rate, or possibly higher mass boilers for a given firing rate. Simply stated, for a hydronic system, the homes need more baseboard for the firing rate.

For each delivery of fuel the run time from the monitoring web site can be combined with the actual delivered gallons to calculate the average firing rate of the burner since the last delivery. Figure 3-11 illustrates this for two selected sites. Site 69 has a nozzle with a nominal firing rate of 1.00 gph and Site 73 has a nominal firing rate of 0.85 gph (in both cases based on installed nozzle size). This method of estimating the actual firing rate has two specific sources of potential error. The first, results because the monitoring system used in this project calls the web site with information only once a day. If the delivery was made at a time different than the time at which the unit called, there will be a small error in the consumption and hour count between deliveries. The second potential error is the assumption that the tank is filled to exactly the same level with each fill.

The run-time information, provided by the flame quality monitoring can be combined with firing rate information to estimate fuel consumption, providing an alternative to the degree day method of planning deliveries. To illustrate this, an analysis was done at one site with a nominal nozzle size of 1.25 gph. Delivery data was obtained for this site over a one-year period. Using the data for the first delivery at this site during the test, the amount of oil predicted to be delivered, based on nominal nozzle size, was 8% (or 13 gallons) lower than the actual delivery. Based on the first delivery data it was calculated that the actual firing rate was 1.35 gph (fuel pump pressure was not measured). Using the calculated firing rate, the actual delivery and the delivery predicted based on burner run-time were then compared for the next 6 deliveries. Figure 3-12 shows this comparison. The largest difference between the actual and predicted deliveries in this case was 5.9 gallons. The average difference was 2.2 gallons. Figure 3-13 shows a similar comparison for several other sites which did not have as many deliveries over the test period. The largest difference between actual and delivered using this method is in the range of 20 gallons. All of these sites have 275 gallon tanks.

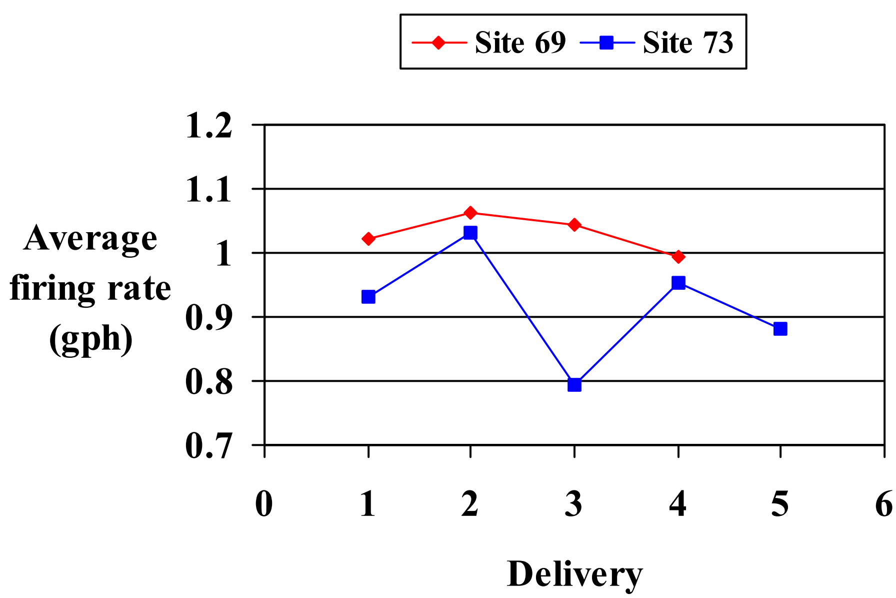

Figure 3-11. Variation in average firing rate, determined from delivered gallons and run-time for two sites.

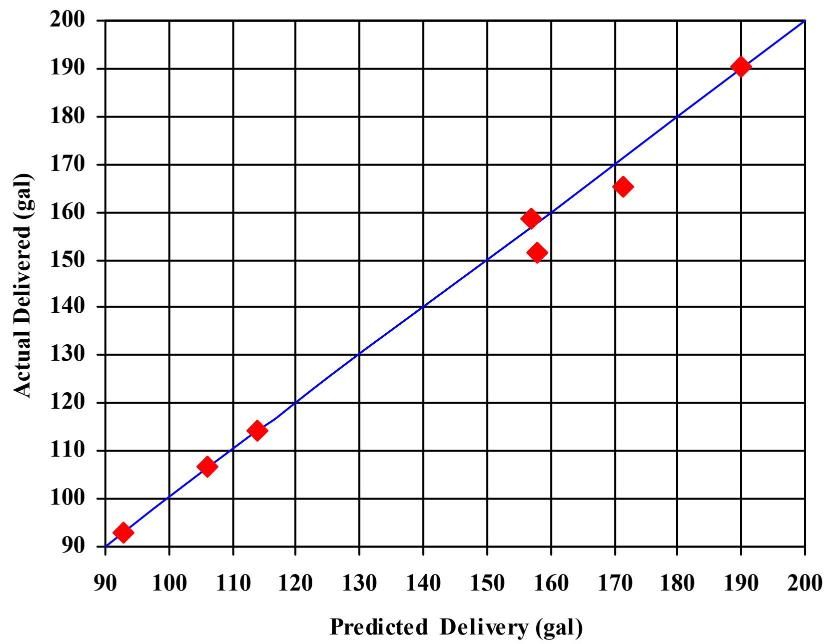

Figure 3-12: Comparison of actual amount of oil delivered to one site with the predicted amount based on run-time from the monitoring system.

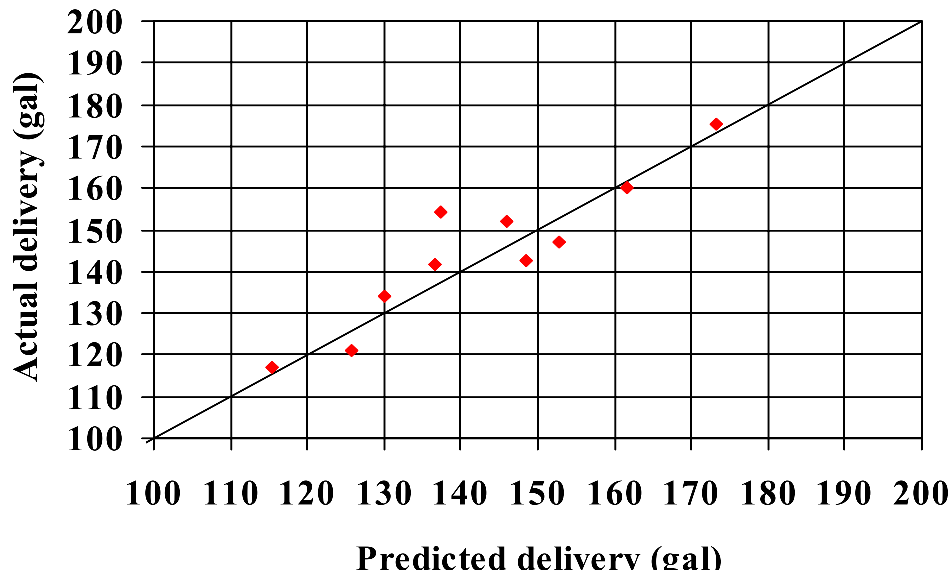

Figure 3-13 Comparison of actual amount of oil delivered to several selected sites with the predicted amount, based on run-time from the monitoring system.

4. DISCUSSION

This field test has served in large part as an introduction of monitoring techniques to the service industry. Results have shown that the system can be very useful in reducing service costs by providing early warning of fault conditions and extending the time interval between scheduled service. A significant number of unresolved alarm indications were also received during the project. Taken together, the results indicate that service organizations have to develop their own policies internally for how to use this technology to the best advantage. Certainly one clear shortcoming identified during this project was that not all of the service technicians in each organization were trained in the technology. This lead to repeated cases where the units were serviced, often under urgent conditions, by technicians who were not involved in the project and were unsure how to deal with the monitoring equipment. Some of this was a practical result of the "test" nature of this project. There was installed at each site much more equipment than is envisioned for commercial use and much more setup and calibration was required in this field test.

Discussions with service technicians and service managers during and at the end of the project provided some interesting feedback on their perceptions of the concept and the hardware used in this project. The most common points are as follows:

1. *The time required for installation of the equipment is too long. The addition of the second cad cell has to be eliminated.* This was the most common concern which was raised and this is, to a large degree, unique to the test program. The FQM device was developed to a large degree to eliminate the second cad cell and the long setup time.

2. *Getting a phone connection is a very significant part of the installation cost.* This concern is certainly accurate although it is very much site dependent. When presented with the tradeoff of phone connection cost and the ability to get information from the site easily, all service organizations indicated a preference for the phone connection. Options such as wireless connection were discussed although cost seems to be prohibitive at present.

3. *All participants were very enthusiastic about this concept but would be very concerned about large numbers of unresolved alarms.*

4. *This technology is seen as mostly positive in terms of their relationship with the customers, although some customers did not understand it and were apprehensive about it.*

5. *Service organizations, in general, do not want the information about alarms to be displayed to the homeowners.They feel that the homeowners should not have to be concerned about watching for alarm conditions, particularly in this case where the alarms are intended to be early warnings* In the case of the FQM, this requires that careful consideration be given to the methods in which alarm conditions are communicated to the service organization. The FQM closes a set of contacts when an alarm occurs. This could be easily integrated with a home alarm panel where one exists. In other cases options may include a local audio alarm, or external dialer.

6. *At some sites where there are repeat unresolved alarms monitoring may not be an economic option.* This technology is seen as an evolving one. As the industry gains more experience it is expected that there will be less sites in this category.

7. *The ability to view site trends on the webs is seen by some service organizations as a very desirable (in some cases necessary) feature. All service organizations want alarm notification that requires no time input on their part* (e.g., they do not want to log onto a web site daily and look for alarms).

Any service organization considering this technology should consider a cost/benefit analysis. To a very real degree this is company and even site specific depending on labor rates, the availability of alarm systems and / or phone lines and other factors such as usage, occupancy, and value. An expensive home with occupants who are not home all day or who travel for part of the year would obviously be a stronger candidate for this technology. For the service organization the most significant cost benefits are:

1. Reduced emergency phone calls – with early warnings of problems the service organization can get to the site during daytime hours.

2. Reduced time between scheduled service intervals – using flame monitoring the service organizations can transition to a policy involving on demand vs. annual cleanings and tune-ups.

3. Reduced occurrences of soot-ups. This refers to conditions where the boiler has become nearly blocked with soot deposits on the heat exchangers. At best, this requires a lengthy boiler cleaning and at worst soot stains in the home require costly interior cleanings.

4. Reduced number of oil deliveries per year. This is only a benefit if monitoring burner run time, which at present is only available as an AFQI feature. By better knowing how much oil has been used the number of deliveries can be reduced substantially. In addition to reduce labor costs this carries a possible advantage in service requirements. The biggest service cost for the industry is fuel related problems caused by storage degradation. This degradation increases with time in storage. Larger "drops" – i.e., filling tanks when the level is lower – leads to less time in storage for delivered oil. For typical residential oil tanks which are 275 gallons the average drop size based on a sampling of data from this project, is about 150 gallons.

For further analysis on this last point, one specific home was selected. A plot of oil consumption vs date was developed based on run time from the project web site and this is shown in Figure 4-1. Fuel delivery schedules were developed based on fixed drop sizes of 100 and 200 gallons and these are shown in Figure 4-2. From this data, the fraction of the first (Fall) fill remaining in the tank was calculated as a function of time. For the 100 gallon fill case it took 12 months for the initial fall fill to be consumed. For the 200 gallon fill it took 6 months. The outcome of this calculation will obviously depend upon the time of year selected for the "first fill" but this point is clear that larger fills can reduce residence time of oil in the tank and <u>may</u> help reduce service costs due to oil degradation.

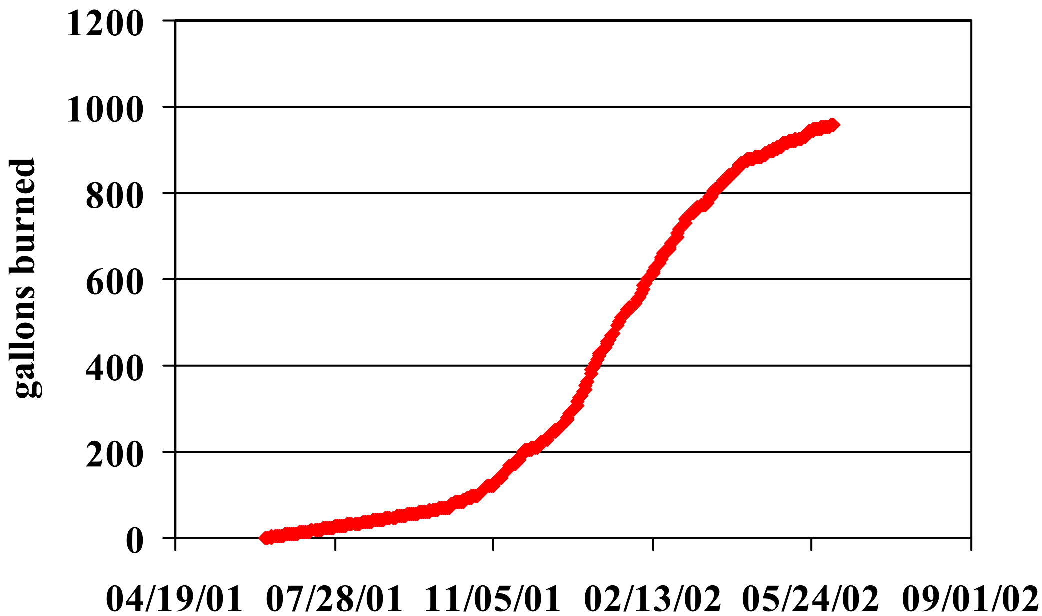

Figure 4-1. Fuel consumption profile used for analysis of fills at one site. Data from project web site

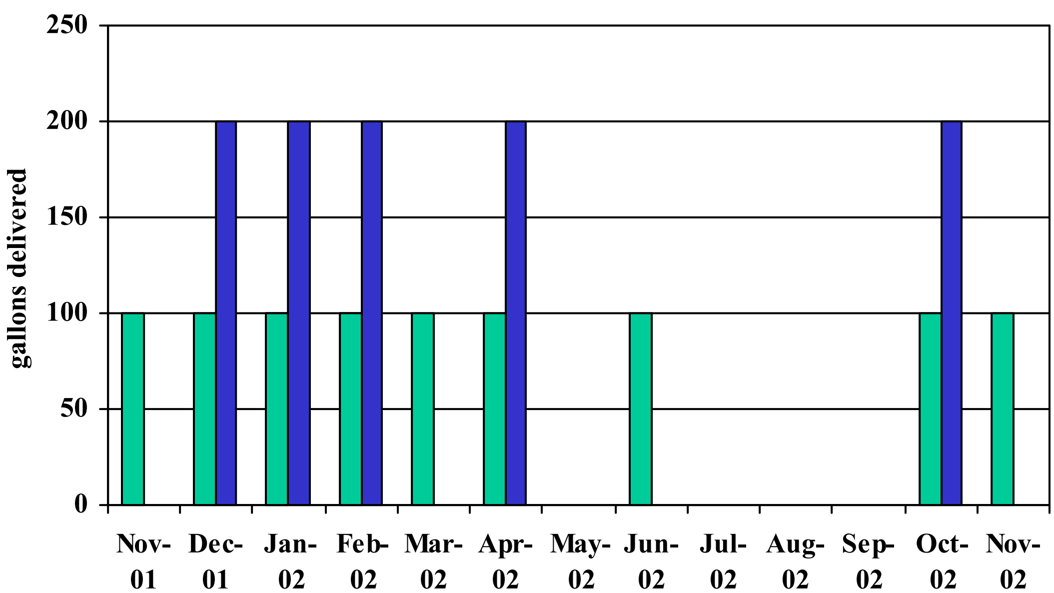

Figure 4-2 Comparison of fill patterns with 100 gallon and 200 gallon average drop size

A cost/benefit analysis method has been developed from the perspective of the service organization. For this model the following key input have been used based on inputs from industry:

1. The average retail price of fuel oil... $1.50
2. Average customer oil consumption - gal. per year 850
3. Efficiency improvement with FQM - % 2.0
4. Frequency of serious soot events (home damage) /1000 customers 0.43
5. Cost to clean a home after a soot event .... $3,500.
6. FQM reduction in soot events - % 95
7. Cost of service to the service organization - per hour .... $45.
8. Current scheduled service calls per year 1
9. Time of typical annual service call – hours 0.75
10. Reduction in service calls with FQM - % 40
11. FQI extra service calls (false alarms) - % 5
12. Time required to clean a sooted boiler - hours 3
13. Reduction in sooted boiler cases - % 85
14. Current emergency ("no heat") calls per 1000 customers per year 78
15. Reduction in emergency calls with FQM - % 50
16. Emergency call average cost premium - % 30
17. Dealer hardware cost (FQM only) .... $40.
18. Installation time – hours 0.5

Based on the above inputs the annual estimated cost benefit of the FQM is $14.67 and most of this comes from extending the service interval, eliminating the planned annual service visit and extending this to 2 years with service in between, as needed. The simple payback period is estimated to be 4.3 years.

This simple cost/benefit analysis does not include any benefits from improved fill schedules, which would require an approach closer to that of the AFQI system. The cost benefit of larger drops is estimated to be on the order of $10.00 per year per home. This analysis also does not consider other factors which are more difficult to quantify such as new customer development and retention of existing customers**.** There are other benefits which have not been quantified but which are clearly attractive, based on discussions with service organizations during the program. This includes, for example, freeze-up protection which can prevent a tremendous amount of damage to homes.

5. CONCLUSIONS

This two year test of the Honeywell FQM has shown that the concept can be very useful in reducing service costs and improving reliability by providing early warning of fault conditions. However, false alarms still do occur. Originally 100 homes were planned, but the number actually installed was 83. Host organizations in Virginia, New Jersey, Pennsylvania, New York, and Connecticut participated. The most common outcome was no alarms and no burner problems. There were, in the set of homes, however, a significant number of problems which occurred and triggered alarms. These included nozzle fouling, fuel line blockage, collapsed chambers, and failed fuel pumps.

Service organizations can get the most benefit from this technology by having a fully integrated, company-wide program including training and close follow up on alarms. Service organizations want direct feedback in the case of alarms without alerting the homeowners. This type of feedback can be provided through an existing home alarm system. Where an alarm system is not used an alternative communication method may need to be developed.

The value of this type of monitoring approach could be enhanced by incorporating fuel consumption calculated from run time. Additional advantages provided from run-time information would include reduced number of fills per year (and so reduced labor cost) and faster turnover of oil in the tank which may lead to reduced service cost associated with fuel degradation.

6. REFERENCES

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5. Sinha, R. Field trials of advanced controls of oil-fired heating equipment, Proceedings of the 1991 Oil Heat Technology Conference and Workshop, Upton, N.Y. September 30- October 1, 1991 R. McDonald ed., (BNL 523450) July 1992.

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APPENDIX

APPENDIX I
Fast Start Steps and Test Plan
(Included in the Project Binder provided to each host organization)

Fast Start!!
AFQI / FQM FIELD TEST
SETUP STEPS

1. Install Honeywell 7184 Primary Control and 2nd cad cell in burner (see Insight AFQI manual p. 10)
2. Fire and tune burner
3. While burner is running (after tuning) measure the resistance on the added cad cell. Adjust by adding cap as required to get 500 ohm reading (see AFQI manual p. 9). Record Ohms. Stop burner.
4. Connect cad cell to AFQI (see Insight AFQI manual p. 7)
5. Connect flue temperature probe to AFQI (see Insight AFQI manual, p. 7)
6. Connect phone jack to AFQI
7. Connect data cable from Honeywell 7184 Primary to Honeywell FQM
    - Ends are interchangeable
    - Ends only go on one way
    - Before removing ends (if necessary later) you must first carefully pry back plastic latch.
8. Calibration (Establishing FQM and AFQI setpoint)
    - Plug in the Insight AFQI unit power supply to a wall receptacle.
    - Run burner
    - Calibrate FQM by pressing "calibrate" button after warmup period is over (see Honeywell FQM manual, page 3).
    - Calibrate AFQI by pressing "SET 1" button after warmup period is over (see AFQI manual, page)
9. Check connection to Internet / Web Server
    - On AFQI press "Run" button
    - Lights will all flash on and then go through a test sequence. Last in the sequence in "Down Arrow" light. If this comes on, connection to server is confirmed. If not, call us.
10. After any future service, redo step 8.

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Field Test of the Flame Quality Monitor
Field Test Plan

Insight Technologies, Inc.
Agreement ID No. NT 40994

November 2000

Objective

This two-year field test will attempt to quantify the benefits, primarily service cost savings associated with the use of the Flame Quality Indicator monitoring.

Scope of Work

The Honeywell Flame Quality Monitor (FQM) and the Insight Advanced Flame Quality Indicator (AFQI) will be installed in 100 homes. In each of these homes, the flame quality indicator signal from the AFQI will be monitored remotely using a phone connection from the home to the Insight Webserver.

During the test period, flame quality indicator signal as well as service requirements for each site will be carefully monitored by all project participants. The basic performance (combustion monitoring with a portable gas-analyzer) will be recorded and evaluated at all sites at the start, midpoint, and end of the program, as well as intermediate times as appropriate.

At the end of the program, the service required at the test sites, which was logged during the test program, will be reviewed and compared with the historical data (FQI signal, stack temperature, total burner runtime, and no. of burner cycles) from the Webserver database.

Role of the Host Organization

The host organizations, in these tests, will be the oil heat service companies. The host organizations will be responsible for the following:

1. Site selection. This will include the customers' consent for participation in the study
2. Installation of the Honeywell FQM (QS7100F) and Insight AFQI monitoring devices in customer homes. FQM Installation requires a change-out of the original equipment Honeywell Primary Control.
3. Installation of the new Honeywell Primary Control (R7184) which has the provision of a data port to enable communication with the Honeywell FQM accessory module.
4. Connection of the AFQI to an existing phone line

5. Heating appliance performance measurements (O_2, CO_2, Excess Air, Stack Temperature, Draft and Smoke Number) and recording of these basic data
6. Basic site data will be measured by the service technician and logged (upon the initial visit and throughout the test program)
7. Respond to AFQI "service required" alarms and log any services performed in response to these alarms
8. Record all service required at the sites (even if service is not FQI related)
9. Keep Insight and BNL informed of unusual problems at a particular site

Role of Insight Technologies, Inc.

1. Provide AFQI hardware to the host organizations
2. Provide training (along with BNL) to the host organization staff on FQM and AFQI installation as well as instructing them with regard to service protocols

   (Note: The host organization is expected to identify a small dedicated team of service technicians who will be trained for this program.)
3. Maintain the Webserver and website to manage the AFQI customer database
4. Monitor all incoming data from the AFQIs and inform the service organizations and BNL when problems at specific sites are indicated

   (Note: While all participants can access data on the Insight Webserver, Insight will have responsibility for regular monitoring of this data.)

Role of BNL

1. Develop the basic test plan and assist the host organization in site selection and data management for this project

   (Note: All participants will agree on basic site selection criteria. The service organization is expected to add specific sites to the program on a short-notice basis depending upon service schedules. Equipment installation will be done in combination with regular cleanings/maintenance to reduce installation costs.)
2. Assist in the training of the service technician team at each host site
3. Where there are sites at which the FQM and/or AFQI has not properly indicated a fault or has falsely indicated a fault, BNL will visit this site, in coordination with the host organization, and attempt to understand and correct the situation. BNL will also conduct lab studies as necessary.

Role of Honeywell, Inc.
Honeywell will provide the required burner primary controls and the FQM units for this test. As the organization primarily involved with commercialization, Honeywell will participate in all phases of this program including planning, monitoring, and review of results.

Site Selection Criteria

The following are our working criteria for site selection:

1. Sites will include both hydronic boilers and warm-air furnaces. Some preference however, is given to boilers where fouling rates are higher.
2. Beckett and Carlin burners may be included in this study. Riello burners are not included at this time because of the additional time required to perform the AFQI installation and incompatibility of the Honeywell primary control with the Riello burner.
3. We hope to incorporate some "problem sites" – i.e., those at which there is a history of chronic problems.
4. Homes where there is limited access to a phone line or availability of power near the boiler will not be included in the study.

Calibration Procedures

All FQM and AFQI devices will be bench-tested prior to deployment for installation in the test sites.

Honeywell will perform tests to determine the actual points (High and Low limits) where the FQM trips an "out-of-range" alarm.

Insight's circuit boards are QA tested by the circuit board manufacturer in a test fixture before shipping to Insight. The power, sensor inputs, and modem are all tested before shipping the circuit boards to Insight. Before Insight will deploy AFQI units for use in this study, each circuit board will be tested "in-house" to insure the microprocessors are functioning properly. AFQIs will be pre-programmed by Insight with the Webserver's 800 number (toll free) and a unique Serial No. which will be used for identification throughout this study. Default settings for monitoring options will also be verified in the firmware.

During field installation and setup, critical measurements will include burner excess air and smoke number. The smoke number test is done in accordance with the ASTM standard and is used an approximate measure of the condition of the flame. For excess air measurement, all host organizations will use portable electronic gas-analyzers with electrochemical cells. BNL has two new portable analyzers of this type for use during this field test. The BNL analyzers, which measure flue gas oxygen content, will be checked in the BNL lab against a BNL paramagnetic flue gas oxygen analyzer which is, in turn, calibrated against standard grade gas mixtures. During meetings with the host organizations, the BNL portable analyzers will be used to check the host organization equipment using a local combustion source (boiler at the host organization site).

Periodically, gas analyzers from the host organization will be shipped, express, to BNL for a calibration check in the BNL lab, against the paramagnetic analyzer. This will be done at the highest frequency practical without interfering with the host's service operations.

Steps in the Field Test Program

1. Planning – BNL, Insight, and possibly Honeywell, will meet with the host organizations, review the site selection criteria, maintenance record management practices and the overall plan for the field test.
2. Formation of the service team – the host organization will select the service technicians who will be participating in the test program and will begin to consider sites for participation.
3. Training – BNL and Insight will visit the host organizations and provide training to the selected service technician team, service managers, and others involved with the project. This will include installation and operation of the AFQI and FQM, required site data, event-recording procedures, use of the Insight monitoring website, and overall project plan.

The team will also provide the host service organization with step-by-step instructions covering the installation procedure for all the requisite hardware.

4. Installation – The technical teams at the host organizations will install the test equipment. As necessary, BNL and Insight will visit the host organization to provide technical assistance.
5. First Year Monitoring – Insight and BNL will monitor all AFQI trend data through the website. As faults are indicated by the remote AFQIs, the appropriate host organization will be notified. For sites where alarm conditions occur, a service technician from the host project team will visit the site. At that time, basic performance measurements will be taken and the need for corrective action will be assessed and noted. Repairs will be made as required. The AFQI setpoint will be reestablished and the site will be returned to routine monitoring.

If service is required at the sites for non-FQI reasons (e.g. a no-heat call), Insight will be notified as soon as possible. If the burner is running, the basic combustion performance will be measured before repairs are made. The repairs will then be performed and the performance measurements repeated. The AFQI and FQM setpoints will be reestablished and Insight will be notified. The site will then be returned to routine monitoring.

6. End of the First Year – During the Spring, Summer, and Fall of ’01 the units will be cleaned and tuned according to the usual service practice of the host organization. Basic performance measurements will be made before and after the cleaning. The host organization will inform Insight before this routine service is

performed. After the service is performed the AFQI and FQM setpoints will be reestablished.

7. Analysis of First Year Results – After the end of the '00 – '01 heating season an analysis of all results will be done to identify areas in which the program needs to be improved for the following season and to complete a first analysis of the service cost savings associated with this technology. In doing this analysis the service records and costs for the test period with the FQI will be reviewed to determine the number of service visits required, service time required, time of day service was conducted, frequency of "no heat" incidents, cost of service visits, and replacement parts costs. A similar review will be made for the remainder of the homes (no FQI control) within the hosts' customer base for this heating season and last heating season. This will enable a direct comparison of the service costs with and without the FQI. In addition, for FQI homes where service calls were required during the heating season, a review of the nature of the service call and an assessment of the effectiveness of the FQI technology in allowing the service company to schedule service at a convenient time rather than on an emergency basis will be made. The cost benefits of this will also be assessed with the service company. Some of the installed FQI's may not have been in place for the entire heating season and, for this reason, some of the results may be considered indicators as opposed to final results.

   Some of the benefits of the FQI technology are more difficult to quantify. These include, for example, avoided disruption to customers with no-heat calls, improved customer perception of the service provided by the host organization, and increased reliability of the heating system during periods when the homeowner is absent (avoided freeze-ups). After the review of the results, Insight will meet with the host organizations, discuss their opinions on any of the above benefits, and attempt to quantify, rationally, the cost value associated with these factors.

   The results of this analysis will be used to formulate a preliminary cost/benefit analysis of the FQI.

8. Second Year Monitoring – Monitoring during the second year will be essentially the same as the first year. Prior to the start of the heating season Insight and BNL will meet with the host organization teams and make changes to planned procedures as necessary, based on the first year results.

9. Analysis of Second Year Results – After the end of the second year an analysis similar to that of the first year will be done to assess the service cost benefits of employing this technology.

Removal of FQI test equipment. At the end of the-'01 – '02 heating season the host team will remove all test equipment. Support will be provided, if needed, by Insight and BNL. It is possible that the service organizations and participating homeowners may wish to keep some of the installed monitoring equipment. The team will meet to discuss this option at that time.

Appendix II
Product Information on the Honeywell FQM
(Included in the Project Binder provided to each host organization)

Honeywell

QS7100F
Flame Quality Monitor
Advanced Feature Module

INSTALLATION INSTRUCTIONS

APPLICATION

The QS7100F Flame Quality Monitor is designed to be used in conjunction with any of the Honeywell Electronic Oil Primary Controls, such as the R7184A,B,P, or U by simply connecting the devices together with the communications cable supplied.

When these two devices are installed as a system, the burner properly adjusted and the Flame Quality Monitor initialized, the FQM provides continuous monitoring of the flame and gives warning when the combustion process has changed from its original operational state. This warning normally occurs three to five days before the primary control would shut down on safety lockout. Depending on the specific cause of the warning, the actual time may be shorter or longer.

Alarm contacts are unpowered and provide both normally open (NO) and normally closed (NC) contacts to match the alarm system, tank monitoring system or phone dialer to which the FQM is connected. Typically, the FQM is attached as a zone to the home security system or can be connected to a small alarm in the home. In either case, the person responsible for monitoring the alarm function is provided with directions on how to contact the appropriate oil service dealer so that service can be scheduled at a mutually convenient time.

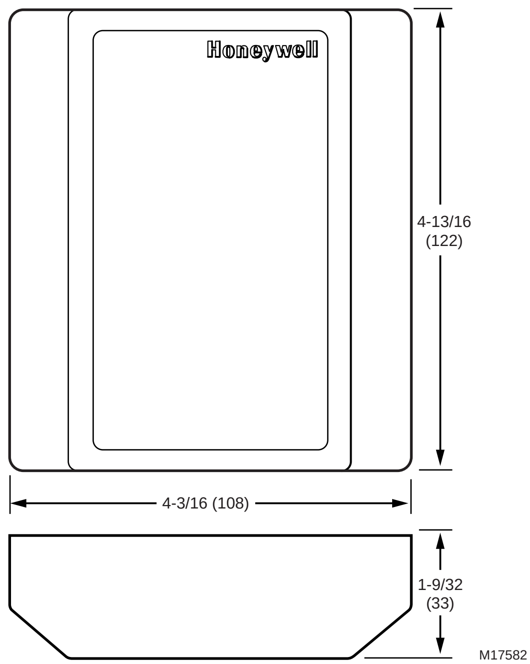

Fig. 1. QS7100F approximate dimensions in in. (mm).

SPECIFICATIONS

Electrical Ratings:
Input: 20 to 30 Vac, 60 Hz, 150 mA maximum.
Output:
Alarm relay contact ratings: 30 Vac, 2A, isolated NO/ NC contacts, pilot duty.
Communication Port: Rated only for use with Honeywell R7184 Oil Primary Controls.

Environmental:
Operating Temperature Range: -40°F to +150°F (-40°C to +66°C).
Shipping Temperature Range: -20°F to +150°F (-28°C to +66°C)
Humidity: 90% relative humidity at 95°F (35°C).
Vibration: 0.5 G. nominal.

Dimensions: 4-13/16 in. (122 mm) high x 4-3/16 in. (107 mm) wide x 1-9/32 in. (33 mm) deep. See Fig. 1.

Mounting and Orientation:
Case Mounting: Mount on wood, sheet metal, masonry or gypsum board surface using two no. 6 by 1 in. screws (supplied).
Case Orientation: No orientation restrictions.

Accessory: 32004703-001 Bag Assembly, consisting of communications cable and cable ties.

INSTALLATION

When Installing This Product...

1. Read these instructions carefully. Failure to follow instructions can damage the product or cause a hazardous condition.
2. Check ratings given in the instruction and on the product to make sure the product is suitable for your application.
3. Make sure the installer is a trained, experienced service technician.

4. After completing the installation, use these instructions to check out the product operation.

⚠ WARNING

Explosion or Fire Hazard.
Can cause serious injury or death.
1. Disconnect the power supply before beginning installation to prevent electrical shock or equipment damage.
2. Make sure the combustion chamber is free of oil or oil vapor before starting the system.

Location

1. Mount the device on the appliance or on a mechanical room wall using the screws (and drywall plugs, if necessary) provided in the package.
2. To mount on a panel or wall, remove the cover from the QS7100F and use the base as a guide to mark the location of the mounting holes. Drill starting holes at the marked location.
3. Make sure the operating temperature is between -40°F and +150°F (-40°C and +66°C).
4. Locate the FQM so that the communication wiring is routed away from the hot surfaces of the burner and other appliances. Use wire ties supplied with the FQM.

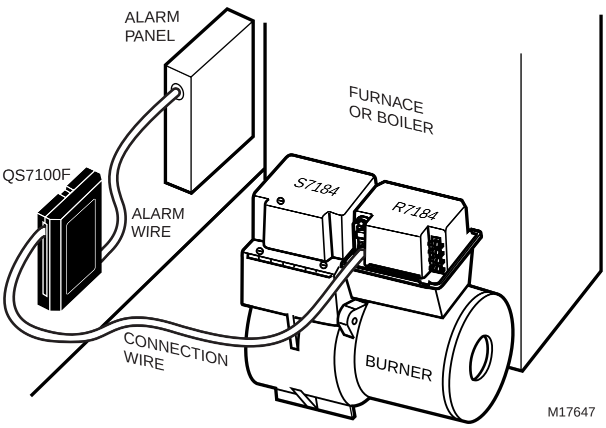

Fig. 2. QS7100F typical mounting.

WIRING

Low Voltage Wiring Connections

After mounting the QS7100F Flame Quality Monitor, make low voltage connections as follows (Fig. 3):

⚠ WARNING

Electrical Shock Hazard.
Can cause serious injury or death.
Disconnect all power to unit prior to making wiring connections.

1. Turn off power to unit.
2. Plug communication wire (provided), with special three-hole socket, into the oil primary control.
3. Plug other end of communications wire into the QS7100F Flame Quality Monitor Advance Feature Module.
4. Connect low voltage wiring from the alarm system, tank monitoring system or phone dialer to the appropriate screw terminals: COM, NO or NC.
5. Return power to the system.

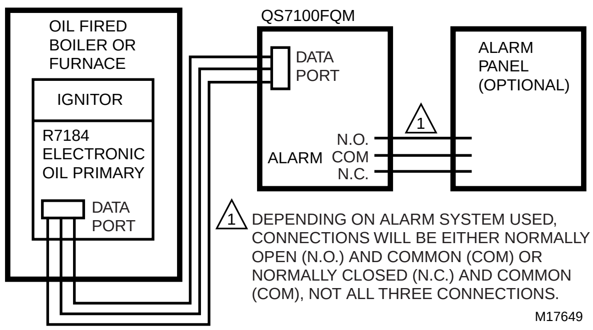

Fig. 3. Simplified wiring block diagram.

OPERATION

The FQM includes a selectable timer that allows the service technician to select a warm-up time that is compatible with the particular appliance. See Table 1 for suggested warm-up times and Fig. 4 for warm-up delay switch settings. The warm-up time allows the system to reach stable operating temperatures in the combustion chamber prior to measuring the flame signal.

Table 1. Warm-up Times

Warm-up Time Selection (Minutes)	Typical Appliance
2	Warm Air Furnace
3	Dry Base Steel Boiler
4	Wet Base Steel Boiler
5	Cast Iron Boiler

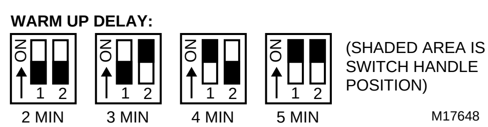

Fig. 4. Warm-up delay switch settings.

Once the heating appliance has reached steady state (as defined by the adjustable warm-up setting) the Optimal LED will cease flashing and remain on to indicate that the FQM is monitoring the flame and that combustion is in the optimal range. Once the burner cycles on and has run for more than the pre-selected warm-up time, if the flame exceeds either the high or low limits, it will register out of range operation. When three consecutive out-of-range signals are detected, the FQM will trigger the alarm, indicating a need for service soon. The High or Low LED will simultaneously turn on, providing a guide for troubleshooting. See Troubleshooting Section for more information.

Adjustment

After all connections are properly made:

1. Select the appropriate warm-up delay period by setting the DIP switches as shown in Table 1 and Fig. 4.
2. Initiate a call for heat and allow the appliance to run for a minimum of 10 minutes. (See NOTE, below.)
3. Following industry accepted adjustment procedures, adjust the burner per the burner OEM directions for zero (0) smoke, stack temperature, overdraft, CO_2, etc., and record the readings.
4. The Optimal indicator LED should be flashing.
5. When all adjustments are final, push and hold the calibration button for approximately three seconds. The Optimal LED indicator will go out and then flash. Release the calibration button.
6. The Flame Quality Monitor is now set for calibration. On the next burner cycle that exceeds the warm-up delay time, the Flame Quality Monitor will take an initial reading and store that information in the device memory.
7. With the burner still running, press and release the Reset button on the R7184 Oil Primary Control and check the resistance reading flash code on the oil primary control LED. The oil primary control must respond with three or less flashes.

NOTE: If the system has not been run for a week or longer, the system should be cycled in the normal heating mode for a minimum of one hour before initializing the FQM.

IMPORTANT

Any time the burner setup is altered, either by an adjustment in air, change in nozzle size or spray pattern or changes in draft, it will be necessary to retest combustion for proper firing and readjust the setup of the FQM. Repeat steps 1 through 7, above.

CHECKOUT

Use instruction sheet(s) provided with the oil primary control to check system operation.

TROUBLESHOOTING AND MAINTENANCE

IMPORTANT

1. *Only a trained, experienced service technician should perform the troubleshooting procedures.*
2. *This control and associated oil primary control contain no field-replaceable parts. Do not attempt to take them apart. Replace the entire control if operation is not as described.*

Detecting a Combustion Problem

1. The FQM will indicate that a change in flame quality has occurred during a burner on cycle when either the High or Low LED indicator light turns on. See Table 2 for a guide to Indicator Light (LED) information.
2. If the FQM does not appear to be working properly, check the cad cell resistance as described in step 7 of the Adjustment Procedure. If the resistance is high, check for soot deposited on the glass face of the cad cell. Clean or replace the cad cell.
3. Alarms can be caused by accumulation of soot or oil on the burner tube which will decrease or increase the amount of light seen by the cad cell. Clean the burner tube. See Table 3 for a guide to the possible causes of alarms.

Table 2. LED Service Guide.

<table>
<tr><th rowspan="2">Status</th><th colspan="4">LED</th></tr>
<tr><th>Power</th><th>High</th><th>Optimal</th><th>Low</th></tr>
<tr><td>Power up.</td><td rowspan="7">Constant On.</td><td>Off</td><td>Off</td><td>Off</td></tr>
<tr><td>Warm-up.</td><td>Off.</td><td>Flashes on-off.</td><td rowspan="4">Off.</td></tr>
<tr><td>Two or less out-of-range, high.</td><td>Constant on.</td><td rowspan="2">Off.</td></tr>
<tr><td>Three or more out-of-range high, alarming.</td><td>Flashing.</td></tr>
<tr><td>Within acceptable operating range.</td><td rowspan="5">Off.</td><td>Constant On.</td></tr>
<tr><td>Two or less out-of-range, low.</td><td rowspan="4">Off.</td><td>Constant On.</td></tr>
<tr><td>Three or more out-of-range, low, alarming.</td><td>Flashing.</td></tr>
<tr><td>Device is not communicating with Oil Primary Control.</td><td>Two flashes followed by a longer Off period.</td><td rowspan="2">Off.</td></tr>
<tr><td>Oil Primary Control in Lockout, alarming.</td><td>Three flashes followed by a longer Off period.</td></tr>
</table>

Table 3. FQM Troubleshooting Guide.

FQM Signal	Condition	Possible Cause
Out-of-Range High	Fuel rich	Combustion air supply blockage.
		Backdraft, downdraft, defective draft control.
		Blocked heat exchanger.
		Poor atomization.
		Excess fuel.
		Oil accumulation on burner tube.
		Change in aromatic content of fuel oil.
Out-of-Range Low	Fuel lean	Too much excess air.
		Partially clogged nozzle, filter, line.
		Boiler leak into combustion chamber.
		Cracked heat exchanger.
		Soot accumulation on burner tube. Change in aromatic content of fuel oil.

Nuisance Alarms

Nuisance alarms are usually valid alarms that are the results of hard-to-detect causes. If an FQM alarm occurs and inspection of the heating appliance indicates proper operation, i.e., zero smoke, proper CO_2, excess air, then the following items should be checked:

- Chimney Design and Location—It is possible that wind direction and resulting pressure changes from roof, adjacent buildings, trees, etc., can make major differences in the combustion air and drafting.
- Combustion Air Supply—Check to see if the building has been changed since the initial adjustment, e.g., is there more or less combustion air available due to changes from sealing the building, changing windows or doors, etc.? Have doors or windows or outdoor air makeup systems been blocked or changed? Is there an exhaust or attic fan that is on or off?
- Oil Tank and Oil Quality—has the tank been filled recently? Has the grade of fuel oil changed or a different supplier filling the tank, resulting in a change in fuel quality?
- Fuel Filter and Oil Supply Lines—Is the filter clogged and restricting fuel flow to the oil burner fuel pump? Is the fuel filter or strainer dirty? have the oil lines been damaged, restricting fuel flow?
- Combustion Chamber and Combustion Environment—Check the integrity of the combustion chamber or refractory. Check for cracked boiler sections, sand holes, seal failures. In warm-air furnaces, be sure to check the integrity of the heat exchanger.
- Draft Regulator—Check to assure that draft regulator is working properly.
- Oil Pump pressure weak.

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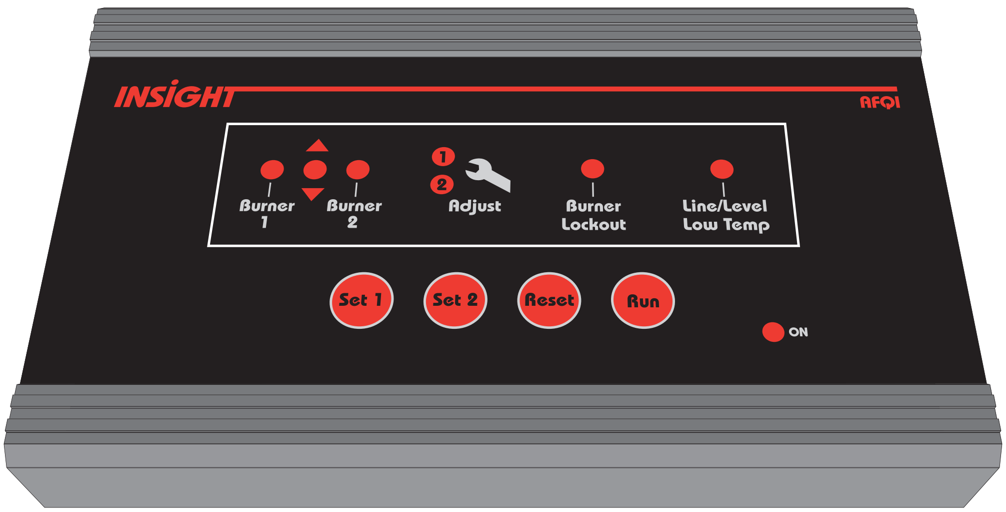
Appendix III
Product Information on the Insight AFQI
(Included in the Project Binder provided to each host organization)

AFQI

installation manual



important

This electronic device should be installed by a qualified service technician who will be responsible for the observance of all existing national and/or local code regulations. Test instruments must be used to achieve proper burner combustion in order for this device to perform as intended.

Rev. HW991203

AFQI

CONTENTS

about the Insight AFQI

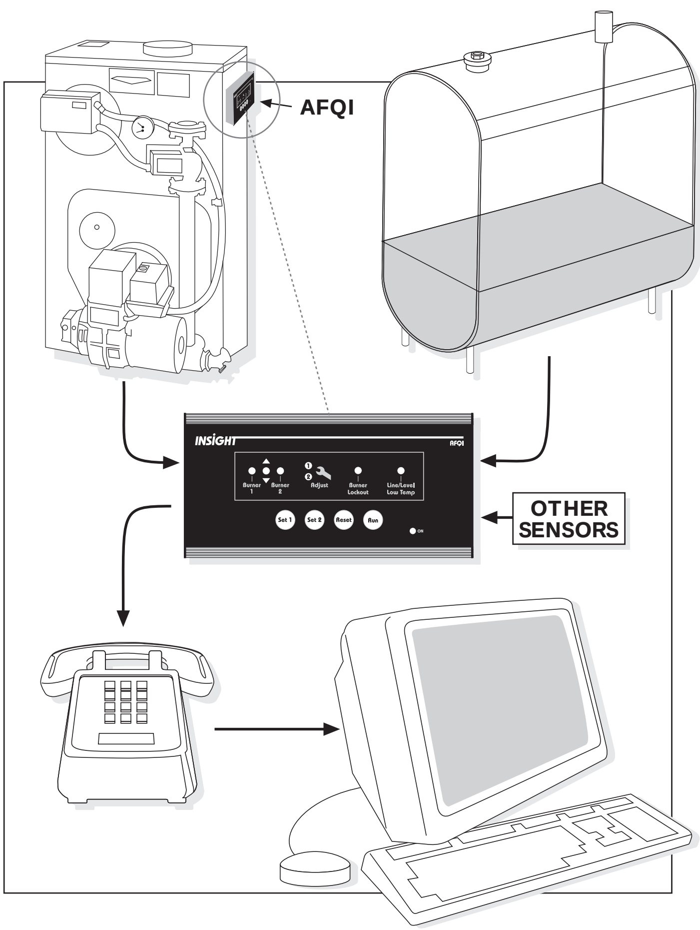
The Advanced Flame Quality Indicator (AFQI) represents a major advance in oil heating system management and monitoring. The AFQI is capable of problem detection and reporting to a Central Station Computer the conditions that will lead to oil burner failure if not attended to. The AFQI can send alarms and alerts over the customers phone line to signal the presence of a problem. It regularly reports on the operational status and performance history of the equipment giving the service agency an opportunity to respond to an undesirable condition before it develops into an emergency service situation and a potentially dissatisfied customer.

The AFQI is capable of monitoring several sensor inputs. When the desired operating range limits are programmed into the AFQI's memory (EPROM) it is enabled to send an alarm or alert should any of the following conditions occur:

- Oil burner flame degrades due to fuel contamination, fouled nozzle, unfavorable draft conditions (obstructed heat exchanger or chimney, backdraft from exhaust fans, etc.) or any other malfunction resulting in a change in the air/fuel ratio
- Burner is in lockout mode
- Oil tank level drops below low limit
- Oil level increases unexpectedly
- Oil line and/or oil filter becomes restricted to fuel flow
- Temperature in a heating zone falls below a low limit
- Water leaks onto a surface

description of operation

The AFQI is mounted on the heating appliance and connected to various sensors. Sensor inputs are continuously processed and automatically update a customer database on a Central Station Computer. The Insight AFQI provides an accurate determination of oil tank level and permits oil deliveries to be scheduled for maximum efficiency. Trouble with the burner, oil filter or oil tank are indicated well in advance of an emergency situation allowing for the convenient scheduling of service. Additional alarms are provided for low oil, burner lockout, low temperature and water leaks. Proper use of flame quality monitoring will reduce heat exchanger fouling and sooting to eliminate related no-heat service calls. The AFQI provides a new level of value-added customer service and creates new opportunities for dealers and service contractors to provide remote monitoring services. The AFQI will increase heating equipment reliability and safety, reduce fuel delivery and service costs and enhance customer satisfaction.



This diagram illustrates how the AFQI functions as a system monitoring input from different sensors. The AFQI processes the sensor inputs and reports alarms or alerts to a Central Station Computer (CSC) over the customers phone line. The AFQI automatically reports the operational status and performance history and updates customer information in a database.

specifications

Dimensions: height 4.1"; width 7.5"; depth 1.3"
Enclosure: Extruded aluminum with anodized finish
Display: Flat panel (velvet polycarbonate) with backlit indicators
Power: 9 VDC (500 mA)
Inputs:

- (2) Cadmium sulfide optical sensor (Honeywell No.C554 A 1794)
- (1) Combined oil level/oil filter pressure sensor
- (2) Temperature (thermistor operating range: 0-100 degrees C)
- (1) Safety Lockout (24 VAC Optical-isolated relay)
- (1) Water sensor

Outputs:

- NC/NO contacts (Default=NO, NC is selectable via internal jumper, rating=12 VDC, 3 Amp)
- RJ-11 modular phone jack
- RS-232 Interface (optional interface cable—available separately)

other parts needed

❑ "Handy box" with 110 VAC duplex outlet and cover
❑ RJ-11 modular phone jack
❑ RJ-11 single-line modular extension cable (red and green conductors only)
❑ Phone cable
❑ Low voltage wire
❑ 24 VAC transformer (for burner lockout monitoring with Beckett AFG Burner)

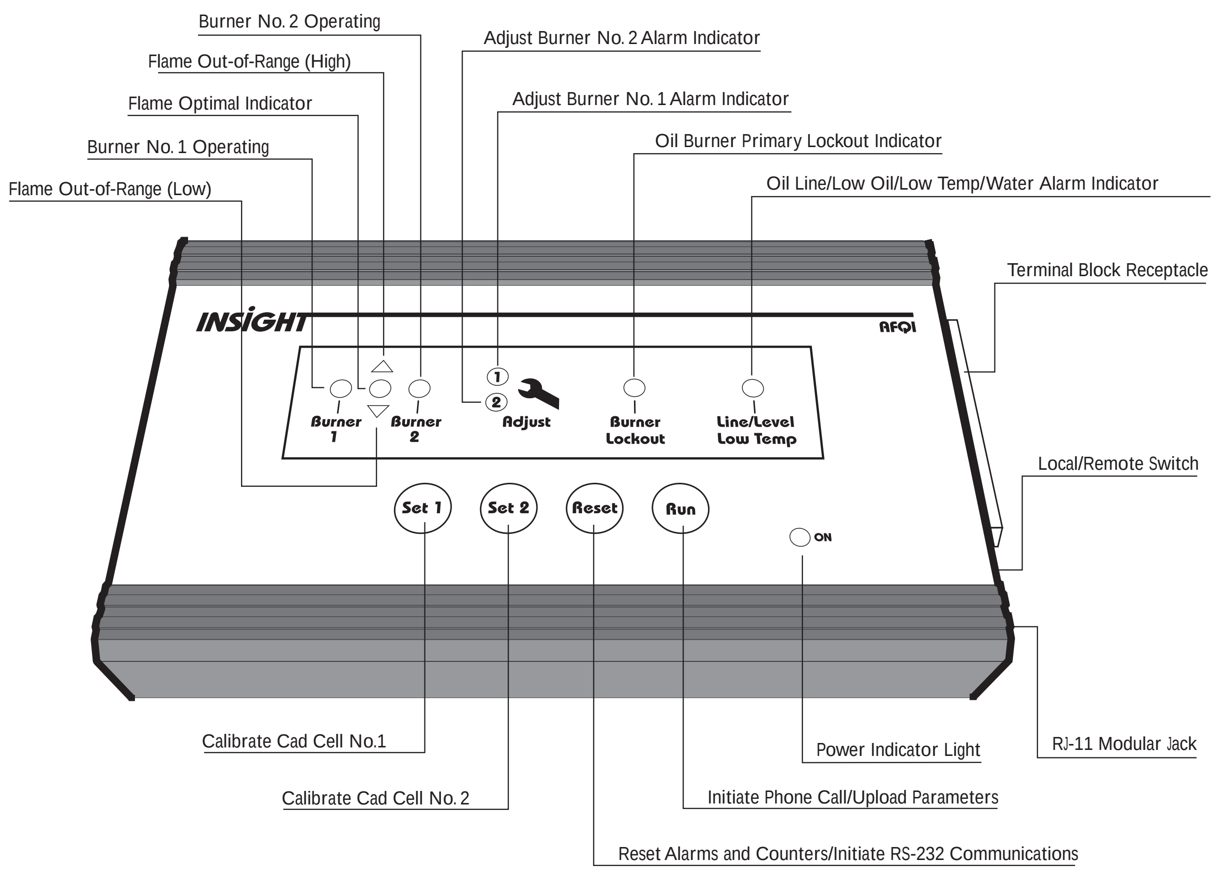
tools required

❑ Wirestripper
❑ Small screwdriver
❑ Volt/Ohm meter
❑ Palmtop or notebook PC (running Windows 95, 98, NT, or Windows 2000)

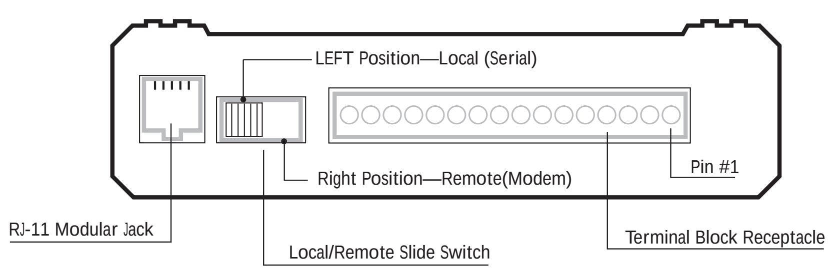
parts required

Monitoring Application	Required	Supplied	Insight Part No.
Flame Quality (w/Riello burner)	Hamamatso Cad cell (model no. P930-05)	NO	CC-RCSUL
Flame Quality (Beckett or other)	Honeywell Cad cell (model no. C554A1794)	NO	CC-CSUL
Flame Quality (Beckett AFII)	Piggyback monting clip	NO	I-PMC
Burner Lockout (w Honeywell Primary)	Honeywell Cad Cell Primary with Dry Contacts (model no. R8184G 4082)	NO	H-PRA
Burner Lockout (w Carlin Primary)	Carlin Cad Cell Primary with Dry Contacts (model no. 60200-02)	NO	CT-PRA
Riello Lockout (std w/Riello Primary)	Insight 10 ft. Lockout Cable	NO	RLC-10
Oil Tank Level (model IMS-1100A or B)	Stainless Steel Pressure Sensor	YES	SSPT-A or B
Oil Tank Level (model IMS-1100)	N/A	NO	N/A
Oil Filter Status (model IMS-1100A or B)	Stainless Steel Pressure Sensor	YES	SSPT-A or B
Stack Temperature	RTD-870 Stack Temperature Probe	NO	RTD-870
Low Temperature (model IMS-1100A or B)	Temperature Thermistor (0 to 100 C)	YES	TT-10K
Optional Low Temperature	Remote Temperature Sensor (o to 100 C)	NO	DTS-RT

AFQI description



right side view



Quick Setup

Mount the Insight AFQI control unit
- Use the mounting template provided (Appendix) to locate mounting screw locations

Install a second cad cell in the burner
- Securely mount the cad cell in the burner chassis
- Route the cad cell leads through the chassis
- Connect to the terminal block connector at pin nos.10 and 11 *(cad cell no.1)*

Install the oil line/level pressure sensor
- Install the brass tee in the oil line between the oil filter and burner pump
- Install the pressure sensor on the tee
- Plug the Packard connector end of the wire harness into the pressure sensor
- Route the sensor wire (keep away from line voltage leads)
- Connect to the terminal block connector using pin nos. 12,13, and 14 *(pressure sensor)*

Install the temperature sensor
- Find a suitable location for placement of the temperature thermistor
- Route the sensor wire (keep away from line voltage leads)
- Connect to the terminal block connector at pin nos. 5 and 6 *(temperature sensor)*

Install the water leak sensor
- Place sensor on the floor with the metal contacts facing down
- Route the wire and connect to the terminal block at pin nos. 7 and 8 *(water sensor)*

Connect to a power supply
- Check polarity (+/-) of the provided 9VDC power transformer
- Connect leads to the terminal block connector (9VDC(+) to pin no. 16 and ground(-) to pin no. 15)
- Plug the transformer into a 110V duplex outlet

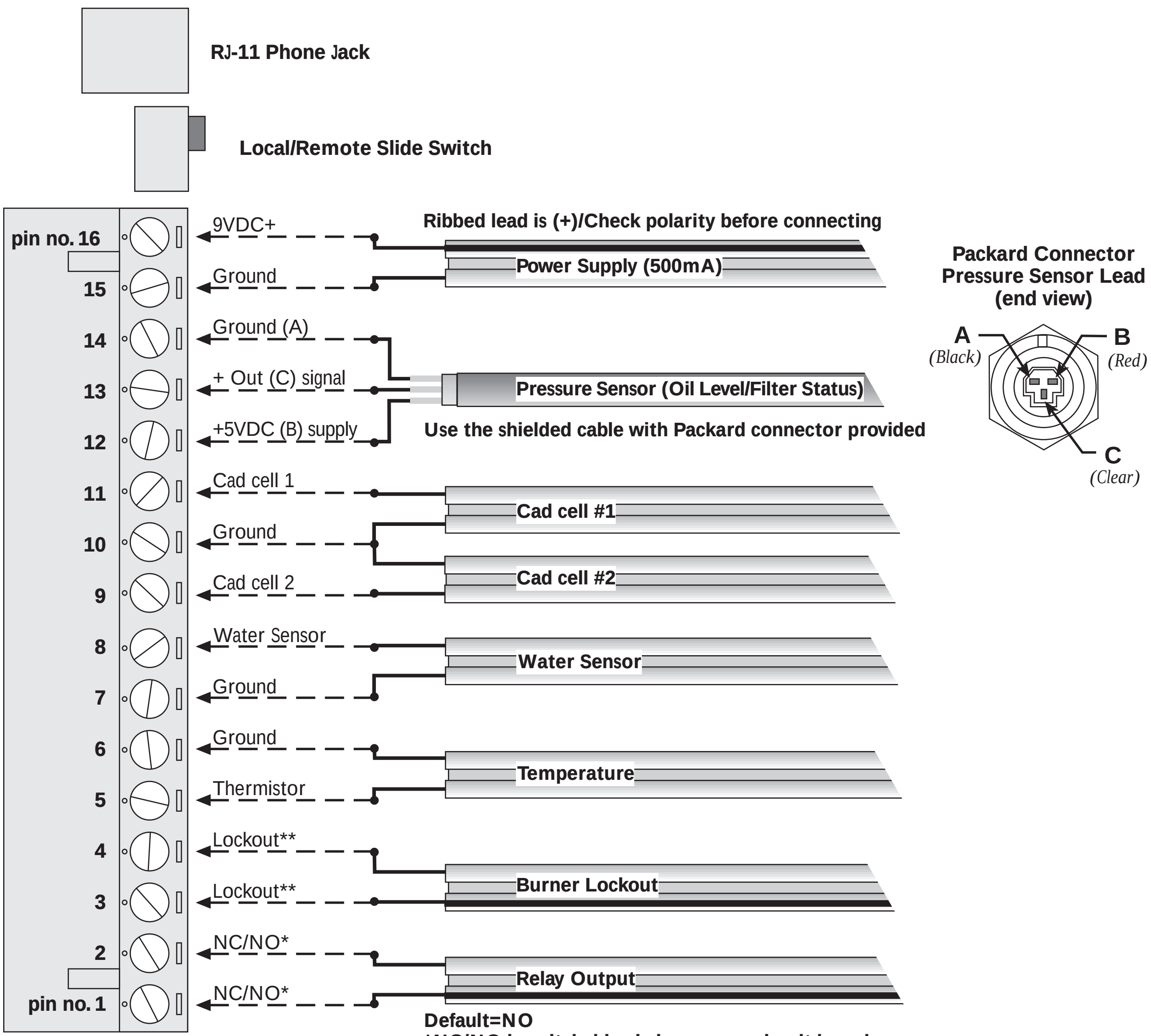
Insert the terminal block connector
- Make all connections to the supplied terminal block connector
- Position the terminal block connector so the screws are on the bottom (away from you)
- Plug the connector into the AFQI **with the RED DOT facing you**

  The terminal block connector is designed to be inserted one way—***do not force it!***
- Route all wires to prevent overheating or interference with the burner

Program the AFQI
- See “programming” section (begin on page 18)
- Suppress unused alarms and alerts (see page 24)

Calibrate the AFQI
- Press the SET 1 button to calibrate the cad cell channel No. 1
- Press the SET 2 button to calibrate the cad cell channel No. 2 (only if monitoring a second burner)
- Connect a phone line
- Force a call by pressing the RUN button

terminal block connector diagram



Default=NO
*NC/NO is switchable via jumper on circuit board

**24VAC signals lockout
(greater than 24VAC requires a series resistor)

Install the AFQI

Mount the AFQI control unit

- Find a location convenient for access to a power supply and telephone junction
- Use the mounting template supplied to install the two #10 sheet metal mounting screws
- Hang the control using the keyhole slots on the back of the enclosure

Determine which monitoring features are desired

- Consult the "applications" section of this guide to determine which sensors are required
- Install sensors and connect leads to the correct pin nos. on the terminal block connector-*see page 7*

Connect to a phone line

- Install a modular phone jack within 6' of the AFQI control
- Use a single phone line modular extension cord to connect the AFQI to the modular jack

Connect to a power source

- Check the polarity of the 9VDC wall transformer power supply included with the AFQI
- Connect the 9VDC power supply to the terminal block connector

  Make certain that the 9VDC(+) is connected to pin no. 16 and the ground(-) to pin no. 15 or the AFQI will not function. The 9VDC transformer may also become damaged if not installed correctly.

- If a power source is not available, install a "1900 box" or "handy box" with a 110V duplex outlet
- Plug the 9VDC transformer into a 110V outlet

Install the terminal block connector

- Insert the terminal block connector into the 16 pin male terminal block receiver on the side of the AFQI
- All the front panel LEDs should light for a second and the power indicator LED should remain "ON"

  If the power indicator does not remain lit then, refer to the "troubleshooting" section in this guide

Program the AFQI

- Setup the RS-232 Interface before you can begin programming-*refer to page 18*
- Determine which monitoring functions will be enabled
- Proceed to the appropriate "programming" section and follow the instructions as outlined
- Suppress unused alarm functions-*refer to "programming" section on page 24*

Force a call

- Complete programming of the required sensor parameters
- You are now ready to initiate the first call to the Central Station Computer
- Press the RUN button and observe the sequence of lights on the front panel display

  If the DOWN arrow indicator does not light after the OPTIMAL, UP, ADJUST 1, ADJUST 2, then refer to the troubleshooting section

flame quality monitoring

Install a second cad cell in burner no. 1

- Position a second cad cell sensor within the burner chassis pointing toward the flame
- Securely mount the cad cell within the burner housing
- Route the cad cell leads through the burner chassis and connect to pin nos. 10 and 11

Before connecting the second cad cell leads to the AFQI terminal block, use an Ohm meter to verify that the cad cell resistance is in the range of 350-700 Ohms. 500 Ohms is an optimal resistance reading (if the cad cell resistance is outside this range, refer to the "troubleshooting" section).

Install a second cad cell in burner no. 2 (optional)

When monitoring two oil burners (example: a boiler and water heater) make certain the burner that operates year-round is designated cad cell channel no.1.

if two burners share the same oil supply line, then both burners must have a second cad cell installed and monitored.

- Position the second cad cell sensor within the burner chassis pointing toward the flame
- Securely mount the cad cell within the burner housing
- Route the cad cell leads through the burner chassis and connect to pin nos. 9 and 10

Before connecting the second cad cell leads to the AFQI terminal block, use an Ohm meter to verify that the cad cell resistance is in the range of 350-700 Ohms. 500 Ohms is an optimal resistance reading (if the cad cell resistance is outside this range, refer to the "troubleshooting" section).

Setup the oil burner

- Make certain the chimney and heat exchanger are free of soot and debris and there is proper draft
- Setup the burner to manufacturer's specifications
- Check burner setup with combustion exhaust test instruments
- Warm-up the heating appliance

Program the AFQI for flame quality monitoring

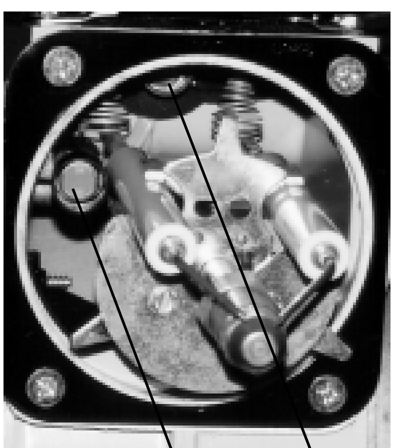
refer to "programming" section—begin on page 18

mount a 2nd cad cell

Beckett SR, AF and AFG Burners

- Drill an 1/8 inch hole through the burner chassis on the right side (opp. the escutcheon plate)
- Position the cad cell pointing toward the endcone of the burner
- Securely fasten the cad cell to the chassis with the supplied machine screw and nut
- Route the leads through the notch in the wall of the internal wiring box
- Connect the cad cell leads to pin nos. 10 and 11 on the terminal block connector

This top view shows how the second cad cell is securely fastened to teh burner chasis with a machine screw and nut.



This photo shows the proper placemant of the second cad cell in the Beckett AFG burner. The cad cell must be securely tightened so it will not vibrate loose. It should have a good line-of-sight, looking along the axis of the blast tube at the flame (the blast tube has been removed for the purpose of illustration).

mount a 2nd cad cell-*cont'd*

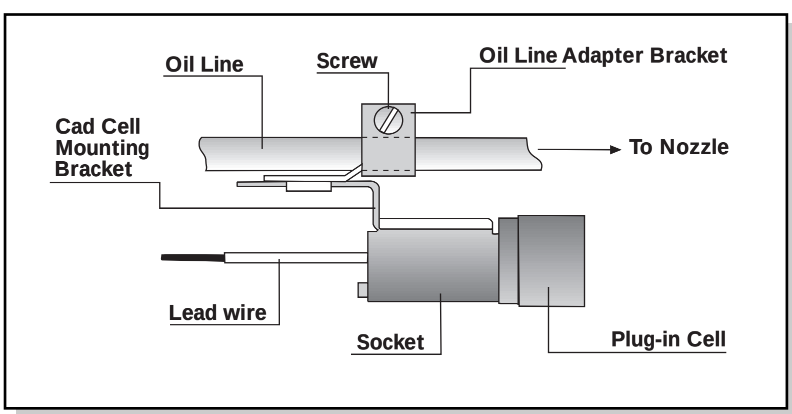
Beckett AFII Burner

- Open the rear access door
- Remove the tray assembly for additional working space
- Attach the piggyback mounting clip to the existing primary cad cell
- Route the leads from the second cad cell out of the chasis along the burner motor line voltage leads ***before*** attaching the second cad cell to the mounting clip
- Snap the second cad cell into the piggyback mounting clip alongside the primary cad cell
- Connect the cad cell leads to pin nos. 10 and 11 on the terminal block connector

The photo shows the rear of the AFII burner with the access door removed. The second cad cell is mounted alongside the primary cad cell with the "piggyback" clip provided.

Carlin Burner

- Install the second cad cell on the oil line using the adapter bracket provided with the cad cell
- Position the second cad cell on the bottom side of the oil line away from the electrodes
- Position the cad cell as far back from the retention head as possible and tighten securely
- Route the leads out of the burner so they do not interfere with the ignition electrodes
- Connect the second cad cell leads to pin nos. 10 and 11 on the terminal block connector



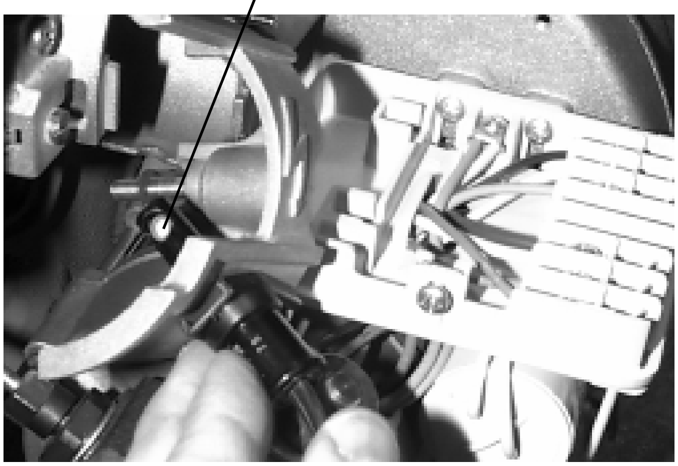
Use the oil line adapter bracket supplied with a Honeywell C554A to mount the second cad cell on the oil line.

mount a 2nd cad cell-*cont'd*

Riello Burner (model F3-*shown*)

- Remove the primary control
- Remove the air tube cover plate
- Insert the Hamamatso cad cell through the pre-drilled hole in the cover plate and fasten with screw
- Replace the air tube cover plate with the cad cell in place
- Connect the second cad cell leads to pin nos. 10 and 11 on the terminal block connector

Hamamatso cad cell

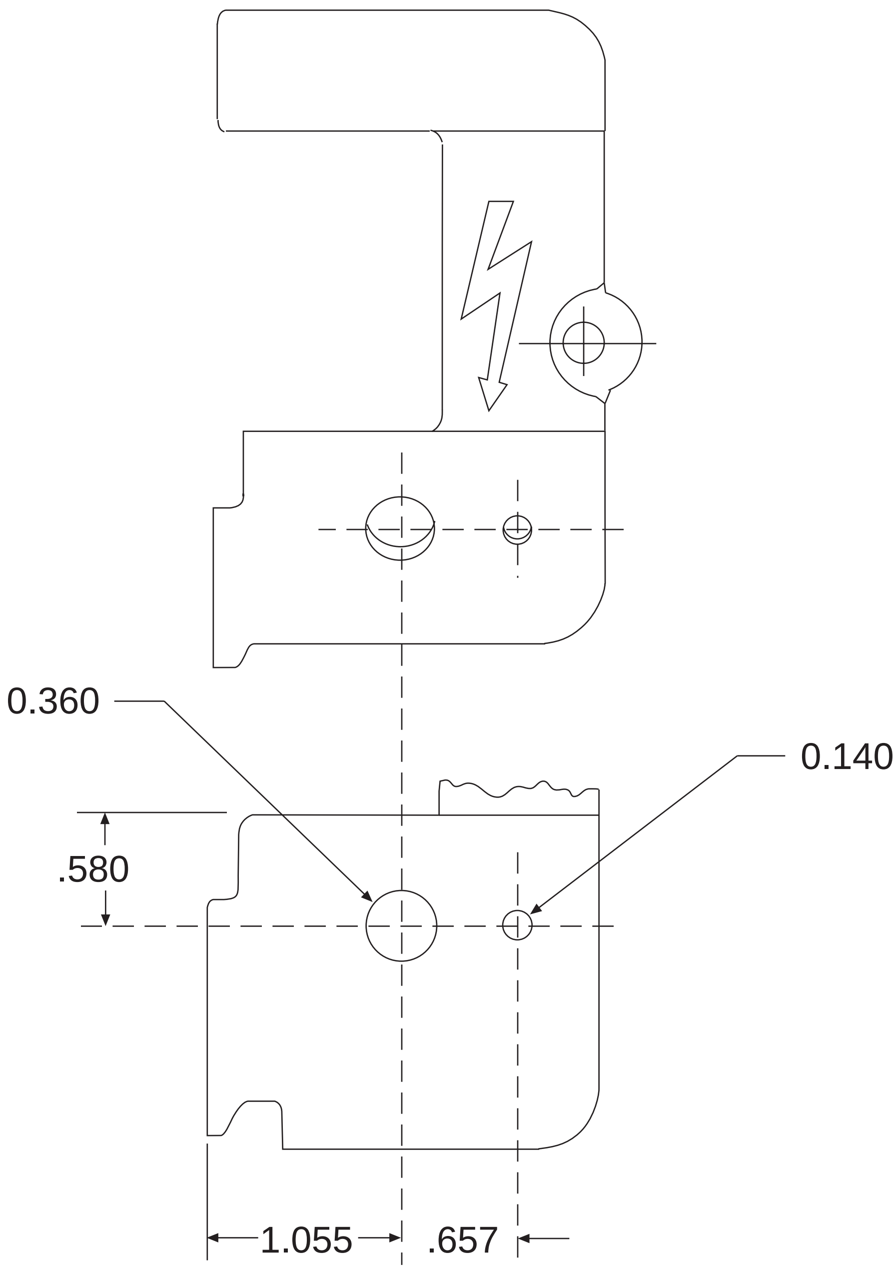


Removing the airtube cover plate. Insert the Hamamatso cad cell into the predrilled hole and secure with the mounting screw.

airtube cover plate

Replace the airtube cover plate and securely tighten the airtube cover plate screw.

modify the Riello F3 airtube cover plate



burner lockout monitoring

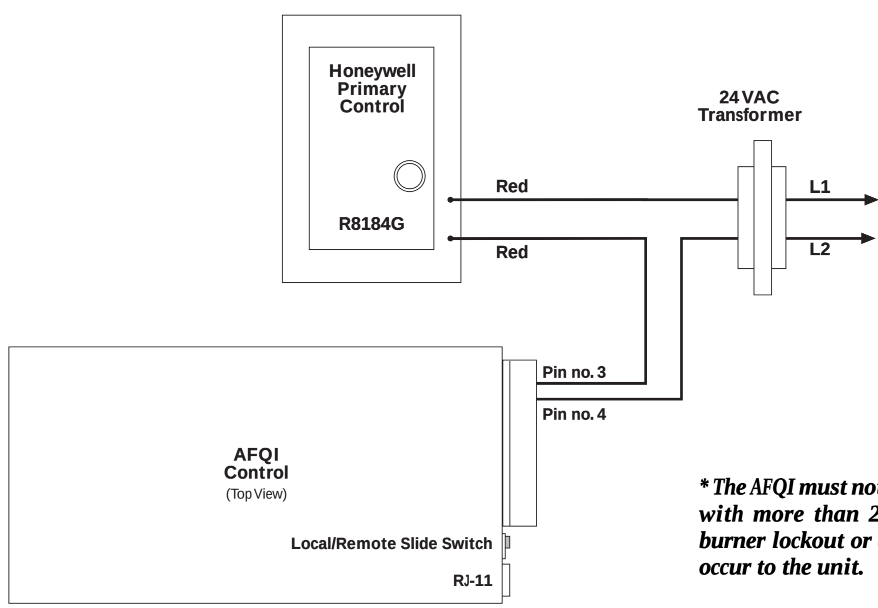
A Beckett, Carlin or similar type burner must be equipped with a primary relay that provides a set of NO (Normally Open) contacts for alarm monitoring. Use either a Honeywell part no. R8184G or Carlin part no. 60200-02 Primary Relay.

Riello burners (F40 Series and Mectron Series) supply 110VAC through a contact on the primary relay upon lockout. ***The 110 VAC must be stepped down to 24VAC or less.***

Power the lockout circuit with a 24VAC power supply (Beckett and Carlin burners)

- Install a 24VAC transformer or relay if one is not already present or accessible
- Wire the alarm circuit following the schematic diagram below
- Connect the common(-) from the transformer to pin no. 3
- Connect the the Red alarm wire from the primary relay to pin no. 4

Schematic—Lockout wiring circuit using a Honeywell R8184G Primary Relay



**** The AFQI must not be supplied with more than 24 VAC upon burner lockout or damage will occur to the unit.***

oil line/tank level monitoring

Install the oil line/tank level pressure sensor

- Shut off the oil supply
- Install a brass tee in the oil line between the oil filter and burner oil pump where it is easily accessible
- Thread the pressure sensor into the tee fitting and tighten securely
- Make certain there are no leaks
- Plug the Packard connector end of the wire harness into the sensor
- Route the wires (keep away from line voltage leads) and attach to the terminal block connector
- Connect the Red lead to pin no. 12, Clear to pin no. 13, and Black to pin no. 14

The photo shows the pressure sensor installed with a brass flare tee in the oil line. The sensor is located between the oil filter and the burner so that pressure drop across the filter can be monitored.

remote low temperature monitoring

Install the remote temperature sensor

- Find a suitable location for installing the low temperature sensor
- Cut a hole and install an outlet box in the wall
- Run wire from outlet box to the temperature sensor input on the terminal block connector
- Connect wire to pin nos. 5 and 6 on the terminal block connector
- Connect the sensor to the wire in the box and assemble with the Decora cover plate

water leak monitoring

Install the water sensor

- Identify an appropriate location to monitor for the presence of water
- Place the sensor so the four sensor contacts are against the surface to be monitored
- Use the center recessed area for permanent installation of the sensor with a bolt or screw

Do not drill outside the center recessed area or the unit will be damaged

before you begin

RS-232 interface setup

- Position the Local/Remote slide switch ***down*** to the “Local” position (away from you)
- Connect the female 9-pin connector end of the RS-232 Interface cable into a PC serial port
- Connect the modular plug end of the interface cable into the modular jack on the side of the AFQI
- While running windows 3.x, launch the Terminal program (if Windows 95 or NT 4.x, use Hyperterminal)
- Set the communications protocol to ***1200 baud, 8 bits, no parity, 1 stop bit, no flow control***
- Set keyboard “Caps Lock” to ***on*** (AFQI will only respond to commands using “uppercase” characters)

flame quality monitoring

RS-232 interface setup-***see page 18***

To change the "normal operating range" parameters (limits have been factory preset)

Do not change factory settings without consulting with technical support before changing any factory preset limits.

- Press the RESET button to accept new values
- Wait for a prompt
- Enter "H" for High limit out-of-range, then
- At the next prompt, enter a value for the high limit, in percent above the set-point (the factory preset value is 135=135%), and hit Return

When monitoring two oil burners, this will set the same high limit for both cad cells no. 1 and no. 2.

- Wait for prompt
- Enter "L" for Low limit out-of-range, then
- At the next prompt, enter a value for the low limit, in percent below the set-point (the factory preset value is 085=85%), and hit Return

When monitoring two oil burners, this will set the same low limit for both cad cells no. 1 and no. 2.

Enter the central station computer phone number

- Press the RESET button
- Wait for prompt
- Enter "P" for Phone number, then
- At the next prompt, enter the Phone no. (up to 12 digits) and hit Return

Enter the AFQI ID no.

- Press the Reset button
- Wait for prompt
- Enter "I" for ID, then
- At the next prompt, enter the ID no. (you may use up to 12 characters-alphanumeric) and hit Return

Enter the scheduled call back time (the time interval between scheduled calls)

- Press the RESET button
- Wait for prompt
- Enter "C" for Call back time, then
- At the next prompt, enter the call back time (use the format ddhhmmss) and hit return

flame quality monitoring-*cont'd*

Enter the alarm call back time (the time interval between unsuccessful attempted calls)

- Press the RESET button
- Wait for prompt
- Enter "A" for Alarm call back time, then
- At the next prompt, enter the alarm call back time (use the format ddhhmmss) and hit return

Suppress unused alarms and alerts—***see page 24***

Calibrate the AFQI for monitoring flame quality

- Press the SET 1 to calibrate cad cell no. 1
- Press the SET 2 to calibrate cad cell no. 2 (if monitoring a second burner)

After 2 minutes of burner operation the AFQI will automatically "record" the "optimum" set-point (the optimum set-point is designated "100% flame intensity" and the corresponding bit value is stored in the EPROM). Upon subsequent burner cycles (longer than the preset 2 minute warm-up interval), the AFQI will automatically "compare" the "real-time" value for flame intensity signal with the stored "optimum" value.

- Connect the AFQI to a phone line using the internal RJ-11 modular jack
- Force a call to the Central Station Computer by pressing the RUN button

tank level monitoring

RS-232 interface setup-*see page 18*

Enter the central station computer phone number-*(skip this procedure if already programmed)*
- Press the RESET button
- Wait for prompt
- Enter "P" for Phone number, then
- At the next prompt, enter the phone no. (up to 12 digits) and hit Return

Enter the AFQI ID no.-*(skip this procedure if already programmed)*
- Press the RESET button
- Wait for prompt
- Enter "I" for ID, then
- At the next prompt, enter the ID no. (you may use up to 12 characters-alphanumeric) and hit Return

Enter the scheduled call back time (the time interval between scheduled calls)-
(skip this procedure if already programmed)
- Press the RESET button
- Wait for prompt
- Enter "C" for Call back time, then
- At the next prompt, enter the call back time (in the format ddhhmmss) and hit return

Program the alarm call back time (the time interval between unsuccessful attempted calls)-
(skip this procedure if already programmed)
- Press the RESET button
- Wait for prompt
- Enter "A" for Alarm call back time, then
- At the next prompt, enter the alarm call back time (in the format ddhhmmss) and hit return

Suppress unused alarms and alerts—*see page 24*

Calibrate the AFQI for monitoring low oil limit
- Connect the AFQI to a phone line using the internal RJ-11 modular jack
- Force a call to the Central Station Computer by pressing the RUN button

low temperature alarm

RS-232 interface setup-*see page 18*

Enter the central station computer phone number-*(skip this procedure if already programmed)*

- Press the RESET button
- Wait for prompt
- Enter “P” for Phone number, then
- At the next prompt, enter the phone no. (up to 12 digits, letters or numbers) and hit Return

Enter the AFQI ID no.-*(skip this procedure if already programmed)*

- Press the RESET button
- Wait for prompt
- Enter “I” for ID, then
- At the next prompt, enter the ID no. (you may use up to 12 characters-alphanumeric) and hit Return

Enter the scheduled call back time (the time interval between scheduled calls)-
(skip this procedure if already programmed)

- Press the RESET button
- Wait for prompt
- Enter “C” for Call back time, then
- At the next prompt, enter the call back time (in the format ddhhmmss) and hit return

Program the alarm call back time (the time interval between unsuccessful attempted calls)-
(skip this procedure if already programmed)

- Press the RESET button
- Wait for prompt
- Enter “A” for Alarm call back time, then
- At the next prompt, enter the alarm call back time (in the format ddhhmmss) and hit return

Set the low temperature limit

The factory default is set so that the low temperature alarm is suppressed

- Press the RESET button to accept a new value
- Wait for a prompt
- Enter “T”, then
- At the next prompt, enter a bit value for the low temperature limit (in counts) and hit Return

Refer to the Lookup Table in the Appendix to correlate a bit value (in counts) to the low temperature limit desired.

Suppress unused alarms and alerts—*see page 24*

water leak alarm

RS-232 interface setup-*see page 18*

Enter the central station computer phone number-*(skip this procedure if already programmed)*

- Press the RESET button
- Wait for prompt
- Enter “P” for Phone number, then
- At the next prompt, enter the phone no. (up to 12 digits, letters or numbers) and hit Return

Enter the AFQI ID no.-*(skip this procedure if already programmed)*

- Press the RESET button
- Wait for prompt
- Enter “I” for ID, then
- At the next prompt, enter the ID no. (you may use up to 12 characters-alphanumeric) and hit Return

Enter the scheduled call back time (the time interval between scheduled calls)-
(skip this procedure if already programmed)

- Press the RESET button
- Wait for prompt
- Enter “C” for Call back time, then
- At the next prompt, enter the call back time (in the format ddhhmmss) and hit return

Program the alarm call back time (the time interval between unsuccessful attempted calls)-
(skip this procedure if already programmed)

- Press the RESET button
- Wait for prompt
- Enter “A” for Alarm call back time, then
- At the next prompt, enter the alarm call back time (in the format ddhhmmss) and hit return

Set the water leak limit

Note: The factory default is set so that the water leak alarm is suppressed

- Press the RESET button to accept a new value
- Wait for a prompt
- Enter “W”, then
- At the next prompt, enter a bit value for the water leak alarm limit, in counts, and hit Return

  To enable the water leak alarm, enter a bit value of 128 counts

Suppress unused alarms and alerts—*see page 24*

suppress unused alarms

RS-232 interface setup-*see page 18*

Suppress "flame quality" alarm

- Press the RESET button
- Wait for prompt
- Enter "H" for High limit (out-of-range)
- At the next prompt, enter a bit value of 255 and hit return
- Wait for prompt
- Enter "L" for Low limit (out-of-range)
- At the next prompt, enter a bit value of 000 and hit return

Suppress "low oil" alarm

- Press the RESET button
- Wait for prompt
- Enter "O" for low Oil limit
- At the next prompt, enter a bit value of 000 and hit return

Suppress "low temperature" alarm

- Press the RESET button
- Wait for prompt
- Enter "T" for Temperature low limit
- At the next prompt, enter a bit value of 255 and hit return

Suppress "filter clogged" alarm

- Press the RESET button
- Wait for prompt
- Enter "F" for Filter clog limit
- At the next prompt, enter a bit value of 255 and hit return

Suppress "oil drop" alarm

- Press the RESET button
- Wait for prompt
- Enter "D" for oil Drop threshold
- At the next prompt, enter a bit value of 255 and hit return

Suppress "water leak" alarm

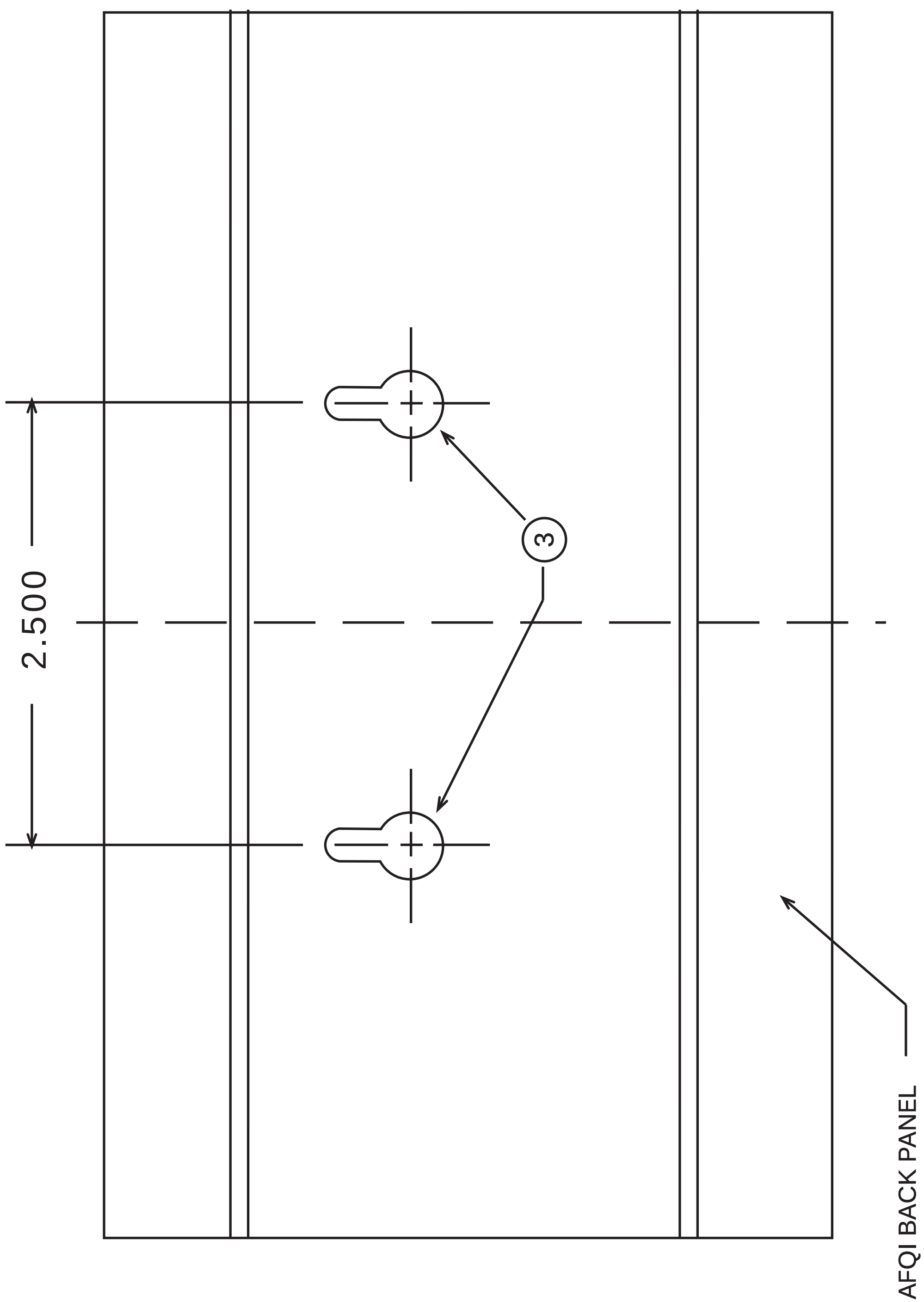
- Press the RESET button
- Wait for prompt
- Enter "W" for Water sensor
- At the next prompt, enter a bit value of 000 and hit return
- Wait for prompt then enter an "X" to EXIT programming mode

You may EXIT the programming mode at any time by entering "X" at a prompt.The AFQI will also "time-out" to the default "active" mode after several seconds of inactivity in Local mode.

AFQI

N O T E S

mounting template (IMS-1000 series)



MOUNTING INSTRUCTIONS

1) Locate mounting area
2) Use diagram to locate mounting screw hole locations
3) Drill 9/64 inch diameter pilot holes
4) Use the self-tapping screws supplied for mounting. Leave 2-3 threads showing (approx. 0.1").

Appendix IV
Note on project data

All of the data for the test sites has been archived in a comma separated file (CSV) which can be imported into many spreadsheet and database programs. This data has been submitted, along with this final report on a compact disk (CD-ROM) along with a Readme file providing information on the data format. Those interested in obtaining a set of this data, please send an email to butcher@bnl.gov.

In some of the houses indoor room temperatures were recorded with separate, portable data loggers. This data might be useful in more closely examining relations between outdoor conditions and run times, with corrections for setback. This data is also available. Figure A-1, below provides an example of the measured indoor temperature variation in one home during 5 January days.

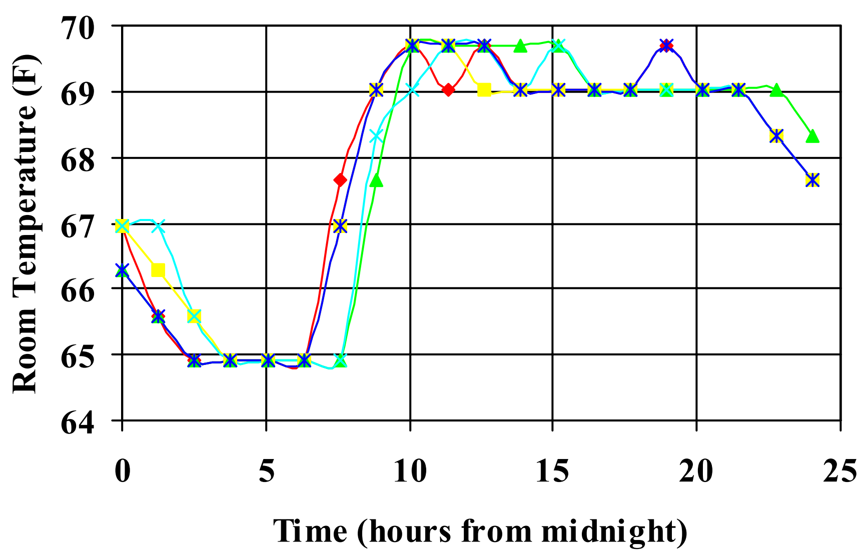


Figure A-1. Results of measurements of variation of indoor air temperature in one test home over 24 hour period.