PIER Advanced Automated HVAC Fault Detection and Diagnostics Program

California Energy Commission
Contract # 500-03-030

D5.4f – Final Report Describing Strategy for Processing Data and Design of the User Interface

Project 5: Rooftop Unit Diagnostics

September 8, 2005

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Executive Summary

This report summarizes the strategy for data processing and design of the user interface (Tasks 5.4.4 and 5.4.5) for the Rooftop Unit Fault Detection and Diagnostics (FDD) System. The report is divided into two main sections, Strategy for Data Processing and Design of FDD User Interface. The section on data processing includes a discussion of Data Collection, Distributed versus Centralized Data Processing (Task 5.4.4), Data Processing Approach, and Data Processing Implementation and Testing. The section on the user interface includes a discussion of Objectives of the Central User Interface, Central User Interface Features, Central User Interface Development Status, and Technician Field Interface.

Introduction

This report describes the development of the data processing approach and the user interface for the Rooftop Unit Fault Detection and Diagnostics (FDD) System, as defined by Tasks 5.4.4 and 5.4.5. These tasks are summarized below:

> Task 5.4.4 Distributed vs. Centralized Data Processing
> An effort has been made to balance distributed versus centralized data processing during product implementation. In distributed processing, data are completely analyzed in the unit and alarm messages are sent out when service is needed. In centralized processing, data are sent to a common server for analysis. A variety of hybrid approaches were considered and an approach was defined.
>
> Task 5.4.5 User Interface Design
> A web-based user interface is being developed to provide access to monitoring data and analysis implemented in this project. The online service provides features for equipment service management and decision support for remote facility managers and service personnel. An on-site user interface for service technicians is also being implemented and will be PDA based, like the Service Assistant technician tool.

The following report sections describe the technical approaches being developed and the current development status for the data processing approach and user interface.

Strategy for Data Processing

An efficient data processing and storage approach has been developed that balances data requirements with hardware requirements and implementation costs. Distributed data processing has the advantage of reduced data storage and transmission requirements, but limits the information available to the user. Central data processing provides the most information and analysis flexibility, but at the cost of increased data storage and transmission requirements. A hybrid data processing approach is being developed to balance the information provided by the system with the hardware requirements and associated implementation costs.

Data Collection

Data collection is required for a number of measured points in order to accomplish the desired fault detection and performance evaluation for the refrigeration cycle, economizer, and control systems. Measured points include refrigeration cycle temperatures, air temperatures, air relative humidity, and control signal status. In many cases, performance parameters are calculated from the measured data and are used in the FDD algorithms. Additional performance indices are calculated and used for evaluation of system performance. (Data associated with the economizer and control systems are summarized in the report Draft Report Describing Economizer, DCV, and Controls Diagnostic Algorithms.) The data processing and storage approach is being developed to provide the required data for diagnostics and system evaluation while balancing hardware requirements and implementation costs.

Distributed versus Centralized Data Processing

Distributed versus centralized data processing was considered as a means to control and balance system memory requirements, data transmission requirements, system performance information retained, and system flexibility. A hybrid approach was developed that applies a reasonable amount of distributed (local) data processing to limit the memory requirements for the data collection hardware at the monitoring site, but retains the required information to identify faults and evaluate system performance. The approach also limits the requirements for data transmission from the local site to the central data storage location. This facilitates communication from the local data storage location to the central location by means of Ethernet, modem, or cellular. The data processing approach is described in the following section.

Data Processing Approach

The data processing approach was developed in conjunction with the system hardware design. The system hardware configuration is illustrated in Figure 1 and shows local and central data processing and storage locations. Multiple data collection modules (with associated sensors) are located at each HVAC unit at a building. The modules for a given unit are wired to a transmitter module. The transmitter at each HVAC unit sends time-based data to the local data processing and storage unit by wireless communications. This unit processes data, stores it locally, and then transmits it to a central location periodically. Communication to the central data processing and storage location will be by means of Ethernet, modem, or cellular communication.

A unique data processing and storage approach has been developed that customizes the data processing for the FDD application. The approach provides an efficient method for collecting, processing, and storing data that allows identification of faults as well as evaluation of system performance. The flowcharts presented in Figure 2 and Figure 3 outline the distributed (local) data processing that will be implemented in the hardware located at the monitored site. Data are condensed to reduce memory and data transmission requirements while retaining important relationships between parameters. The flowchart presented in Figure 4 outlines the data processing that will be implemented at the central data location. Central data processing includes calculation of additional performance indices, implementation of FDD algorithms, calculation of economic parameters for identified faults, and data processing associated with generating plots. The details of the data processing process are proprietary and are included in a patent application that is in preparation. The details of the invention will be disclosed when authorized by our patent attorney.

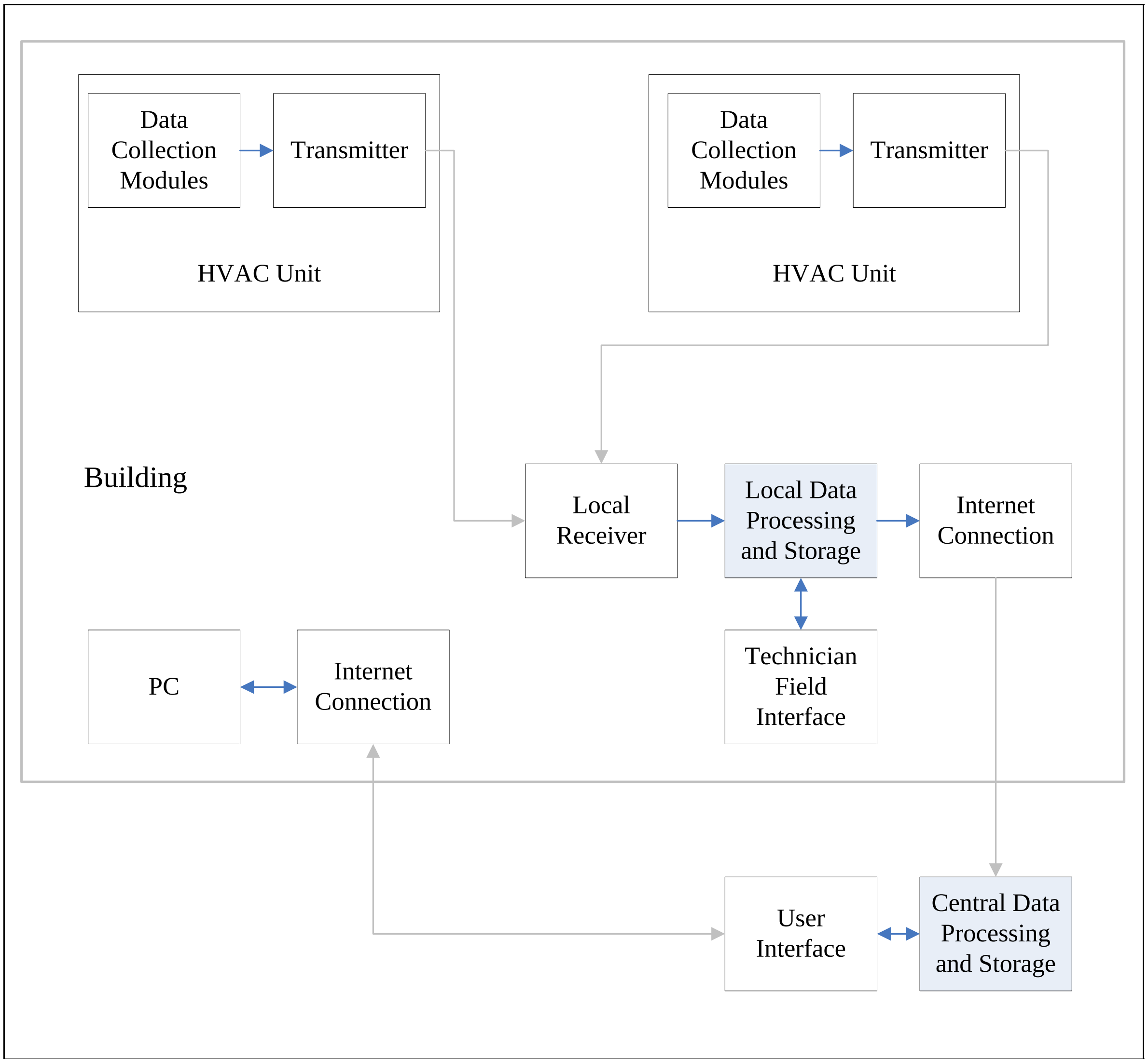


Figure 1. FDD System Monitoring Hardware Configuration

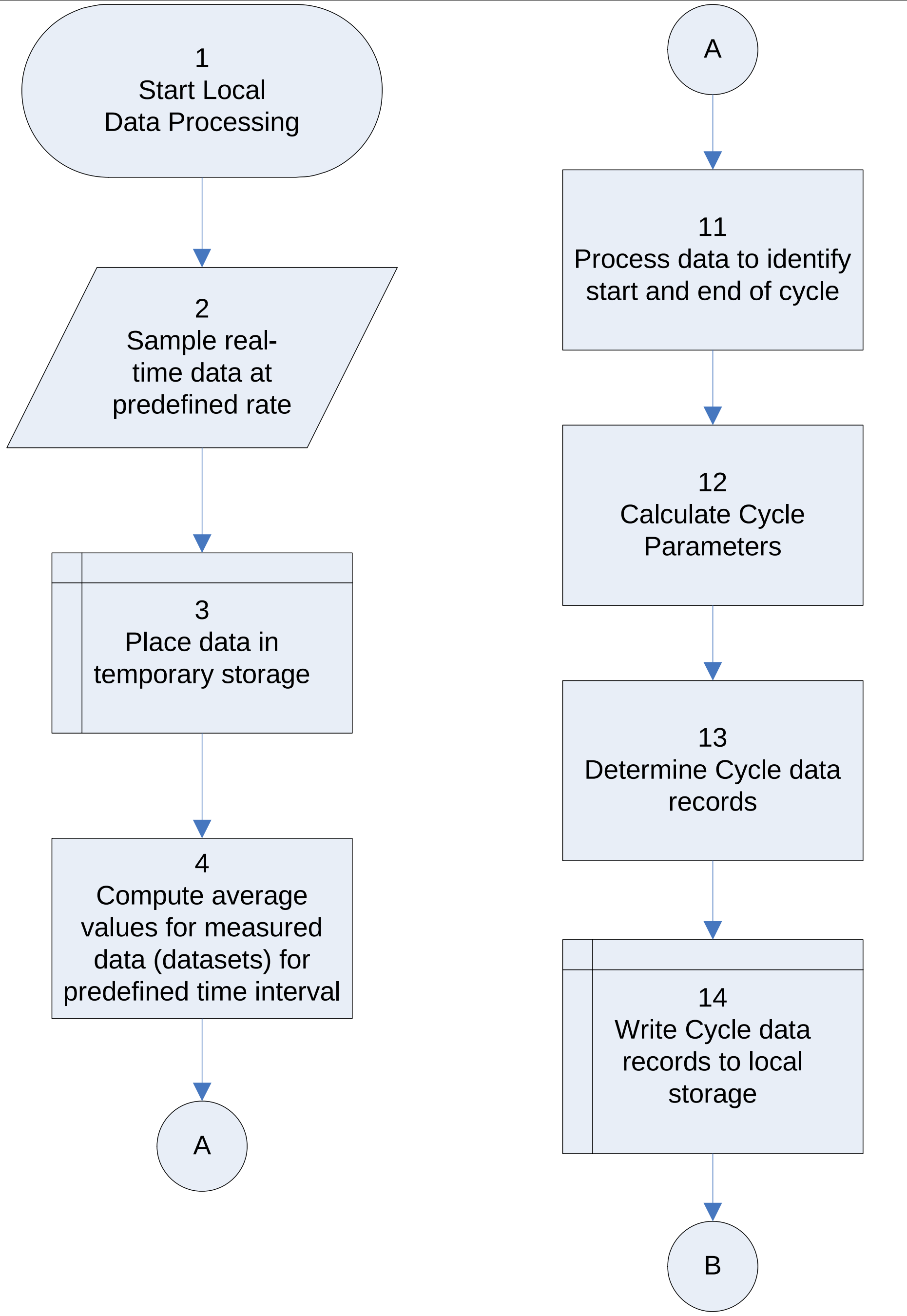


Figure 2. Local Data Processing Flowchart A

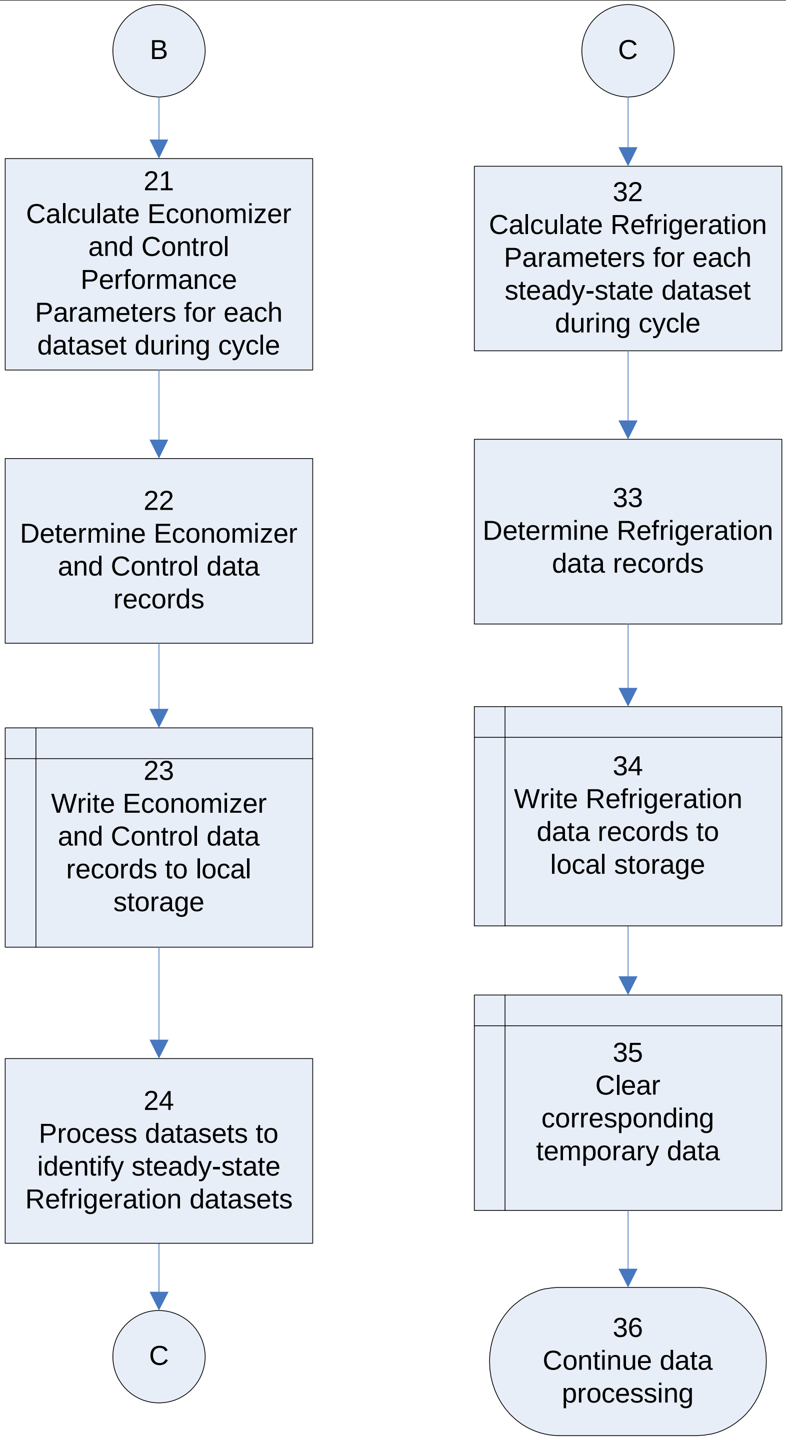


Figure 3. Local Data Processing Flowchart B

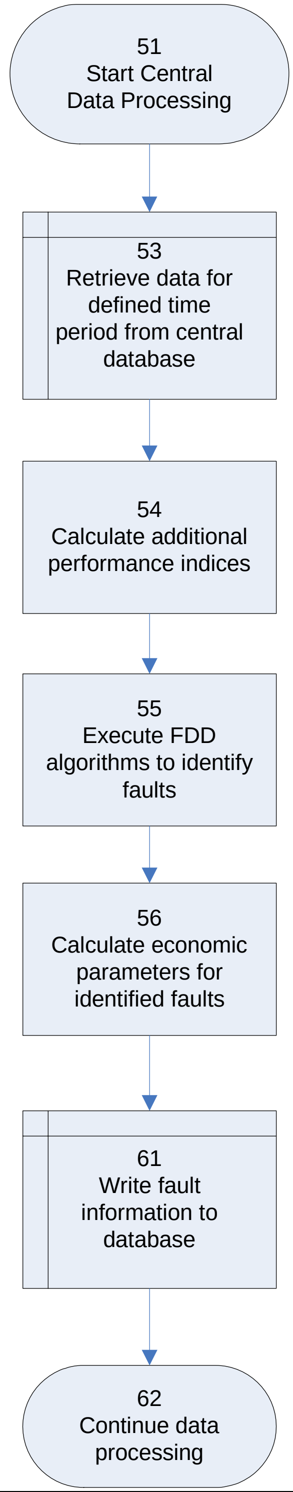


Figure 4. Central Data Processing Flowchart

Data Processing Implementation and Testing

Two implementations of the data processing approach are under development:

1. A two-step central implementation for development and testing, and
2. A distributed-central implementation for the prototype FDD product.

The two-step central implementation is functional and being tested using data from several field test sites (Task 5.6). This approach uses existing data acquisition hardware that uses a trend logging approach to data collection. The time-based data are sent to a central server and all data processing occurs at the central location. The data processing is implemented in two steps to simulate the distributed and central components of the defined data processing approach. The field test sites identified in Table 1 are being used to test the data processing implementation. Results of the testing will be reported under Task 5.6, Initial Prototype Development and Implementation.

The distributed-central implementation is currently being developed for the prototype FDD system that includes new hardware modules and software (Task 5.8). The appropriate algorithms required for distributed (local) data processing are being ported to the new hardware platform and additional software is being developed as required to implement the data processing approach in the distributed and central environment of the prototype FDD system. The first full system prototype with associated hardware and software is planned for the 4^{th} quarter of 2005. Future development and test results will be reported under Task 5.8, Final Product Implementation.

Table 1. Field Test Sites

Site Description	Location	No. of Units	Operational Date	General Unit Description
Walgreens - Anaheim	Anaheim, CA	5	2002	Packaged HP with economizer
Walgreens - Rialto	Rialto, CA	5	2002	Packaged HP with economizer
Honeywell GSRC	Atlanta, GA	5	December 2004	Packaged AC with economizer
UCLA	Los Angeles, CA	8	Planned for September 2005	Packaged AC or HP (1 or 2-stage) no economizer
UCSD	San Diego, CA	7	Planned for September 2005	Packaged AC (1-stage) with gas heat and economizer
CSU Hayward	Hayward, CA	7	Planned for August 2005	Packaged HP (1-stage) with economizer

Design of FDD User Interface

The FDD user interface is being developed as a web-based tool that allows the user to access information and data for the monitored units. The user can view the current status of each monitored unit, alarms/faults that have been identified, performance data, economic data for alarms/faults, and static unit data. There are several options or formats for viewing the data. The following sections present the objectives, features, and development status for the user interface.

Objectives of the Central User Interface

Potential users were identified for the FDD user interface and, based on the potential users and project objectives, specific objectives were developed for the user interface.

<u>Potential Users of FDD User Interface</u>

- Building operation (facility) manager/supervisor
- Maintenance manager/supervisor
- Service technician
- Service dispatcher
- Energy manager

<u>Objectives of FDD User Interface</u>

- Communicate status of HVAC units on an individual and collective (site/building) basis
- Communicate faults/alarms, including severity and economic impact
- Communicate performance information (performance indices)
- Provide method to prioritize repairs
- Track status of repairs or other follow-up actions in response to faults/alarms

Central User Interface Features

Based on the objectives for the user interface, a set of features was developed and the features were organized based on individual web pages. Input from Honeywell personnel and other stakeholders was also used in developing the feature set for the user interface. The main web pages and navigation of the user interface are illustrated in Figure 5. Sample web pages are presented in the following section.

The following numbered lists provide a summary of features to be included in the user interface:

<u>General</u>

1. Access to unit status information including alarms and performance data. Refer to details in sections below.
2. Homepage with simple guide to website with links for additional detailed information.
3. Help features including frequently asked questions and answers regarding user interface.
4. Access to view static site and unit information.
5. Feature to enter corrective measures (repairs) completed and clear alarms.
6. General performance information on units including efficiency index, capacity index, and runtime statistics.
7. List of possible alarms/faults that can be triggered with description, criteria, possible cause, and possible impacts
8. Feature to generate report for a site or unit and a given time frame (identify start date and end date), including options for level of detail to be included in report.

9. Feature to provide e-mail notification of alarms.

<u>All Alarms Page</u>

1. List of all alarms/faults for all units with brief description, unit, category, and economic information
2. Capability to select individual alarm/fault for additional information
3. Capability to select unit or site
4. Alarms categorized as equipment safety, energy savings, comfort, or monitoring system
5. Page allows sorting of alarm entries

<u>Sites Page</u>

1. List of sites
2. Summary of alarms (count) by category (comfort, equipment safety, monitoring system, and energy savings opportunity)
3. Economic analysis of alarms (estimated repair cost and savings)
4. Capability to sort sites
5. Capability to select individual site

<u>Units at Site Page</u>

1. List of units at a given site
2. Summary of alarms (count) by category
3. Economic analysis of alarms/faults (estimated repair cost and savings) is currently disabled pending internal review
4. General unit performance data (efficiency index, capacity index, runtime statistics, etc.)
5. Capability to sort units
6. Capability to select individual unit

<u>Individual Unit Status Page</u>

1. Summary of selected static unit information with link to additional information
2. Summary of unit alarms (count) by category with link to detailed alarm information
3. Summary of unit performance with link to detailed information

<u>Unit Alarms Page</u>

1. Similar to All Alarms page except limited to alarms for a specific unit

<u>Individual Alarm (Fault) Page</u>

1. Individual page for each alarm (fault)
2. Summary of fault condition, criteria, possible cause, possible impact, recommended actions, and fault history
3. Data to illustrate fault (chart or table) for the selected unit

<u>Unit Performance Page</u>

1. Summary of performance indices for selected unit (efficiency index, capacity index, runtime statistics, outdoor air fraction, economizer performance, etc.)
2. Capability to select individual performance index for additional information

<u>Individual Performance Index Page</u>

1. Individual page for each performance index
2. Definition of performance index
3. Data to illustrate performance index for the selected unit

Unit Data Page

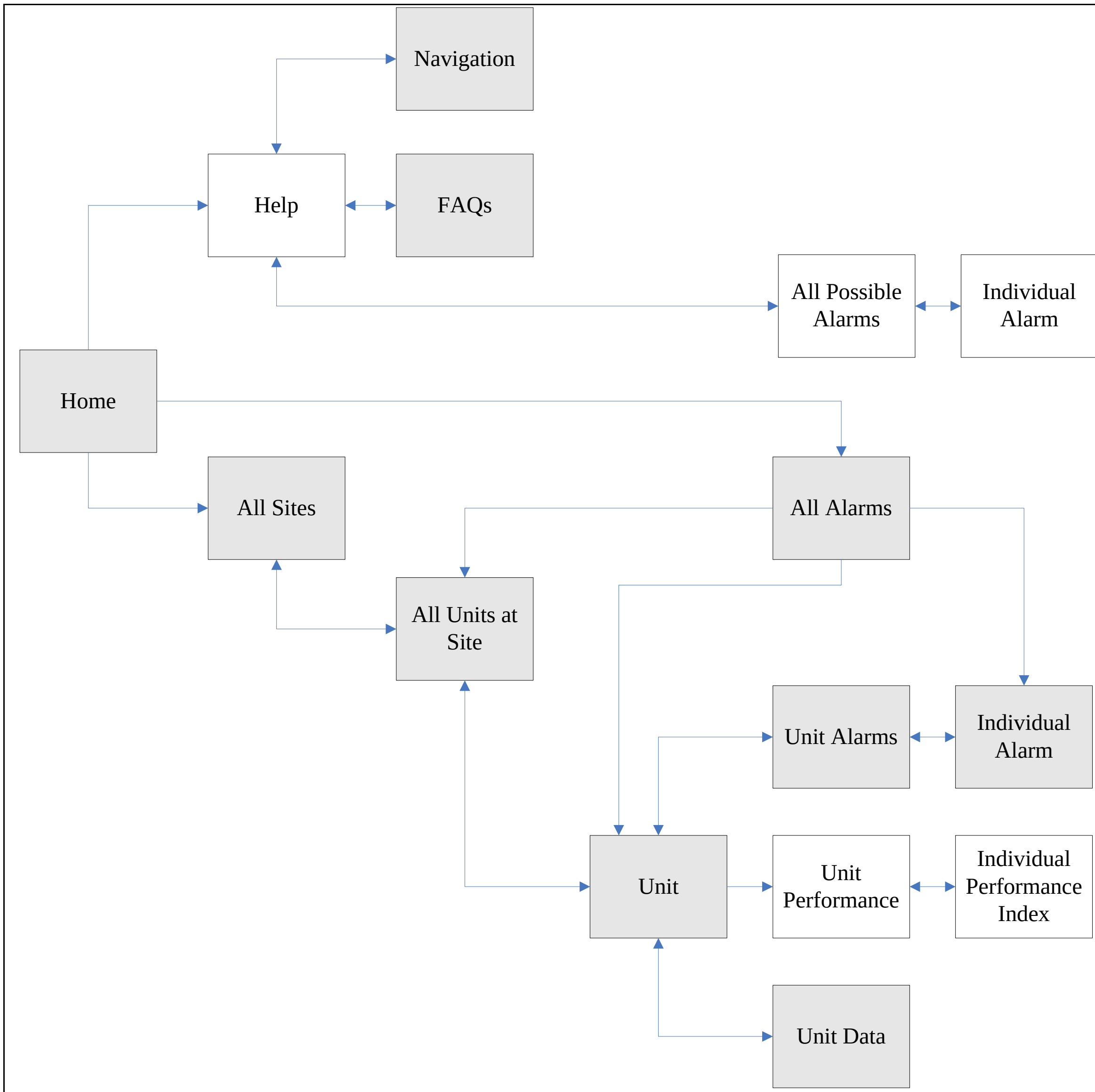
1. Listing of all static data for the selected unit including setup data summarized in Table 2

FAQ Page

1. Frequently asked questions and answers with links to the main pages

Navigation Page

1. Provides a visual guide to features and navigation of the user interface



Blocks with shading represent pages that are currently enabled.

Figure 5. Central User Interface Navigation

Table 2. Static Unit Data

Parameter	Code	Detailed description and options
Unit ID		
Site (Building)		
Company (Owner or Operator)		
Unit make		
Unit model number		
Mechanical cooling stages		
Indoor expansion device		Fixed orifice or TxV
Outdoor expansion device (HP)		Fixed orifice or TxV
Refrigerant type		
Nominal cooling capacity		
SEER		
Zone description		
Zone occupancy schedule		Occupied/unoccupied period defined for each day of the week
Economizer control strategy	ECON	0 None, 1 Dry-bulb changeover, 2 Enthalpy changeover, 3 Differential dry-bulb, 4 Differential enthalpy
Integrated economizer	INT	0 Not integrated (mechanical cooling not available when economizer active), 1 Integrated
Ventilation control strategy	VENT	Fixed minimum ventilation, Demand controlled ventilation (DCV)
Ventilation setpoint for DCV	VS	
Minimum ventilation outdoor air fraction	mOAF	Fixed minimum ventilation rate as outdoor air fraction of total system airflow
Heating type	Htype	0 No heating, 1 Gas-fired, 2 Heat pump (HP), 3 Electric resistance, 4 HP with electric resistance
Energy cost ($/kWh)		
Nominal cooling runtime (h/year)		

Central User Interface Development Status

The user interface is currently being developed, but is functional and can be used to view data for several test sites. The basic features are enabled including alarm/fault summary, site summary, unit summary, individual unit status, and a number of individual alarm pages. The pages that are enabled are shaded in Figure 5. A number of faults/alarms are enabled and additional ones are currently being implemented. Example web pages are presented in Figure 6 through Figure 12. These pages illustrate the currently enabled features. Features not yet enabled include economic evaluation of faults/alarms, a summary of the enabled faults/alarms, e-mail notification of faults/alarms, and detailed unit performance data.

Several field test sites are active or planned and are identified in Table 1. The active sites are being used to test and evaluate the user interface as it is developed. Use of the user interface with the field test sites has been limited primarily to the design team for test and evaluation. Release of the user interface to building operation personnel is planned and will be used to obtain initial feedback from users. An introduction and review of the user interface with key stakeholders at the Honeywell GSRC site is scheduled for early August.

Input is being obtained from a number of sources to guide the development of the user interface. Ongoing correspondence with Honeywell personnel has provided valuable input to the development process. Preliminary review of the user interface was accomplished during the June (2005) monthly project conference call with FDSI, Purdue University, CEC, AEC, and NBI representatives. The development of an advisory committee is also planned to provide additional feedback and input for development of the user interface.

Completion of a fully functional prototype version of the user interface is planned for December 2005 and will be reported under Task 5.6, Initial Prototype Development and Implementation.

Technician Field Interface

A field interface, as identified in Figure 1, is being developed in conjunction with the prototype hardware (Task 5.8). The interface will provide access to the local data processing and storage unit to provide the following functions:

1. Enter setup data required to identify monitored units and building
2. Enter setup data required for local data processing
3. Access information on status of the monitoring system

The interface will be accomplished with a cable connection from a PDA to a port at the local data processing and storage unit. Software running on the PDA will allow entering and accessing information. This interface platform will be consistent with the current PDA-based service tool.

Future development of the technician field interface will be reported under Task 5.8, Final Product Implementation.

Figure 6. User Interface Home Page

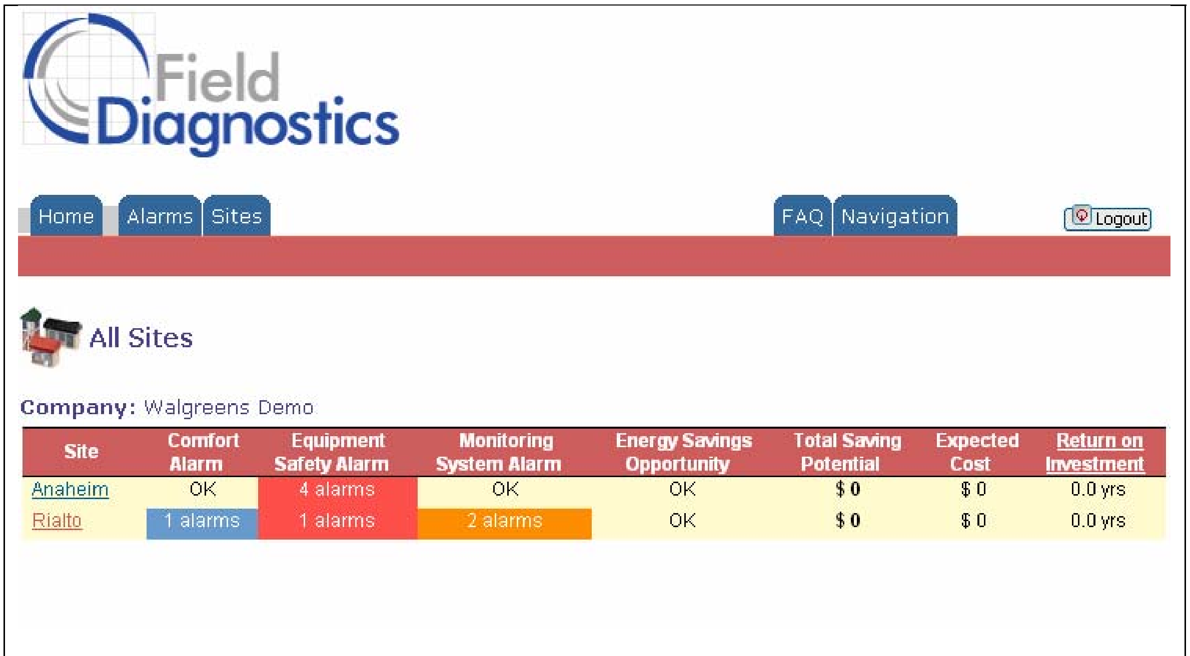


Figure 7. All Sites Page

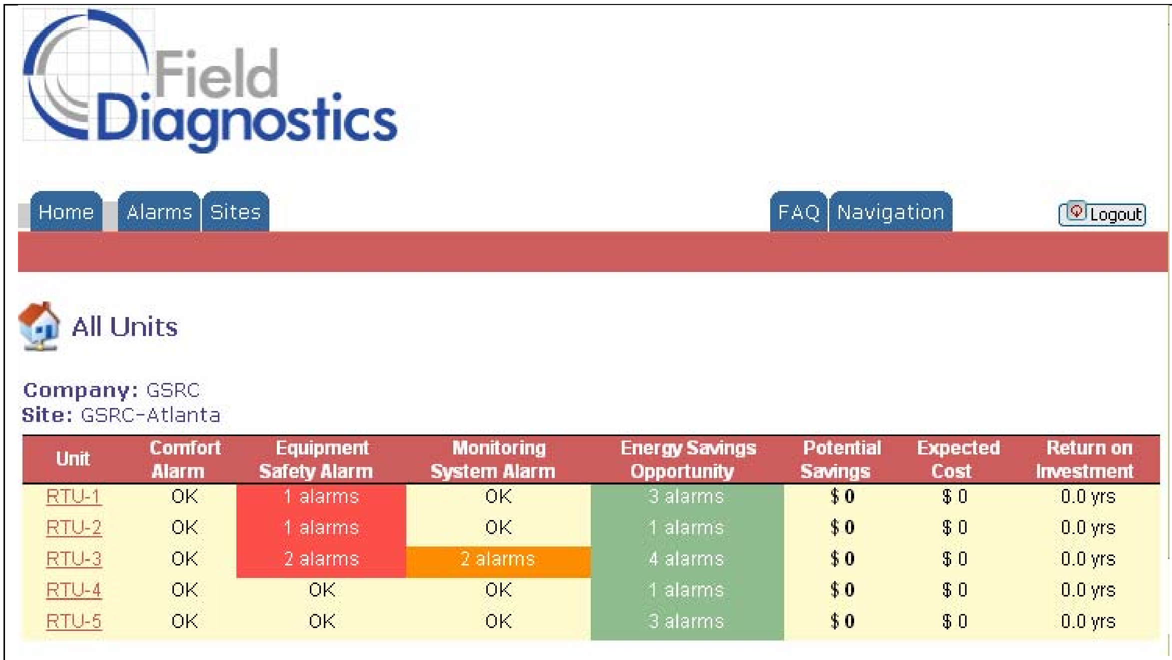


Figure 8. Units at Site Page

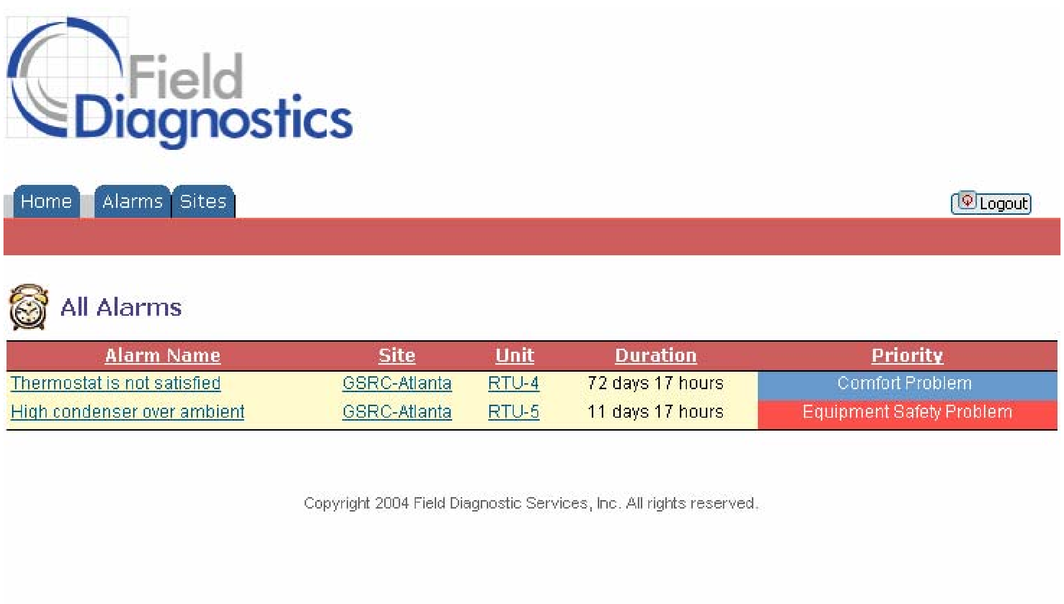


Figure 9. All Alarms Page

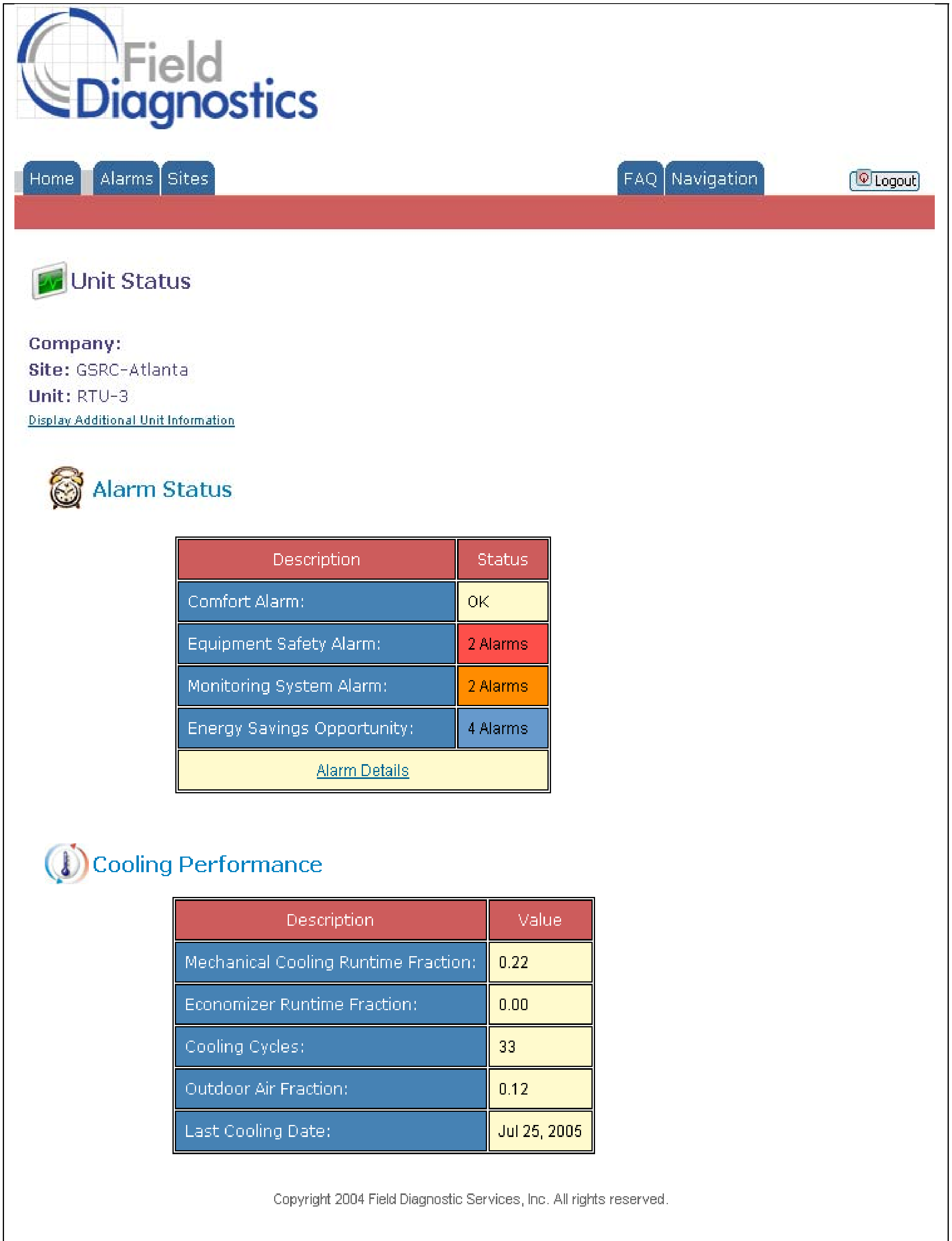


Figure 10. Unit Status Page

Field Diagnostics

Home | Alarms | Sites | FAQ | Navigation | Logout

Low evaporating temperature

Fault Condition:	Steady-state cooling operation and evaporating temperature less than 28 F.
Occurrence Condition:	10 minutes accumulated during a day.
Possible Cause:	Reduced indoor airflow caused by indoor coil fouling.
Possible Impact:	Frozen coil; low efficiency.

Evaporating Temperature (ET) Trend Plot

Unit: RTU-2

Notations Used:

- **ET:** Saturation temperature of the refrigerant as it boils in the evaporator. The ET is averaged over an entire day.

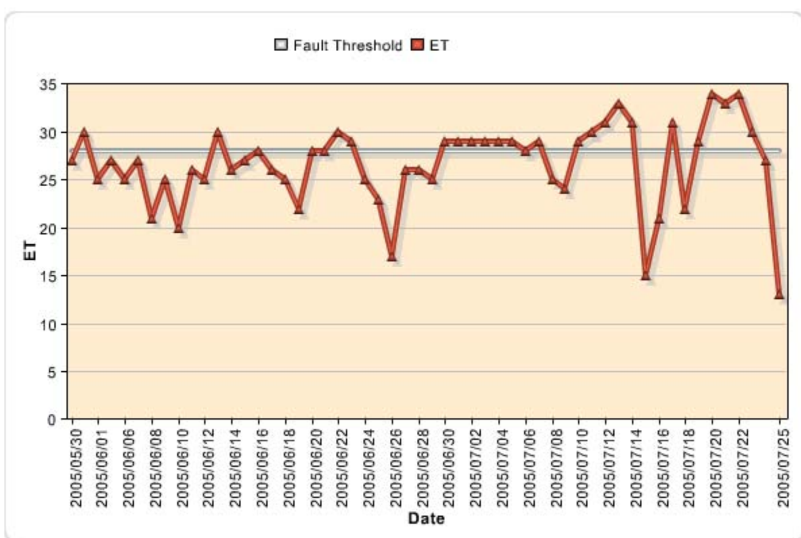


Figure 11. Individual Alarm Page – Low Evaporating Temperature

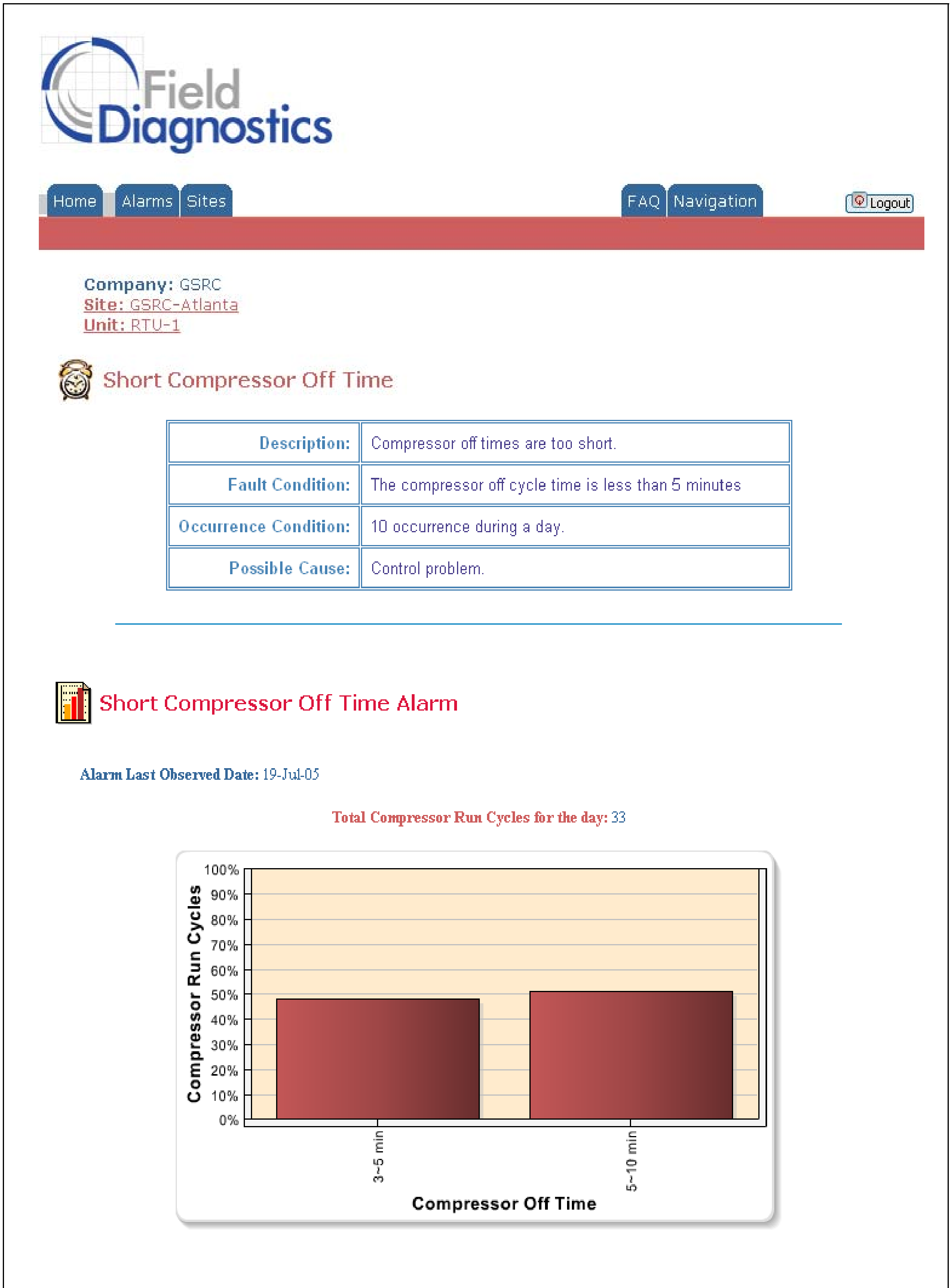


Figure 12. Individual Alarm Page – Short Compressor Off time

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