CASE STUDIES ON THE USE OF REMOTE MONITORING AND CONTROL SYSTEMS TO SOLVE PROBLEMS EFFICIENTLY

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ABSTRACT
Through years of providing engineering and operations and maintenance services for landfill gas collection and control systems and leachate management systems, we have found that too many times data is collected and no one has the time needed to review and analyze the data for proper decision-making. We recognized this as an issue in the industry and have developed systems to streamline the process using the latest technology to help perform routine, sometimes complex, data analysis, and to automatically push reports and alerts to operators, engineers, and project managers. This has been a dramatic change that removes human error in reviewing pages of data and allows people to place focus and time on what really matters. In this paper, we will present several case studies of remote monitoring and control (RMC) systems for landfill gas and leachate systems. We describe our integrated systems which are used for data collection and analysis and how they were used to identify, troubleshoot, and solve real problems in an effective and efficient manner.

INTRODUCTION
RMC systems are similar to their stand-alone control system brethren in that they both contain some of the same types of parts and pieces and that they control a system of some sort. Beyond that they couldn't be more different. RMC systems are like smart-phones, where as stand-alone control systems are rotary-dial phones; both allow you to make a phone call but the smart-phone has many more uses and is much more mobile and adaptable. Specifically, RMC systems help users better understand, troubleshoot, fix, and operate their systems more effectively and efficiently. In general, the purposes of RMC systems include the following:

1. **Remote monitoring**: remote review of real-time and historical operational data.
2. **Remote control**: operating the system from anywhere in the world with access to the internet.
3. **Data recording**: recording operational information from the system on a set interval.
4. **Intelligent alarms**: sending actionable alerts to users.
5. **Data processing/automatic reporting**: automatically create summary reports on a periodic basis from the recorded data.

RMC systems typically consist of the following components:

1. **Programmable logic controller (PLC)**: the "brains" of the system; operates the system based on a pre-programmed sequence of operations.
2. **Human machine interface (HMI)**: also known as a touch-screen; allows local users to operate the system, can be the access point for remote control and used to send alarms.
3. **Data recorder**: also known as a data logger; records operational information from the system on a set interval, can be accessed remotely, communicates recorded data to a remote location, and sends alarms.
4. **Radios and / or fiber optic connections**: communicates data between remote locations that are a part of the same RMC system.
5. **Cellular or wired internet connection**: communicates data between the system and the internet.
6. **Network security**: hardware and software that prevent unauthorized users from accessing the RMC system.
7. **Local/remote alarms**: audible and/or visual alarms to alert users that something is happening with the system.

CASE STUDIES
The following case studies present RMC systems that we have developed and implemented at sites across the United States. They discuss background information on the systems and the innovative ways that we have used them.

Case Study No. 1 - Sonoma County Five Site Cloud Based RMC Project

SCS implemented a cloud based RMC system for five closed landfills that are operated by the Sonoma County's Public Works and Integrated Waste Division. The primary purpose of the RMC system is to monitor liquid levels in real time across multiple sites and notify users when setpoints have been exceeded. The system also monitors grid power, backup generators, and solar power systems to minimize downtime.

Some of the innovative ways that we have used this system include the following:

1. **Alarms**: when an alarm is registered, a combination of email, voice, and SMS alarms are sent to the various liquid haulers and end users. These alarms are sent out through a central internet based cloud gateway that supports all five sites. This allows us to reduce the amount of hardware onsite and to remotely adjust alarms and create new alarms.
2. **Data recording and review**: the system also allows for the review of data from each site individually and all sites together. To enable this we record the data on site and stream it up to the cloud database with the MQ Telemetry Transport or Message Queue Telemetry Transport (MQTT) ISO standard. The data is viewable on a multi-site dashboard and on a site-by-site basis. See Figure 1 for a screenshot of the multi-site dashboard view.
3. **Radio system**: each of the sites has data collection points dispersed across them. To communicate the data collected from these points to the main data recorder, we used Ubiquity Nano 2.4 GHz radios. These radios allow us to create a wireless local area network (LAN) with minimal power consummation, nearly 100 percent uptime, and affordable pricing compared to fiber optic installations.
4. **Industrial cellular modem**: without a dependable internet connection, an RMC system is essentially just an expensive local control system. To help improve the reliability of the internet connection we chose to use a Cradlepoint IBR600 modem at each site. It was selected for its proven reliability, compact design, minimal power consumption, and secure VPN (virtual private network) functionality.
5. **Weather stations**: high rain events can wreak havoc on pumping systems. To help combat this, we installed and integrated a weather station with an ultrasonic anemometer at each site. This allows us to track rain accumulation, temperature, humidity, wind speed, and wind direction. It also gives us the ability to control the pumping systems based on current and predicted rainfall. See Figure 2 for a screenshot of the weather data on the RMC system and Figure 3 for a picture of one of the weather stations.

Case Study No. 2 - Leachate Evaporators

Similar to the previous case study, SCS developed and implemented a cloud based RMC system for a number of leachate evaporators. The primary purpose of the RMC system is to monitor and control the leachate evaporation process. The evaporators have a complex control process with hundreds of sensors and the RMC system provides operators the tools to quickly display, analyze and react to the data.

Some of the innovative ways that we have used this system include the following:

1. **Automatic reporting**: manual report creation is a time consuming and error prone process, but well prepared, accurate, and timely reports add value to projects. RMC systems give you the ability to create these types of value added reports. Because of this we chose to implement automatic reports on this project. The reports are automatically generated and emailed to users on a daily, weekly, monthly, and yearly basis using data collected and calculated from the cloud based database. These reports are customizable and can be emailed to any authorized user. In this specific example, we chose to report the total amount of leachate processed, runtime hours, liquid levels, LFG quality, and LFG flow. See Figure 4.
2. **Modern security protocols**: as we continue to see in the news, security of internet based systems is very important. On this project we implemented Secure Sockets Layer (SSL) technology and Cisco ASA hardware security protocols to protect the data and prevent access by non-authorized users.
3. **Data acquisition and graphing**: data is only as good as its presentation. This project understands this axiom and it presents data in graphical and numerical form. See Figure 5. It also allows users to query real time and historic data collection points and export to them to Excel, .pdf, and .csv formats.
4. **Cross platform**: with the advent of mobile technology (e.g. smart phones, tablets, laptops, etc.) people are using many different operating systems. The web-based user interface of this RMC system allows users to access it on Windows, Apple, Linux, and Android operating systems.
5. **Rapid development**: another applicable axiom is "time is money." With the tight time constraints on this project, the RMC system was quickly

connected to PLCs from multiple different manufacturers by utilizing the standardized Modbus protocol.

Case Study No. 3 - Landfill in the Mid-Atlantic Area

SCS developed and implemented RMC systems for the landfill gas (LFG) blower / flare system and the leachate system at a landfill in the Mid-Atlantic area. These RMC systems and the innovative ways that we've used them are discussed below.

Case Study No. 3a - LFG Blower / Flare RMC System: The primary components of the blower / flare system include a primary blower, primary flare, LFG compression system, backup blower, and backup flare. See Figure 6 for a schematic of the system. Under normal operating circumstances, LFG is pulled from the wellfield through the primary blower and pushed to the primary flare and the LFG compression system. There is an underground liquid handling tank (LHT) nearby which receives and pumps condensate and leachate. The control systems for the blower / flare system and the LHT began as separate pieces but were integrated together into a combined RMC system.

Some of the innovative ways that we have used this RMC system include the following:

1. **Alarms**: as with every mechanical and electrical system, there have been some mechanical and electrical issues that have led to operational headaches. To combat this, we developed alarms, such as high and low vacuum, which alert the operations and maintenance personnel to key occurrences which can lead to much larger problems, such as subsurface oxidation events or subsurface gas migration.
2. **Data recording**: the data recording system on this project has been used extensively to help diagnose and repair mechanical and electrical issues with the system. Two examples of this follow:
    a. **Negative blower discharge pressure**: through a combination of remote alarms and data review, we identified that during times of high LFG demand, the LFG compression system pulled hard enough on the LFG blower to cause an abnormal vacuum on the discharge side of the blower. Furthermore, we identified and repaired a problem in the PLC coding that was contributing to this abnormal phenomenon. After addressing this issue, the number of callouts and amount of system downtime decreased significantly.
    b. **Air compressor problems**: the landfill has a compressed air system which is used to power pneumatic dewatering pumps and pneumatic valves. The RMC system is used to measure and record compressed air pressure at two points in the compressed air system. We used this data for a variety of purposes including evaluating the size of the air compressors and diagnosing and repairing issues with the compressed air piping system and the air compressors.
3. **Radio system**: the connection between the blower / flare control system and the LHT control system is a pair of radios. The radios create a wireless LAN between these two control systems. We use this wireless LAN to communicate data between the two systems including compressed air pressure, totalized liquid flow, pump station high level alarm, and power status.

Case Study No. 3b. - Leachate Tank and Pump System: The primary components of the leachate tank and pump system include a wet-well (manhole) and submersible pump, aboveground storage tank, discharge pump, and two flow meters. See Figure 7 for a schematic of the system. The liquids from the Landfill are pumped and drained into the manhole, from there they are pumped into the aboveground storage tank. The flows into and out of the tank are measured and totalized on a data recorder. The leachate is pumped out of the aboveground storage tank and into trucks which haul the leachate offsite for disposal.

Some of the innovative ways that we have used this RMC system include the following:

1. **Cellular internet connection**: one of the main purposes for this RMC system is to allow leachate haulers to know at any given time the amount of leachate available to be hauled. This information enables them to know on a daily basis how many trucks they should dispatch to the site. This data is conveyed to them through a cellular internet connection. Furthermore, they are able to access this data from their smart phones so they can review the tank volume and flows without leaving their truck.
2. **Data recording**: the data recording system has enabled us to remotely monitor the system and do a number of things including the following:
    a. Review the leachate hauler's manifests against the recorded tank outflow volumes.
    b. Identify problems in the leachate conveyance system by tracking "normal" leachate volumes and identifying and

pinpointing causes of decreased volumes.

   c. Provide monthly reports on the leachate system.

3. **Alarms**: before the RMC system was implemented, the control system contained an autodialer which called out alarms including high tank volume, low volume, etc. This autodialer was removed and replaced with alarms generated by the RMC system. Through this change, we were able to implement the same types of alarms that were on the autodialer and add more complex alarms. Examples of the new alarms include the following:
   a. **Tank outflow**: leaks are a fear with any tank system. Because of this, we developed and implemented text message and email based alarms which are sent out when flow is measured leaving the tank and again when the flow stops. When either of the alarms is sent out, it tells the user what the current outflow and totalized outflows are. This not only provides an alert for potential leaks, but also a record of how much liquid was removed from the tank by the haulers.
   b. **Freeze warnings**: for landfill operators, cold weather and snow brings headaches in the form of freezing pipes and equipment. Because of past issues with frozen pipes due to malfunctioning heating equipment, we installed a series of thermocouples in the piping enclosures. If the measured temperature drops below a setpoint, an alarm goes out and the landfill operators are able to fix problems with heating equipment before pipes freeze.
   c. **Flow meter fouling**: at this landfill, the leachate develops black tar-like deposits on surfaces. By reviewing the flow data, we identified that the leachate flow meters were being fouled by these deposits, in spite of an internal non-stick coating. This fouling was causing the flow meters to underreport the flow rates. To help identify this problem in the future, we developed alarms which alert users when the average measured flows drop below a predetermined setpoint. When this happens, landfill operators are able to clean the flow meters before they start to significantly underreport the flow.

CONCLUSIONS

In an increasingly busy and complex world, RMC systems can give you the tools that you need to help improve safety, increase efficiency, and maximize profitability. As demonstrated in our landfill gas and leachate case studies, there are many creative uses for these systems in our industry. These RMC systems not only gather and store data, but they have the intelligence to automatically sort through mountains of data, identifying what's important, and delivering the important information to owners and operators in real-time or as needed.

Some of the benefits of RMC systems can be summarized as follows:

1. Early detection of problems.
2. Quick and accurate troubleshooting.
3. Minimization of downtime.
4. Efficient and predictive scheduling of technicians.
5. Remote control of components.
6. Real-time viewing, graphing, and analysis of streaming data.
7. Automated reporting.
8. Secure data storage.

	Tank Farms							Power Status	
Site	CAP gal.	Total gal.	Recoverable ga	LVL ft.	Freeboard ft.	Hi LVL	Hi Hi LVL	GEN Pwr.	Grid Pwr
Sonoma	90,680	29,595	26,719	3.81	6.69	Off	Off	Off	On
Guerneville	90,680	20,836	17,960	2.94	7.56	Off	Off	Off	On
Roblar	45,342	16,287	14,849	4.08	6.42	Off	Off	Off	On
Healdsburg	45,342	21,548	20,284	5.08	5.42	Off	Off		
Annapolis	10,000	4,151	3,651	4.98	7.02	Off	Off		

	Weather Stations								
Site	Air Temp F	Humidity %	Barometric InHg	Wind DIR	Wind SPD mph	Rain Rate in	Rain Day in.	Rain wk. in	Rain mo. in.	Rain yr. in
Sonoma	61.1	57.6	29.87	242	1.5	0.00	0.00	0.00	0.64	16.03
Guerneville	61.8	56.7	29.6	110	2.2	0.00	0.00	0.00	0.00	0.00
Roblar	59	54.7	29.96	89	4.2	0.00	0.00	0.00	0.42	19.60
Healdsburg	61.7	48.4	29.73	315	4.5	0.00	0.00	0.00	0.39	28.06
Annapolis	61.1	54.5	29.51	108	0.4	0.00	0.00	0.00	1.24	32.01

	Sump 1			Sump 2			Mid Tank 1			Mid Tank 2		
Site	LVL ft.	Freeboard ft.	Hi LVL	LVL ft.	Freeboard ft.	Hi LVL	LVL ft.	Freeboard ft.	Hi LVL	LVL ft.	Freeboard ft.	Hi LVL
Sonoma	7.7	7.8	Off									
Guerneville	5.46	14.54	Off				2.3	10.2	Off	2.66	8.84	Off
Roblar	2.23	10.27	Off	0.19	11.31	Off						

FIGURE 1: SONOMA COUNTY - RMC SYSTEM MULTI-SITE DASHBOARD

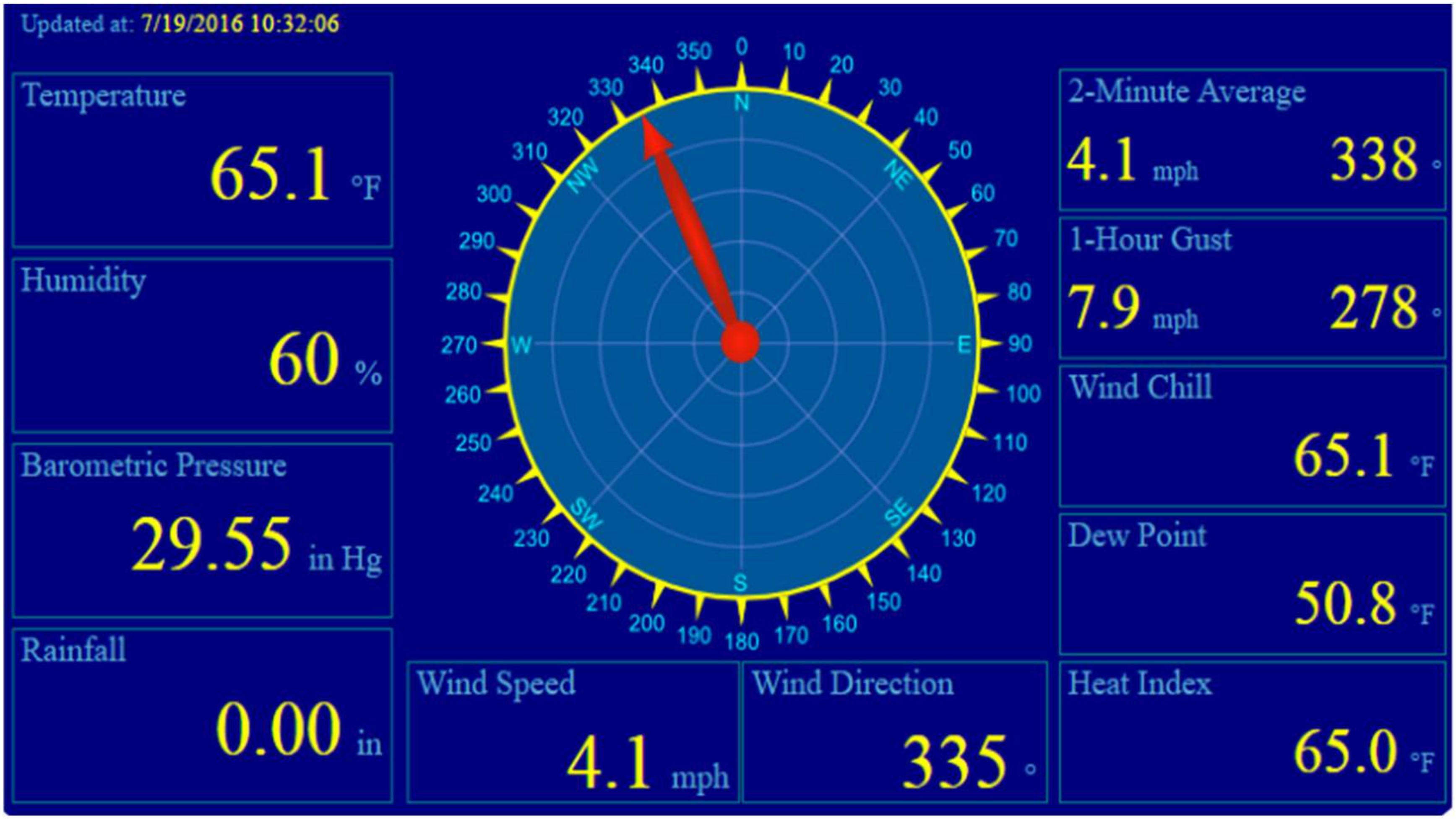

FIGURE 2: SONOMA COUNTY - RMC SYSTEM EXAMPLE WEATHER STATION DATA

FIGURE 3: SONOMA COUNTY - RMC SYSTEM EXAMPLE WEATHER STATION

Evaporator Daily Report

Report Date: 2017-01-22 00:00:00 through 2017-01-22 23:59:59

Daily Leachate Statistics

DCP ID	DCP Name	Total Amount Processed (gal)	Total Runtime (hours)	Starting Leachate Storage Tank Liquid Level (feet)	Ending Leachate Storage Tank Liquid Level (feet)
	Evaporator				

Month-To-Date Leachate Statistics

DCP ID	DCP Name	Start Date	End Date	Total Amount Processed (gal)	Average Daily Amount (gal)	Total Runtime (hours)
	Evaporator					

Project-to-Date Leachate Total

DCP ID	DCP Name	Amount Processed (gal)
	Evaporator	

Daily Gas Flow Statistics

DCP ID	DCP Name	Minimum Methane (%vol)	Average Methane (%vol)	Average Gas Flow (scfm)	Total Gas Flow (scfd)
	Evaporator				

FIGURE 4: LEACHATE EVAPORATOR - EXAMPLE AUTOMATIC REPORT

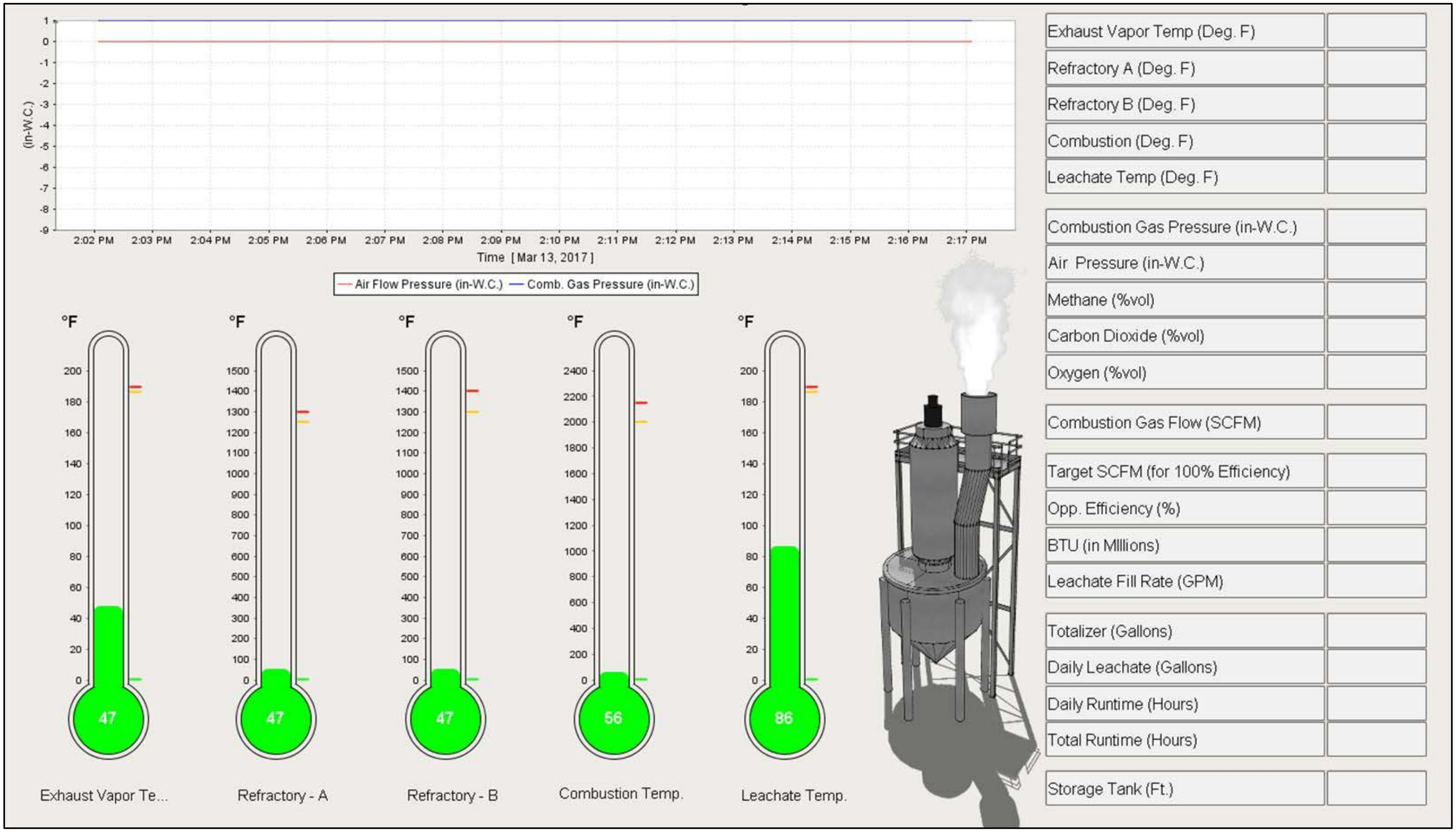

FIGURE 5: LEACHATE EVAPORATOR - EXAMPLE RMC SYSTEM DASHBOARD

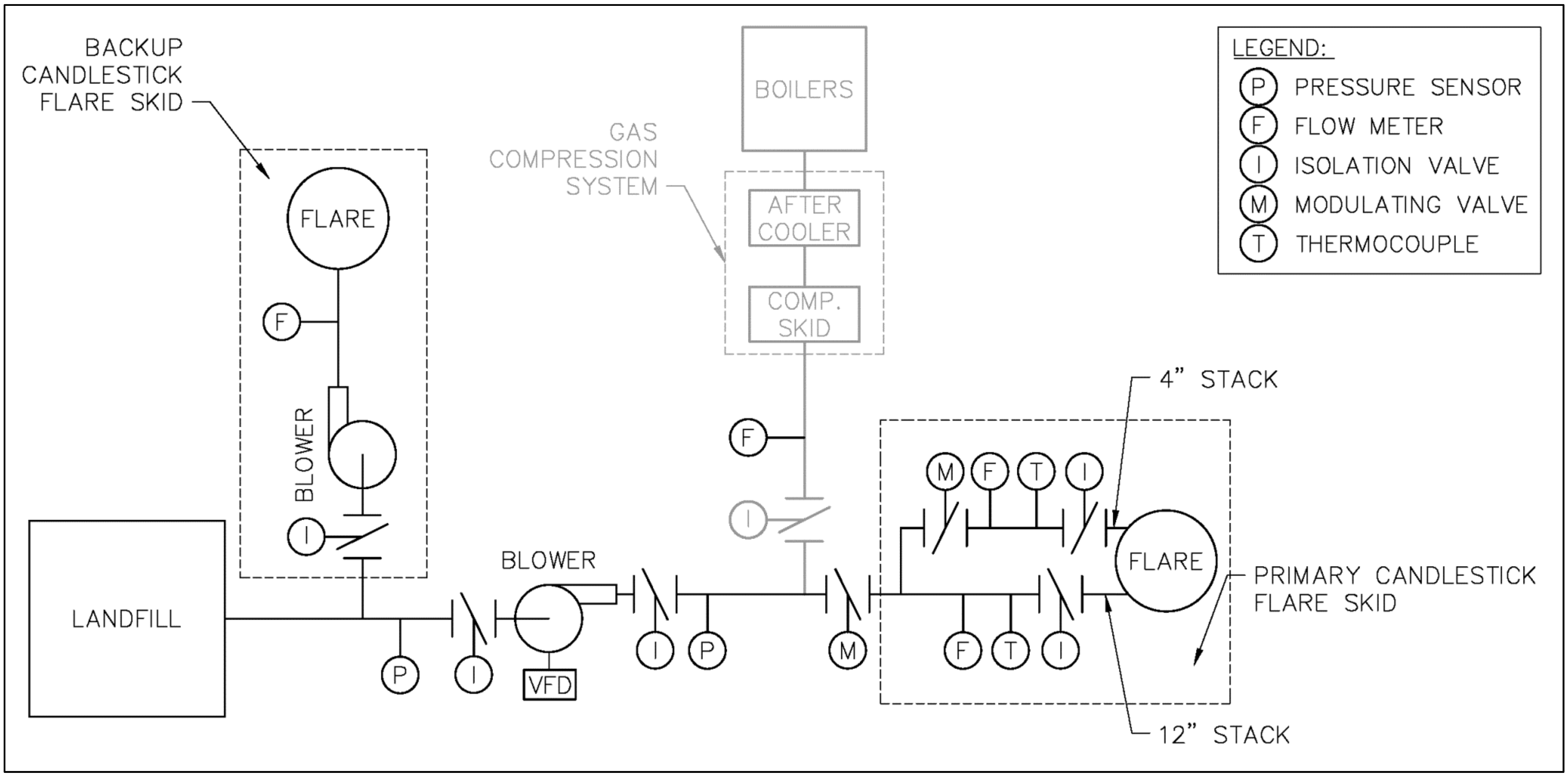

FIGURE 6: LANDFILL IN THE MID-ATLANTIC AREA - BLOWER / FLARE STATION SCHEMATIC

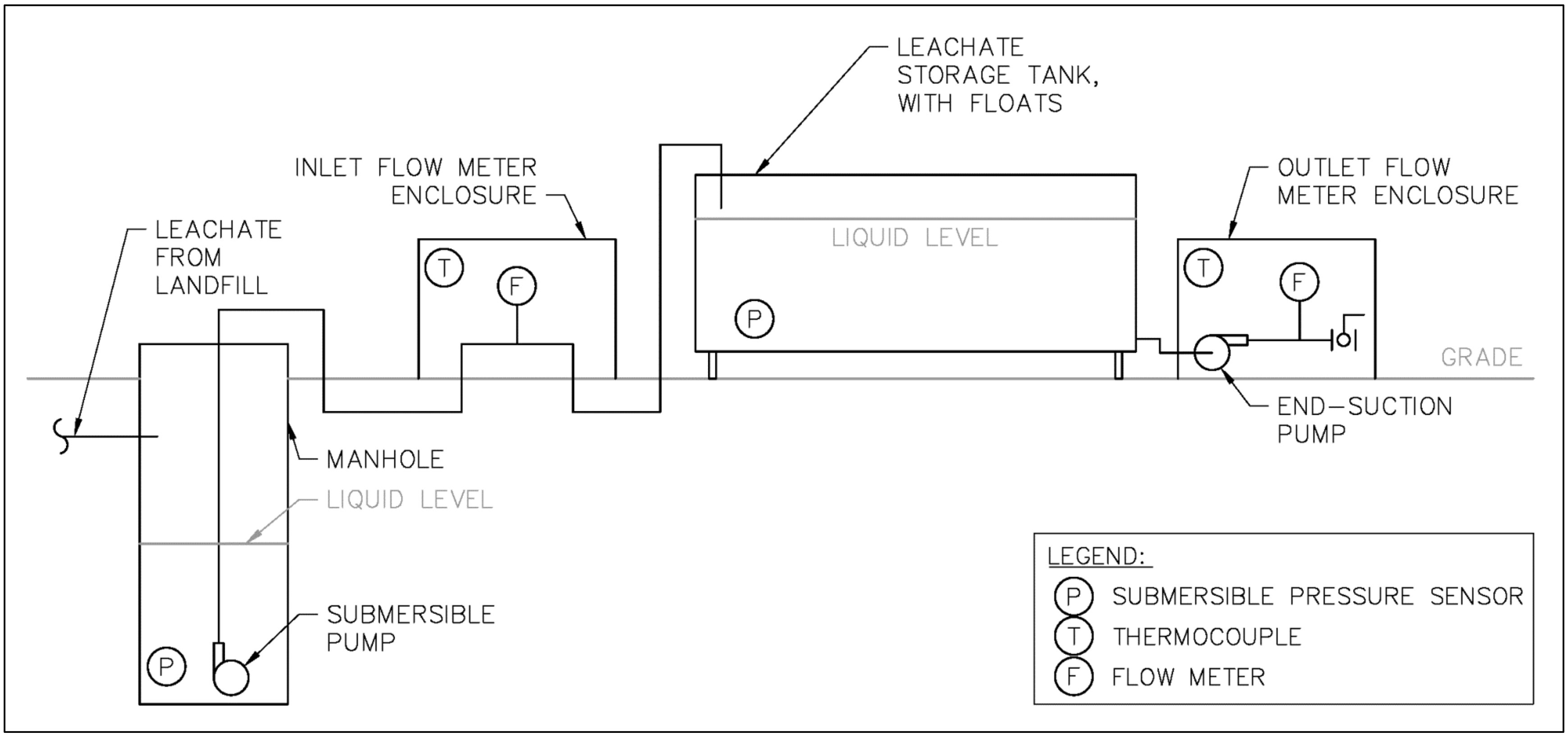

FIGURE 7: LANDFILL IN THE MID-ATLANTIC AREA - LEACHATE TANK AND PUMP SYSTEM SCHEMATIC