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Computerized Control System for Static Pile Composting of Dairy Manure

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Abstract. *The Solid Aerobic Biodrying (SAB) system was developed and installed on an 85-cow dairy in the New York City drinking supply watershed. The SAB uses the static pile composting method to treat the dairy manure for land application or off farm sale. An automatic computerized control system was developed to maintain appropriate temperatures of the compost piles while optimizing for moisture loss and retention time in the building. This paper will detail the design and construction of the graphical programming interface, hardware used, and the costs and benefits of the control system.*

Keywords. Composting, Computer Controls, Biodrying

Introduction

Composting has been proposed for years as one of the best methods to treat dairy manure. There are many advantages to traditional composting. The resultant product is dry and odor free. Also the product can be marketed off farm for a price between \$5 and \$30/m^3. This can turn a treatment system into a benefit for the farm. Selling the compost off farm also helps to reduce the amount of phosphorous applied to the fields. The reduction in manure volume and weight when composting allows farmers to transport the manure farther away spreading nutrients thinner on the fields to comply with best management practices. There are a few disadvantages to traditional composting as well. Dairy manure is too wet to compost directly from the barn. Dry amendment must be bought and mixed with the manure to compost. Also weather affects traditional composting, making it a hard task in the winter.

The Solid Aerobic Biodry system is a static pile composting system built in the New York City watershed in the spring and summer of 2001. This system uses dry recycled compost as one amendment. Biodrying requires a roofed structure to reduce rain and snow falling in the composting bays and slowing the moisture removal process. Fans and the heat of the compost drive moisture from the piles. The computerized system controls the temperature and optimizes the airflow to reduce moisture in the compost.

The goal of the computerized system is to maximize moisture loss while minimizing the cost and time of active composting. The computer program is designed to allow the compost to reach it's optimum temperature quickly. After reaching optimum temperature the program will run the fans as much as possible to drive off moisture while maintaining the temperature of the pile. When the pile starts to loose its energy the fans are set by the program to run continuously to complete the drying process.

Objective

The objective of this paper is to describe the computer control system for a biodrying process and explain the problems encountered.

Design of System

The Biodry system's goal is to create compost from an 85-cow tiestall barn bedded with sawdust and shavings, 100 heifer replacements on a straw bedded pack, and 30 calves in a plastic covered calf facility. Manure from these areas is mixed and further dried with alfalfa hay and other amendments to start composting with 60% moisture content(MC) material. The retention time for each 2.4 m wide, 12.2 m long and 1.8m deep bay is 21 days. In order to maintain the set point temperature of 60^{o}C, each bay has an independently controlled 1.5kW blower. These blowers are attached to a wooden air plenum by a 20cm PVC pipe to distribute the air into the three channels in the floor beneath the actively composting piles as seen in Figure 1. The blowers are specified to deliver 19.9m^3/min at 14cm water static pressure. This process is described in Wright et al., 2001.

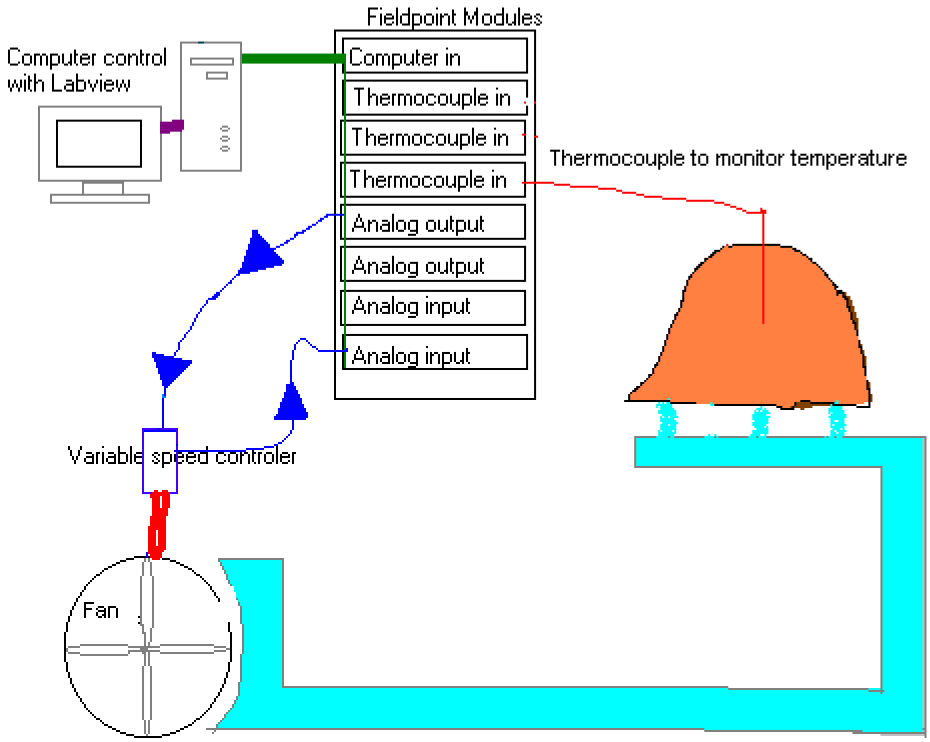

Figure 1: Schematic for one composting bay.

Each blower is controlled by a variable frequency drive (VFD) that is in turn controlled by a 650mhz Pentium 3 computer running LabVIEW 6i equipped with National Instruments FieldPoint Modules. For our purposes we chose to program with LabVIEW, as the software was already purchased for another project.

LabVIEW is graphical programming software that is easy to learn and is versatile in its applications. The greatest benefit in programming with LabVIEW is the graphical user interface shown in Figure 2. This front panel shows what the user needs to see and learn. The front panel is where the user inputs data into the programming code. It is also where data output is presented to the user to monitor the composting process. If designed correctly this panel should be intuitive. This allows the fan system to be controlled on farm by someone with basic computer knowledge. The graphical interface is described in detail in the program characteristics section.

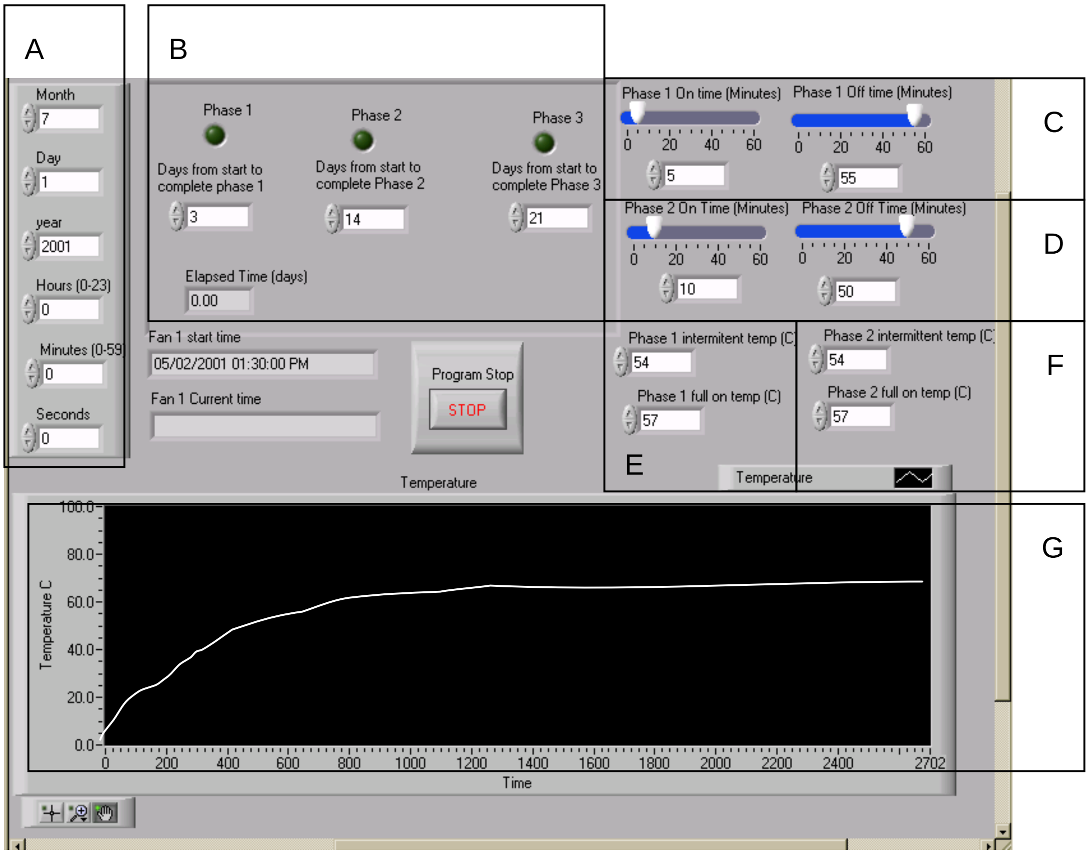

Figure 2: Graphical interface control for Biodry fan as displayed to user.

Traditional computer programming is text based. Text based programming can be difficult to learn, de-bug and interface with. Figure 3 shows a portion of LabVIEW's visual programming code. All the programming language is located on the back diagram of the user interface. This code is something the user does not necessarily need to see or understand. The code is the brain of the program. It takes the user input variables from the front panel user interface and data from the composting batch and makes decisions to run the fan. LabVIEW allows you to track the data flow and probe individual values to debug the program. The individual icons are subprograms, inputs and outputs. The lines are "wires" that move data into and out of the sub programs. The advantage of LabVIEW over text programming is programming ease. LabVIEW code development and changes are fast and simple. A text based language may need multiple lines for one simple change.

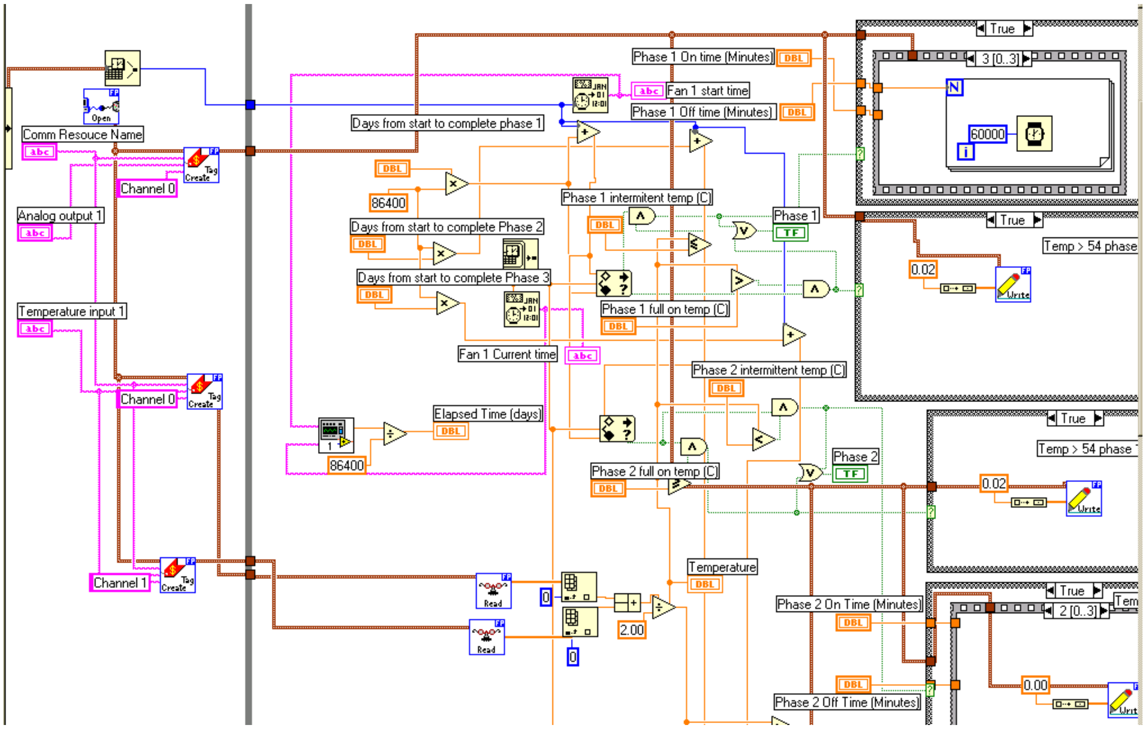

Figure 3: Portion of back diagram code using Labview.

Program characteristics

As seen in Figure 1 Section A, the user must manually enter the date and time each batch of compost is started. This feature was added to allow the user to backdate batches of compost in the event of a power outage.

In Figure 1 Section B, the user controls how long each stage of the compost process lasts. The program defines stage 1 as the startup phase. The goal of this phase is to supply enough air to allow the compost to heat quickly. Phase 2 is defined as active composting. This phase runs from day 3 until day 14 by default. Phase 2 is used to maximize airflow while maintaining the set point temperature. Phase 3 is defined as the drying phase. This phase is activated when the control system can no longer control the temperature of the batch due to lack of energy in the compost. By default this phase runs for 7 days. The user can change these defaults to tailor the system to different compositions of manure and amendment or different weather conditions.

Sections C and D in Figure 1 show where the user may change the minimum time the fans run for phase 1 and phase 2 respectively. This is important when the seasons change from the warm summer months to the cold winter. The default time the fan runs in phase 1 is 5 minutes every hour. This is the minimum time chosen to keep the batch aerobic and not cool the pile significantly. During the winter months this time is set to 5 minutes every 2 hours as the cold air was cooling the pile down and halting composting. During phase 2 the pile is already hot and very active. The increased activity needs more oxygen; therefore the time to run the fans is increased. This time was reduced during the winter as well to maintain a temperature that is suitable for active composting. The variable speed drive could also have been used to reduce the fan speed.

Sections E and F are the input limits for intermittent airflow and continuous airflow. When the temperature of the composting batch is below the minimum temperature for composting the pile receives the maintenance airflow to keep the pile aerobic. If the batch reaches the maximum temperature, the fans will run continuously to remove moisture. The user can change these temperatures dependent on time of year and composting composition. During the summer when the compost tends to heat to a higher temperature the set point temperatures are also raised so air moving through the pile will be hotter and remove more moisture to quicken the drying process to keep electricity costs lower.

Section G is a graphical output of the compost temperature. This history lets the user know if the inputs selected are correct for the batch currently composting and make adjustments as they see fit.

Each fan has its own individual program to maintain the composting process. A separate LabVIEW program records the temperature of each pile and the state of the fan (on or off) every minute and saves that data to a text file for further analysis. The data-logging program has a user interface that has a graph of every fan's history as well. This is the place the user can monitor all 12 fans and running batches from one screen. A screen shot can be seen in Figure 4.

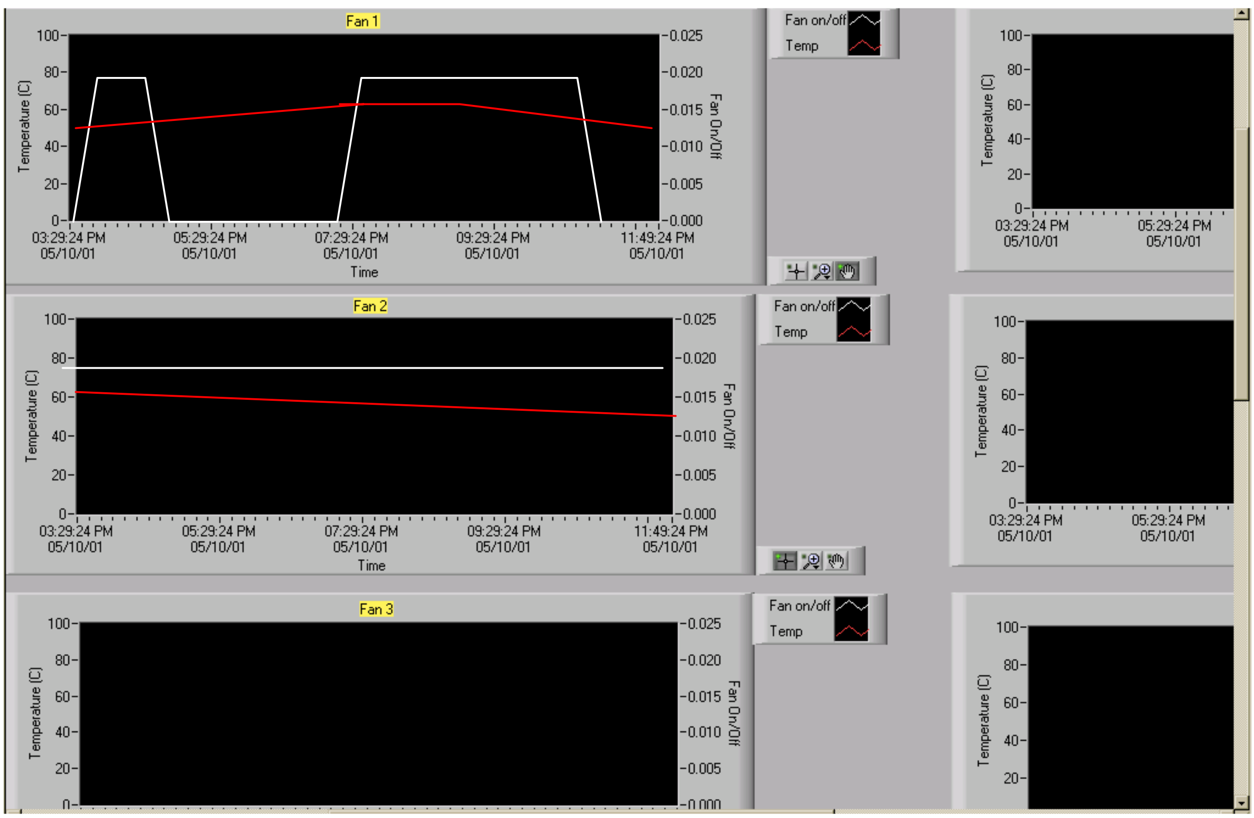

Figure 4: Screen shot of data logging program.

Hardware characteristics

The Biodry system uses a PIII 650mhz computer with Windows 98 operating system running LabVIEW 6i to control the composting process. These programs can run on something with less speed (the original computer was a 350MHz machine). National Instruments developed LabVIEW. Hence we used National Instruments FieldPoint distributed network hardware to both send control signals out to the VFD's to control the fans and to record the temperature of the composting material.

FieldPoint uses individual modules that have unique features to control your system. The Biodrying system uses two analog output, two analog input and three thermocouple modules to run the fans in the system as shown in Figure 1. These modules are connected together by individual bases to a network interface control module. This control module connects to the computer through its serial port. The FieldPoint system can also hook-up through a wireless and Ethernet connection.

Each of the twelve composting batches has two thermocouple probes that give an average temperature to the computer program. These probes are 16-guage type T thermocouples with PVC coating. This thermocouple type has a temperature resistance between -26^{o}C and 105^{0}C, well within the range of our compost temperatures. The wires are taped to fiberglass fencing posts. These posts are flexible, rugged and can withstand the high temperatures and corrosive environment within the compost and make insertion into the compost mix easier.

Altivar 28 variable frequency drives(VFD) from Square D ultimately run the fans. These drives interpret a low voltage signal (0 – 0.020mA) to determine fan capacity. The VFD’s can run the fans at any percentage of full capacity 0 – 100%. These drives convert the single-phase power available on site to the three-phase power needed for the fans and soft start the fans avoiding a possible overload of the power lines. The fans at full capacity are designed to deliver $19.9m^3$/min at 14cm static pressure. Low energy or porous composting materials may require less air and the VFD’s allow the user to lower the airflow easily.

Control System Costs

Table 1: Control System Costs

Item	Description	Estimated Cost
Type T thermocouple wire	1000' Spool PVC coated 16 gauge wire	$970.00
2 - Output module	8 Channel analog output 2- 20mA	$700.00
3 -Thermocouple Input Module	8 Channel Thermocouple	$1050.00
3 -Thermocouple Input module base	Isothermal terminal base	$525.00
1 - Computer interface	RS - 232 interface	$395.00
7 module bases	Non-Isothermal bases for input/output modules	$665.00
2 - Analog Input	8 Channel Analog Input Modules (FP AI 100)	$700.00
PC computer	650 MHz Intel pIII W/ 128 MB ram, 6GB HD, CD ROM w/o monitor	$200.00
PC monitor	15" (14" V.I.S.) CRT monitor	$130.00
LabVIEW Upgrade from 5.0 - 6.1	Upgraded LabVIEW for latest options.	$400.00
12 - VFD’s	One variable frequency drive for each fan.	$3700.00
Total		**$ 9,435.00**

Table 1 is a list of the equipment purchased to build this system. An estimated installation cost for this system is $1,000 including time to run the control wires, hang the variable frequency drive cabinets, and install the thermocouples. The VFD's that were purchased are one item that this system may not need. These drives were purchased in order to lower the airflow into the composting batches during the process to avoid preferential flow and over cooling of the compost. After running the system for eight months, it appears that this option may not be needed.

System Results

Overall, this system has overall performed very well. The producer checks the computer system every day while loading the composting building and data is downloaded from the machine every two weeks. There has been very little loss of data since December 2001. In December, an uninterrupted power supply was purchased to remove electricity lows, peaks and outages. The farm operator learned the interface and was comfortable with it after 20 minutes. As mentioned before, during the winter months the operator changed the time the fans ran because the compost was unable to heat. This adjustment was done without the need for assistance.

Faulty wiring cause a few problems after startup of the composting control system. The thermocouple wires were wired positive to negative making the temperature seem to decrease over time. The original computer needed a new motherboard and processor in December of 2001 as a result of the old processor overheating after a case fan failure. The new system has been working flawlessly since. The variable frequency drives caused faults during the winter when the user tried to run the fans for a maximum time of one minute. During the summer, a few of the variable frequency drives also faulted as a result of high temperature in the cabinet. The variable frequency drive cabinet fans were run on a continuous basis and the filters cleaned every other week during the summer after the report of the faults. Two FieldPoint bases were replaced in spring 2002 as a result of moisture damage. The bases were mounted underneath the two conduits that ran the control wires outside. Condensation dripped on the bases, shorting them out.

Conclusion

The computerized control system for the biodrying building has been presented. This system controls twelve fans individually using a LabVIEW software program and National Instruments FieldPoint hardware at a cost of $9,435. This system was designed to record data and be adaptable to changing programming needs. During the first eight months of operation the system has proven to be dependable. Further experience with it will determine if this advanced system is needed or whether one built with a manual timer switch would perform as well once operating parameters were established.

Disclaimer

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