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An Integrated Video- and Weight-Monitoring System for the Surveillance of Highly Enriched Uranium Blend Down Operations

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ABSTRACT

An integrated video-surveillance and weight-monitoring system has been designed and constructed for tracking the blending down of weapons-grade uranium by the U. S. Department of Energy. The instrumentation is being used by the International Atomic Energy Agency in its task of tracking and verifying the blended material at the Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio. The weight instrumentation developed at the Oak Ridge National Laboratory monitors and records the weight of cylinders of the highly enriched uranium as their contents are fed into the blending facility while the video equipment provided by Sandia National Laboratory records periodic and event triggered images of the blending area. A secure data network between the scales, cameras, and computers insures data integrity and eliminates the possibility of tampering. The details of the weight monitoring instrumentation, video- and weight-system interaction, and the secure data network is discussed.

INTRODUCTION

The project goal was to provide the International Atomic Energy Agency (IAEA) inspectors with an independent, reliable and secure system to verify the amount (in weight) of highly enriched uranium (HEU) material fed into the blend down process at the Portsmouth Gaseous Diffusion Plant in Portsmouth, Ohio [1]. The requirements for this instrumentation were developed in cooperation with the IAEA inspectors, the Department of Energy (DOE), and the plant operator.

In the existing blend down operation a cylinder containing highly enriched UF6 is brought to the feed station on a dolly and with the dolly is placed on a weighing platform consisting of a load cell connected to a scale display. After the cylinder is connected to the feed lines, the scale display is zeroed. The scale indicates the quantity of material withdrawn from the cylinder as a negative weight. Accountability measurements are performed in different settings to determine more precisely the amount of material remaining in the cylinder. Weight values and other identifying

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parameters are manually recorded in log books at scheduled intervals by the plant operation personnel.

To meet the IAEA requirements the system needed to be modified to continuously monitor and record the weight of the material withdrawn from the cylinders, assure data and equipment integrity, and minimize interference with existing plant procedures. Data integrity and equipment security were the driving force behind virtually every design decision.

SYSTEM DESIGN AND IMPLEMENTATION

SYSTEM

The weight monitoring system consists of new scale readouts networked to a data collection Personal Computer (PC) located in a separate room. Two surveillance cameras are also connected to the same network so that either the scales or the PC can trigger the storage of images if "unusual" events occur during the monitoring process. To ensure data integrity all cable connections are made within the scale readout enclosures and within the PC cabinet, and all enclosures have tamper indicating seals. At the blend facility there are nine blending stations numbered 1-3 and 5-10 (Figure 1).

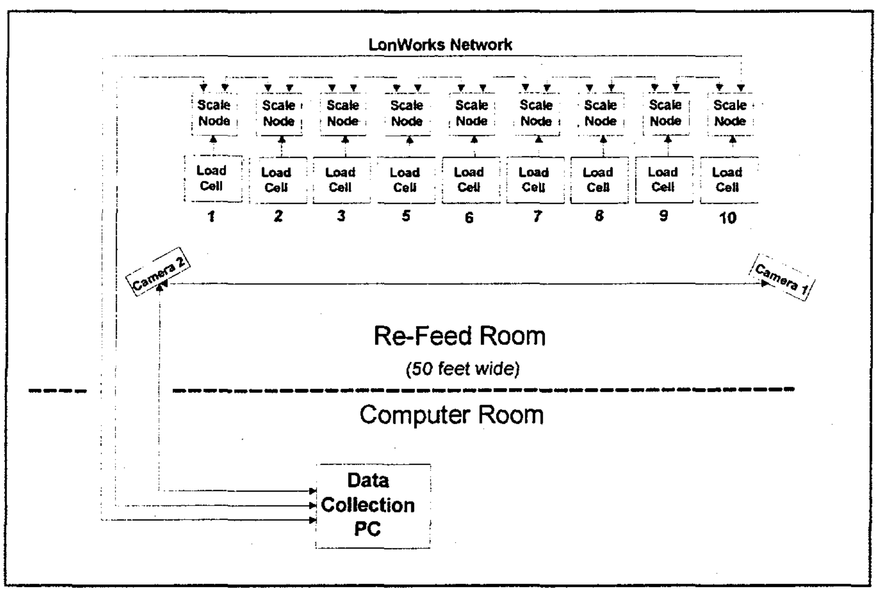

Figure 1. System Hardware block Diagram

NETWORK

The system is connected as a peer-to-peer, free-topology network based on Echelon's LonWorks with a data throughput of 78 Kbps over a twisted-pair wire. To minimize cabling the scale readouts are connected in a daisy chain. Both ends of the chain are connected together at the computer to prevent data loss in case there is a break in the cable. In this implementation the main benefits of the LonWorks are the ease of implementation and the built in message authentication. Each of the scale readouts was modified with the addition of a LonWorks node which is interfaced to the scale readout electronics. The PC communicates with the network via a standard LonWorks interface, while the camera interface was provided by the camera manufacturer.

The built in message authentication provides a secure transmission between the nodes and the data collection PC. For each message transmission the authentication is accomplished by a series of two way communications between the two nodes exchanging messages. These messages are derived by a combination of message content, a predefined key and a random key. Four messages of different lengths occur before the authenticated message is accepted by the receiving node, in this case, the PC [2].

SCALES

The existing Fairbanks scale readouts were replaced with Thurman scale readouts which are operationally identical but have a serial computer interface. A small electronic circuit board, designed to fit within the scale readout enclosure, incorporates the LonWorks node and its interface to the scale readout (Figure 2).

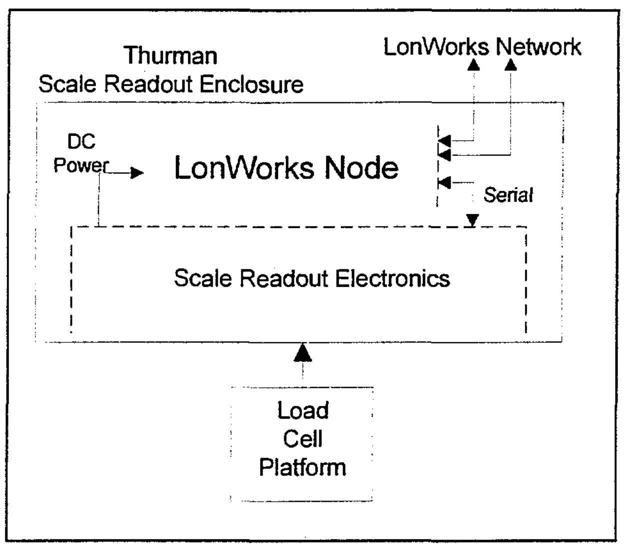

Figure 2. Modified Scale Readout Diagram

The main functions of the LonWorks node are to communicate with the readout electronics via the serial port and to communicate with the PC via the LonWorks network. The node software reads the weight from the readout every few seconds and keeps a running 30 second average. This average value is sent to the PC on request (e.g. about every 10 seconds). If weight changes exceed a predefined threshold in either direction with respect to the average, an abnormal weight event is logged and event information is sent to the PC. At the same time the node also sends a message to the surveillance cameras to trigger an image of the blending area. During periods of high activity, such as changing a cylinder, a time-based lockout in the software prevents the triggering of multiple pictures of the same event.

In addition to the weight monitoring function and network communication, the node electronics were designed to make the scale readout a short-term, standalone data logging system. If the communication with the PC is lost, the data is stored in the node memory until the network communication is re-established. At a predefined data storage interval of 30 minutes, the node can provide a few weeks of storage for weight data and event information.

CAMERAS

Sandia National Laboratory (SNL) installed the two surveillance cameras to monitor the activity in the blending area [3]. The two cameras were integrated into the weight monitoring network by attaching a LonWorks node to each camera. Network messages were then defined to allow the cameras to be triggered by other network nodes.

DATA COLLECTION PC and SOFTWARE

The Data Collection PC is housed in a cabinet together with the Image Collection PC and both computers use the same monitor and keyboard. The cabinet has an uninterruptable power supply, and the applications are self starting when the computer boots up. These features are necessary since there is no access to the equipment inside the cabinet when the cabinet is sealed.

The load cell data acquisition software runs under Windows 95 and was developed in LabView. The application communicates with the scale nodes, displays relevant information (Figure 3), and stores weight data and event information in files on the computer hard disk.

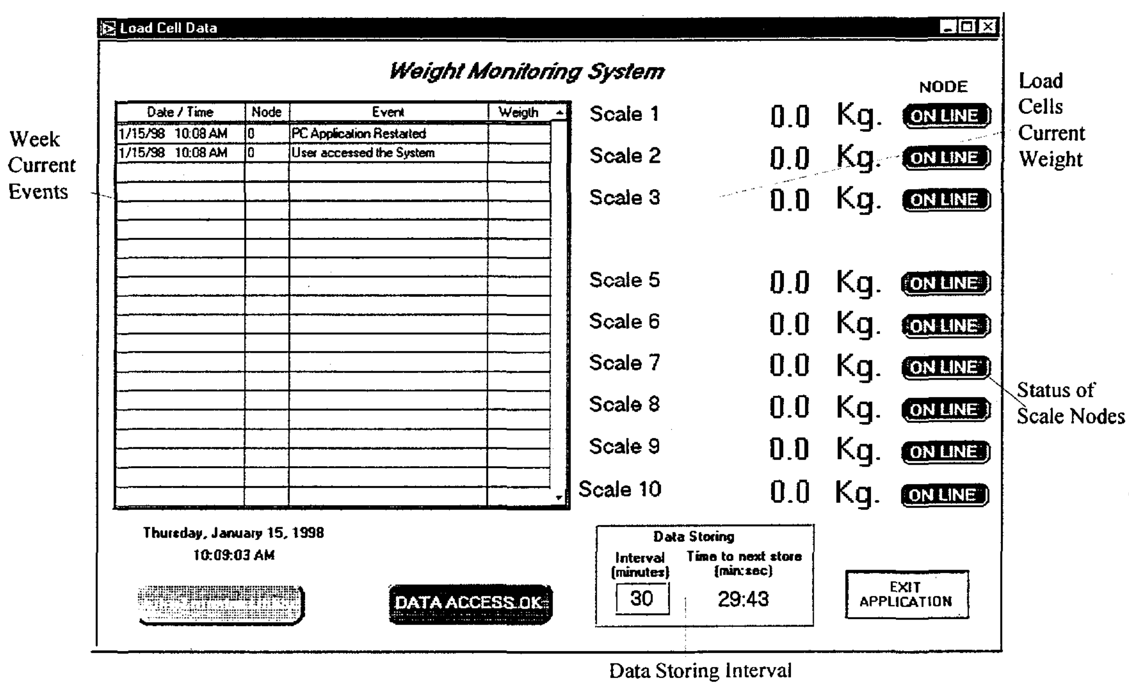

Figure 3. Monitoring screen of the load cell data acquisition software.

Displayed data is updated every 10 seconds with data received from the nodes, and is stored at a predetermined 30-minutes interval in a weekly file. A new data file is created at 12 a.m. every Sunday morning. Event information is also displayed on the screen as it comes from the node or is generated by the PC. This data is also stored in a weekly event file. Like the data files, a new event file is created every Sunday morning. The software also monitors and displays the status of the nodes in the network (on line/off line). The event information is used to indicate activity in the blending area and as an explanation for unusual weight data. Events, which are generated by both the PC and the nodes, include occurrences such as when a scale goes off-line, when a weight is abnormal, when a node goes off-line, when a scale readout is zeroed, and when the node is reset (usually due to a power failure). Some of these events, abnormal weights and nodes off-line, also trigger a camera image. The PC records all of the described events along with such items as when a user accesses the system (mouse activity) and when data files are copied from the system.

DATA REVIEW

The data is reviewed by the IAEA inspectors on a separate review computer away from the blending area. The data files are retrieved from the Data Collection PC with a file transfer utility integrated in the data acquisition software. This utility automates the process of copying to diskettes all the data and event files since the last visit. The data and event files are not deleted from the Data Collection PC, but are archived in a separate directory for future reference.

A data review application, which runs on the review computer, was developed to present the data in tabular or color graphical form (Figure 4).

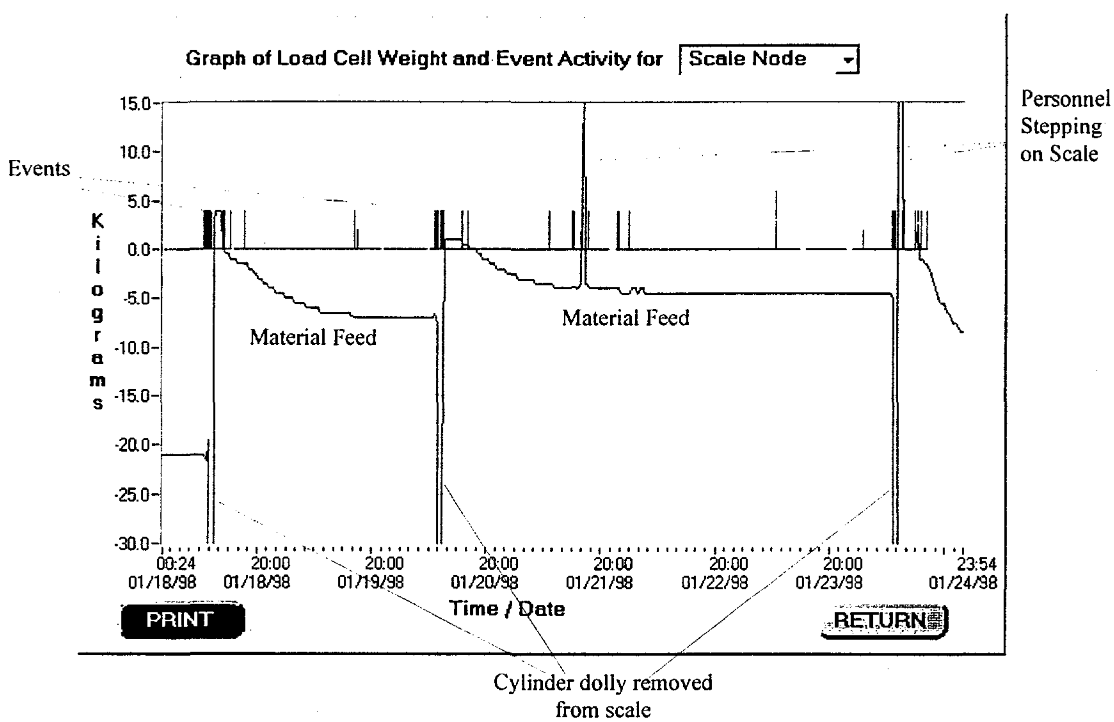

Figure 4. Example of collected data.

The graph shows an example of one week of data (black lines) and event occurrences (red lines) from one of the scale nodes. To determine the type or nature of an event, the user must reference the tabulated event data for that date and approximate time. Some recognized activities are labeled in the figure. To verify the blend down operation, IAEA inspectors correlate the information presented in the these files with the data entered in the log books by the facility personnel and the data from other measurements designed for this verification.

OPERATION

The system was easily installed with minimum interruption to normal operations. The new scale readouts were installed and calibrated when a new cylinder was attached. The operation of the system brought no changes to the current operating procedures. All of the system features were tested by intentionally causing events and power failures. The IAEA inspectors were provided with written procedures and hands-on training for transferring the data files to diskettes and for reviewing the data on the review computer. After reviewing data and event information from a few days of operation, minor software modifications were made to adjust to the facility operational activities and to improve system performance.

In general the system performed well. The inspectors were able to download and review data files to correlate the load cell data with data from other measurements and log books and verify the blending operation. One incident occurred when the PC system crashed and during the subsequent manual reactivation some unexplained event reset all the nodes causing the loss of the data stored at the nodes since the crash (21 days).

CONCLUSION

This project was an experiment in developing instrumentation to help the U.S. Department of Energy test in using international verification of a blend down operation. The weight monitoring system provided an independent history of the number of cylinders emptied and information to confirm the amount of material withdrawn. Data and experience gathered from these measurements will be useful in making improvements in the existing instrumentation and in the design of new ones. This experiment demonstrated that the flexibility of the network hardware and the modularity of the software designed into the system allow this instrumentation to be quickly tailored for similar tasks in the future.

REFERENCES

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