ABSTRACT PRESENTATION OF PROCESS DATA

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ABSTRACT

Case studies of two very different processes, one petroleum production and the other glass melting, show how each presents gigabytes of process data in an abstract manner to find potential for improvement. This has helped non-process-savvy staff focus on unusual process events and subtle relationships that affect company profits.

INTRODUCTION

A Harvard social scientist argued that the computer revolution in the workplace confronted industry with a momentous choice either to automate, dehumanizing work and alienating workers, or to informate, giving workers the knowledge to make critical, collaborative judgments (1). Early industrial computer applications overcame the technical challenge of measuring and collecting data accurately and economically. Early HMI (human machine interfaces) did not convey the same information to workers as did the physical seeing, hearing, and touching experience and, deservingly, suffered from credibility problems. Wide acceptance of now-familiar GUI (graphical user interface) metaphors has now led to a necessarily uniform HMI among SCADA (supervisory control and data acquisition) and DCS (distributed control system) systems. Process symbology has evolved from single line to almost photo-realistic renderings. These adaptations have addressed the early credibility problems to the extent that belief in "what appears on the screen" can even supercede reality and intuition.

A Yale professor developed general principles that have specific visual consequences and apply to the design, editing, analysis, and critique of data representation (2). The challenge is to present as much data as possible in the limited space of a computer display screen and to allow workers to intuitively identify patterns in that data.

THE PRINCIPLE OF ABSTRACTION

Abstraction consists of obscuring the technical and mathematical details surrounding each datapoint (the numerical value of a variable at a particular datetime) and arraying screen elements representing many thousands of datapoints so that patterns in the data are intuitively obvious. This is in contrast with the excessive unnecessary details which clutter and reduce the data density of conventional representations.

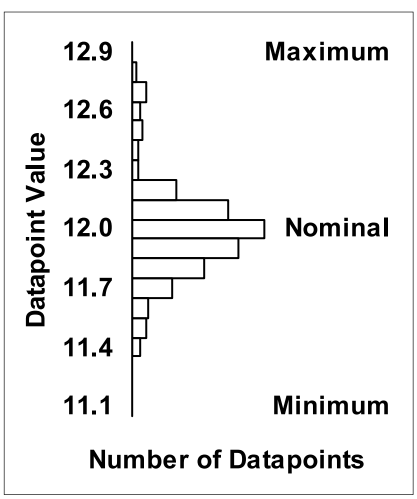

Figure 1 - Distribution of Datapoint Values for Air to Gas Ratio

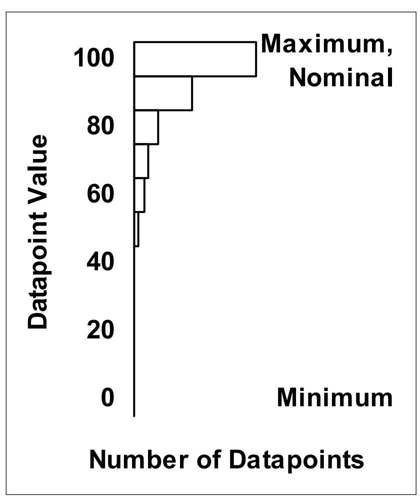

Figure 2 - Distribution of Datapoint Values for Percent Efficiency

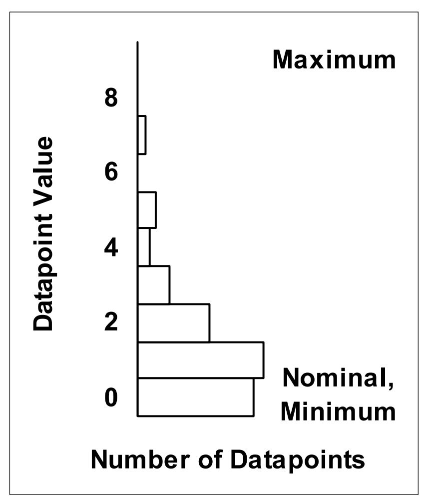

Figure 3 - Distribution of Datapoint Values for Defects per Hour

The conventional histogram in Figure 1 shows the number of datapoints for each of a range of values of the air-to-gas ratio in a furnace, an important environmental and manufacturing cost parameter. The largest number of datapoints occurs at the nominal value, with deviations below to the minimum and above to the maximum. This is typical of a bivariant variable, nominal preferred. Mathematically, it is the Gaussian distribution that most statistical software and statisticians assume to simplify analysis.

Another conventional histogram in Figure 2 shows the number of datapoints for each of a range of values of efficiency, an important manufacturing cost parameter. The largest number of datapoints occurs at the maximum value, with deviation only below nominal. This is typical of a univariant variable, high preferred. Mathematically, it is a Poissonian or error function distribution. It is problematic for most statistical software and leads statisticians to false conclusions when they, often unknowingly with their software, apply the simplifying assumption that the distribution is Gaussian.

Yet another conventional histogram in Figure 3 shows the number of datapoints for each of a range of values of defects per hour, an important quality parameter that is sensitive to any increase. The largest number of datapoints occurs near the minimum value, with deviations predominantly above nominal. This is typical of a univariant variable, low preferred. Mathematically, it is like, and causes the same problems as, the efficiency data of Figure 2.

BRIGHT IS BAD

A line chart and a graphic strip in Figure 4 represent the same 480 datapoints as the histogram of Figure 1. Older data is at the graphic strip's "left" and newer is at its "right". Darker places in the strip represent data with values close to nominal, or desired. Brighter places are farther from nominal. Blues indicate deviation below nominal and reds are above nominal.

For clarity, the graphic strip in Figure 4 is much wider than a strip is in an actual abstract image.

An abstract image consists of up to 50 of such narrow horizontal graphic strips, one for each variable, adjacent to each other. Vertical patterns in an image are events that affect several variables at the same time. Horizontal streaks are individual variables.

Abstraction permits a single image to represent the bivariant, nominal preferred air-to-gas ratio data, the univariant, high preferred efficiency data, and the univariant, low-preferred defect per hour data. The operator viewing the image need not be aware of the scaling details, much less any advanced statistical or analytical issues. The brightness and color of the screen elements indicate the degree of deviation of the datapoint value above or below the preferred nominal.

An automated image generator automatically and continually queries ODBC databases and converts the data to images, "rolls up" short timescale images into long timescale summary images, and stores the images on an image server for rapid retrieval by view clients. Figure 5 shows the general arrangement.

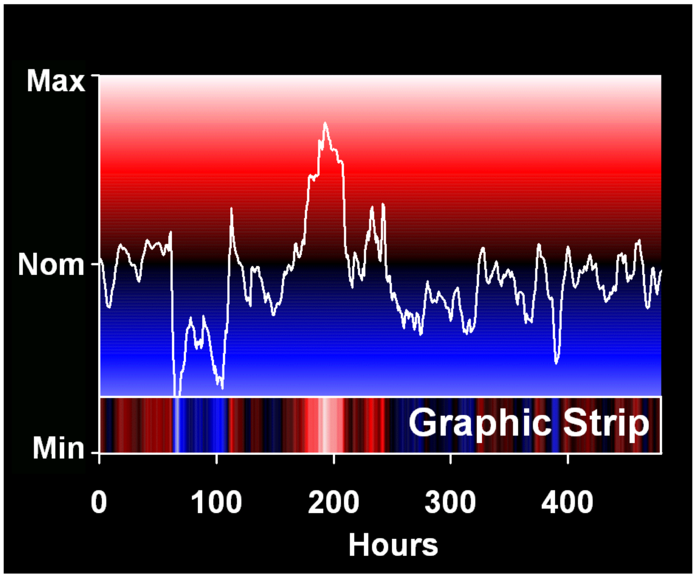

Figure 4 - Line Chart and Graphic Strip for Air to Gas Ratio

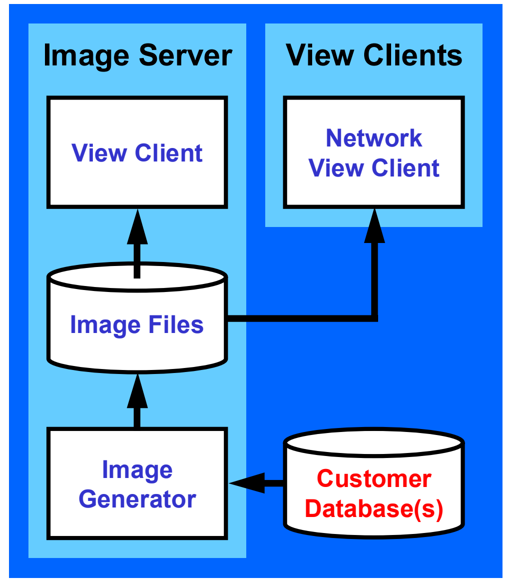

Figure 5 - General Arrangement of Image Server and View Clients

FIRST CASE STUDY: PETROLEUM PRODUCTION GATHERING SYSTEM

This case study describes the application of abstraction to a petroleum production gathering system in the West Texas. Late in 1996, a study team was formed to evaluate the operation of a Chevron field in Crane and Upton Counties, Texas. This 75-year-old field was a mature waterflood with approximately 600 producing wells and 450 injection wells. Production fluids from these wells were handled at 27 different facilities, each having well-test separators, production separators, and tanks with local control. The study team concluded that significant gains in operating efficiencies could be achieved by consolidating production handling to one facility, with remote satellites gathering the production fluids and conducting well tests. The consolidation project was completed in 1998 and as a result four separate gathering systems were installed (3). This case study will focus on one of these gathering systems, MF 197.

Figure 6 shows a simple flow diagram of the gathering system for MF 197. Nine gathering satellites each collect producing well fluids and gas from a one-square-mile section, separate the gas, and pump the gathered fluid to the MF 197 allocation satellite. MF 197 also separates gas and liquids from its own wells in the surrounding one-mile section.

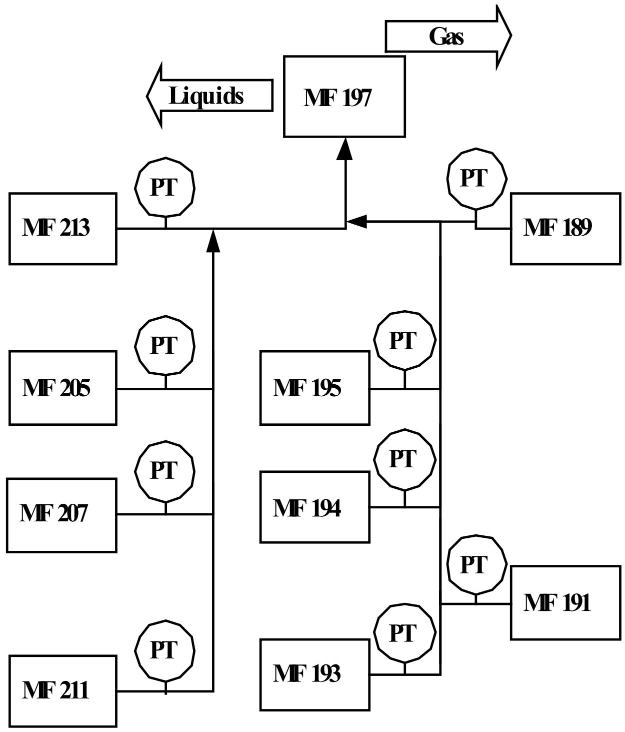

Figure 6 – Simplified Flow Diagram of MF 197 Gathering System

The gathering system feeding MF 197 contains sections of older pipe, so pressure monitoring and control are very important. Also, since the purpose for gathering fluids at nine locations is to enhance well production by reducing well back pressure, maintaining a low gathering system pressure is another goal. The pressures from each gathering satellite were being monitored continuously and logged for trending purposes every 60 seconds. Trends for individual pressures were reviewed most often only during incident investigations.

Since so many variables were being trended, an abstract image generator was implemented in the hope that this visual method of monitoring data would generate additional value from our data logging. The MF 197 gathering system was the first group of variables monitored. Trend data for the nine variables involved was extracted from the HMI database. A 30-day sample of 60-second resolution data was used to determine mean and standard deviation after removing anomalies. These statistical values were used to provide input into the image generator with the upper and lower limits corresponding to 2 standard deviations from the mean of each variable.

The system was installed and began generating images for the nine variables. A few days later, on the afternoon of August 2, 2000, the image showed several gathering system pressures increasing and approaching their upper limits. Figure 7 shows the subject image, where each narrow horizontal graphic strip is four days of data at twelve minute intervals for one variable. After a few phone calls to field operations, it was discovered that the company that purchases the gas from the sections had a system malfunction that temporarily reduced system capacity and raised system pressures.

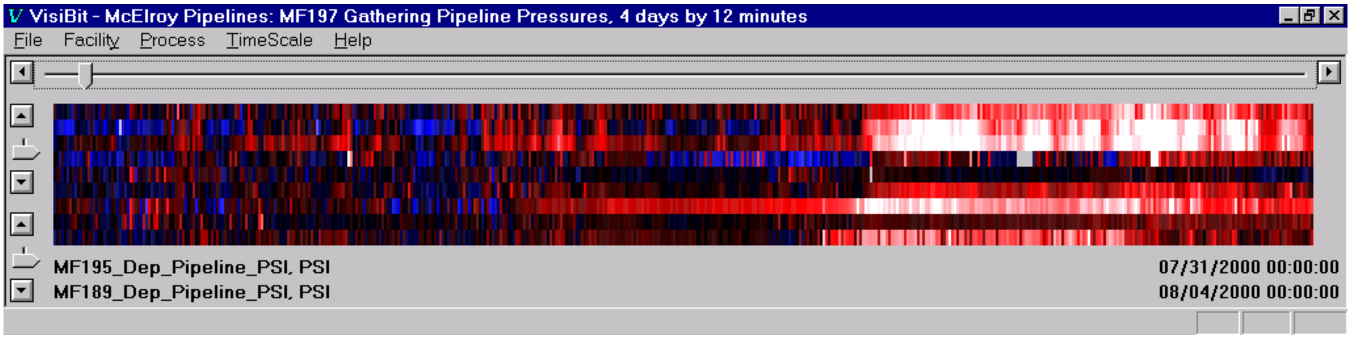

Figure 7 – Abstract Image Showing Increased Pressures on Nine Gathering System Variables

Figure 8 shows the trends for the same event. Here the pressure increases are also seen but the duration is not as readily apparent.

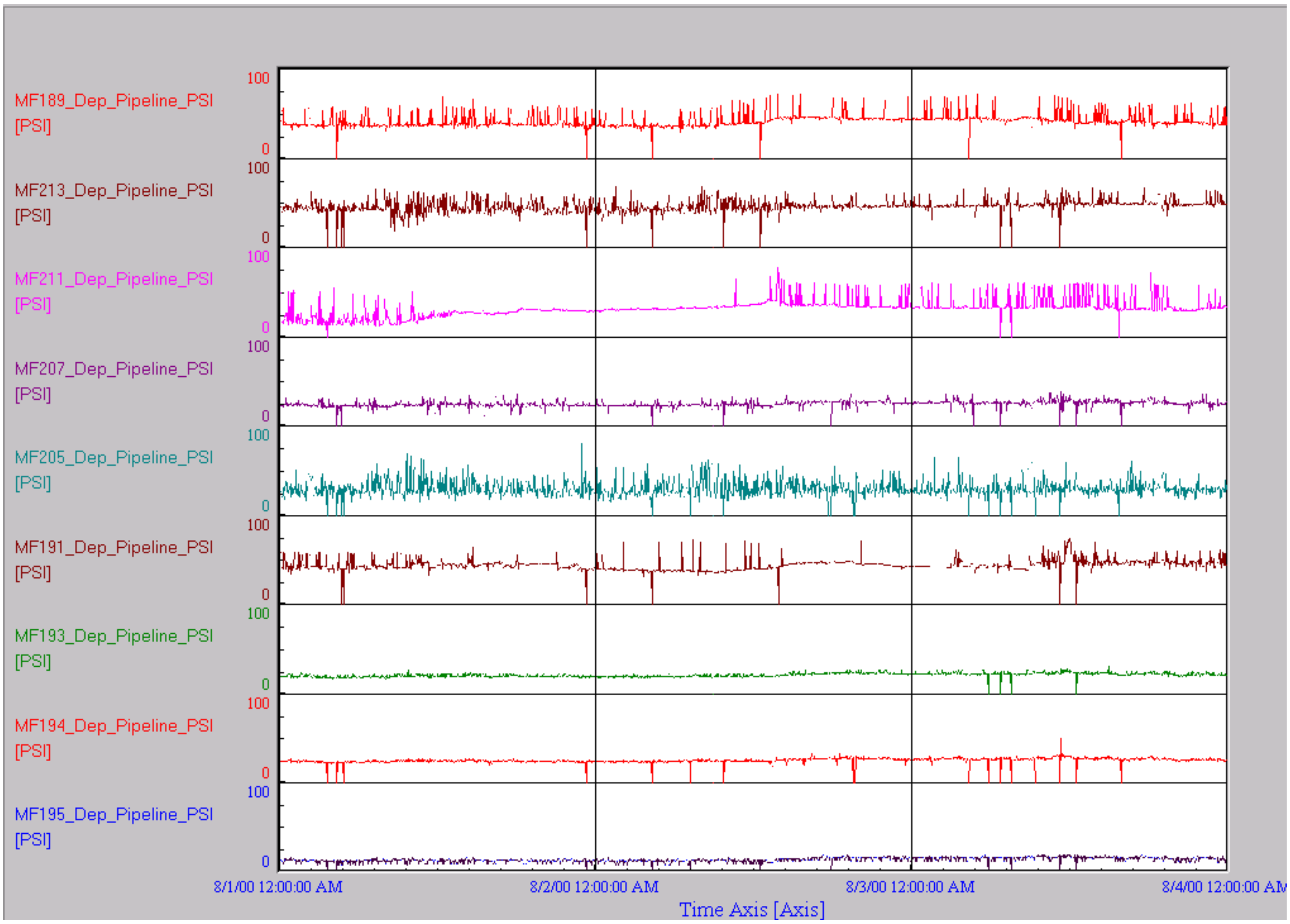

Figure 8 – HMI Trend Showing Increased Pressures on Nine Gathering System Variables

The company purchasing the gas indicated that the system malfunction in question was remedied within a few days. However, the images generated subsequently indicate the system is continuing to operate at a higher pressure. This has affected well production somewhat. According to the current contract, the increased pressures are still below the maximum allowed, so the current situation must be tolerated until the contract expires. However, it is known that lower operating system pressures are achievable and sustainable. Armed with this information, lower system pressures will be a goal to pursue when the purchasing contract is renegotiated.

SECOND CASE STUDY: GLASS MELTING

Saint-Gobain Vetrotex America, Inc. (SGVA) produces glass reinforcement fiber for use in diverse applications. A number of raw components are blended into “batch” and are fed by rotary chargers into a furnace to be melted.

These chargers are controlled automatically by a three-level cascaded control system. Pairs of chargers (left and right) are controlled by the same overall system with a speed ratio offset as an integral part of the controls.

Given the overall process complexity, some level of instability is always present. Short and longer-term oscillations are always present in most PVs (measured process variables). These variations often mask the occurrence of incipient equipment failures until significant process upsets have become evident.

The following trend charts illustrate such a case where a charger drive feedback transmitter began to fail intermittently and then failed completely over the course of twenty-four hours. The problem was detected by the operators only when gross failure had occurred and the maintenance technicians had difficulty determining just what had actually failed.

A careful review of the various charts below by a control engineer clearly indicated that the culprit almost certainly had to be the feedback transmitter generating the PV known as SIC_20PV.

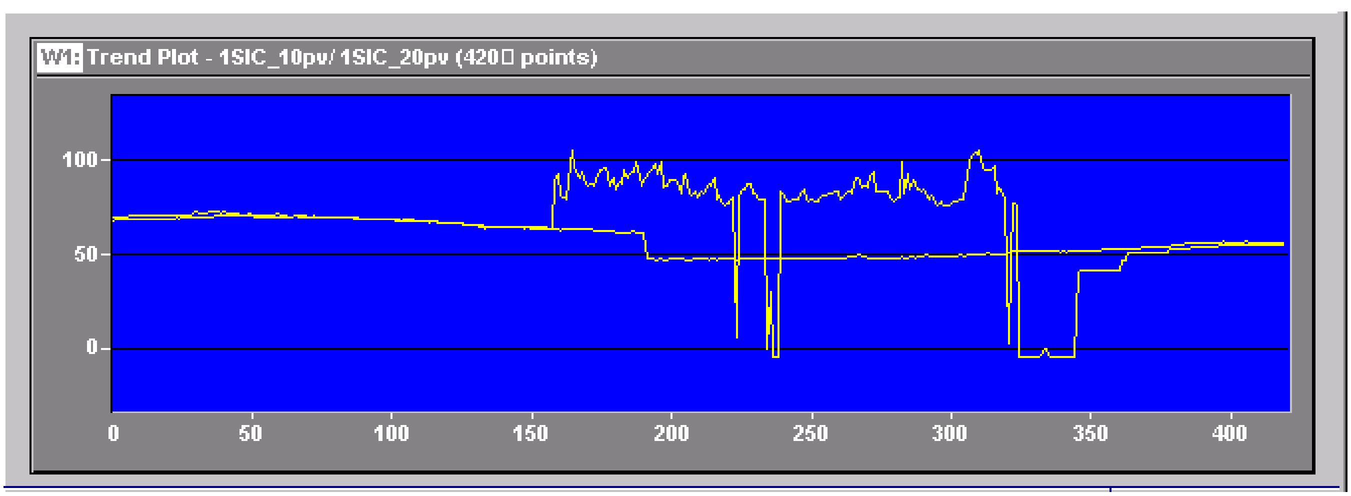

Figure 9 – HMI Speed Feedback of Two Batch Chargers from 10:00 Through 17:00 25 April 2001

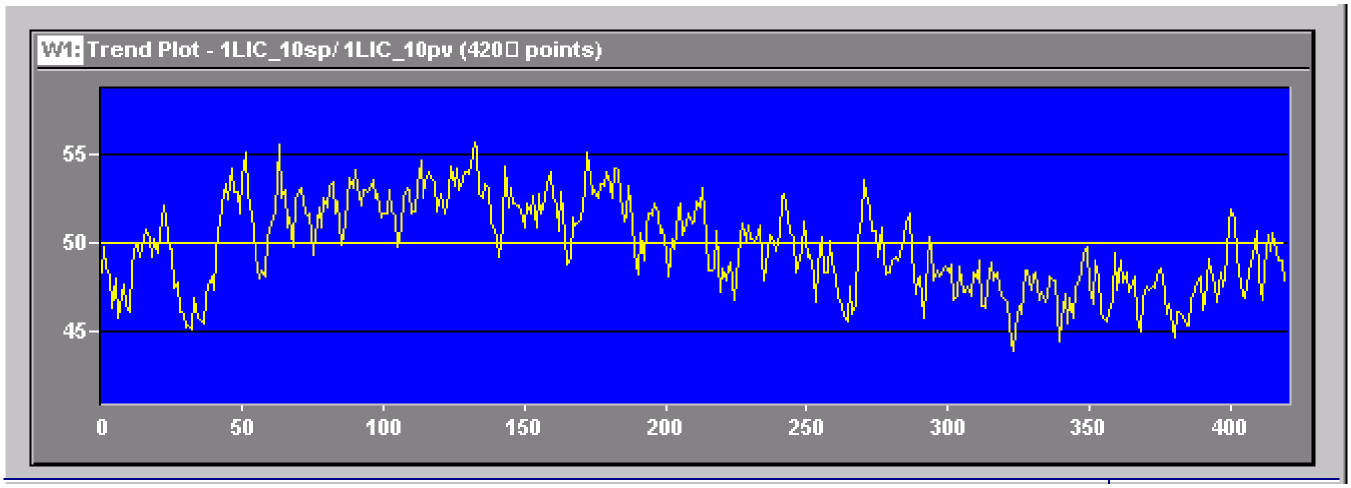

Figure 10 – HMI Level Controller Setpoint and Process Variable During the Same Interval

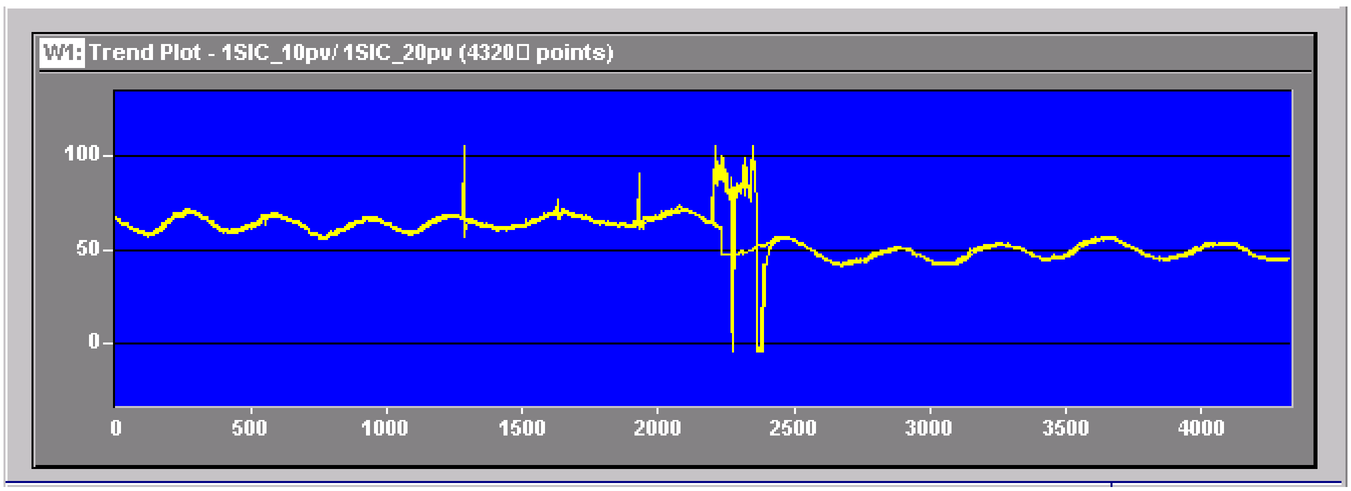

Figure 11 – HMI Speed Feedback of the Two Batch Chargers During a 72 Hour Interval

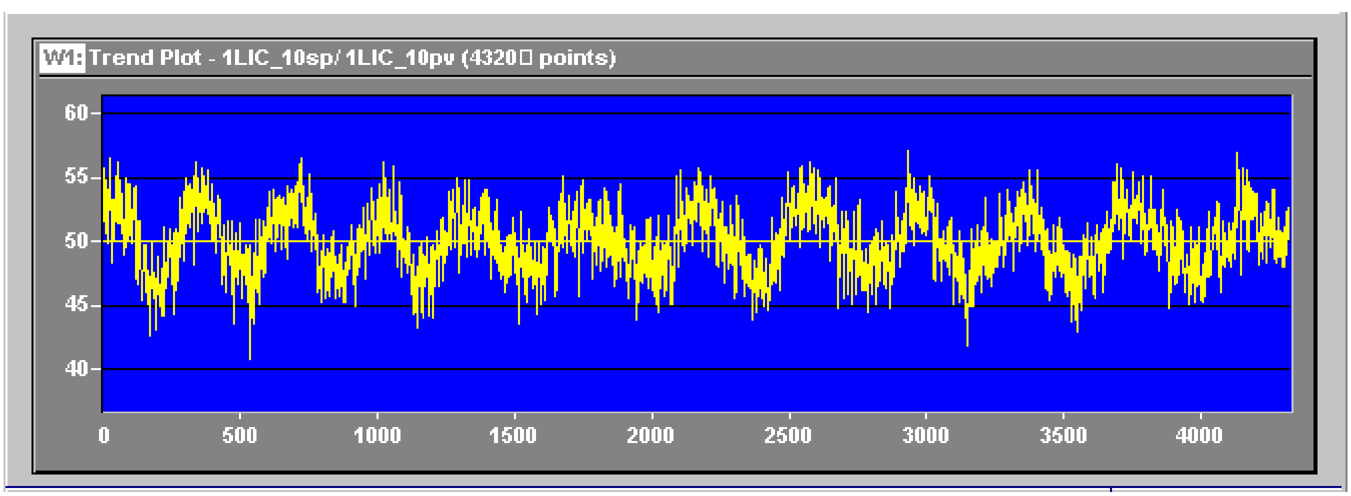

Figure 12 – HMI Level Control During the Same 72 Hour Interval

This conclusion, however, required a high level of knowledge regarding the physical processes involved and the complex control system and an ability to successfully handle a high degree of abstraction to use the multiple trend charts to find the root cause.

The abstract image in Figure 13 shows the same process data as the trend charts. The data for the same four variables appears in one image, so the decision as to which chart to use is not a roadblock for the less qualified (or determined) user. Again, each horizontal graphic strip is four days of data at twelve minute intervals for one variable.

The color changes indicate just which PV has departed from normal bounds over the relevant time interval. It also shows that other related PV's remain in normal ranges, and this generally removes them from the immediate troubleshooting exercise.

A region of interest is indicated with the mouse cursor. The variable labels at the lower left of the image show that the top variable in the region of interest is LIC_10SP and that the troublesome SIC_20PV is the bottom variable. The datetime labels at the lower right of the image show that the region of interest is from 12:00:00 through 16:00:00 25 April 2001.

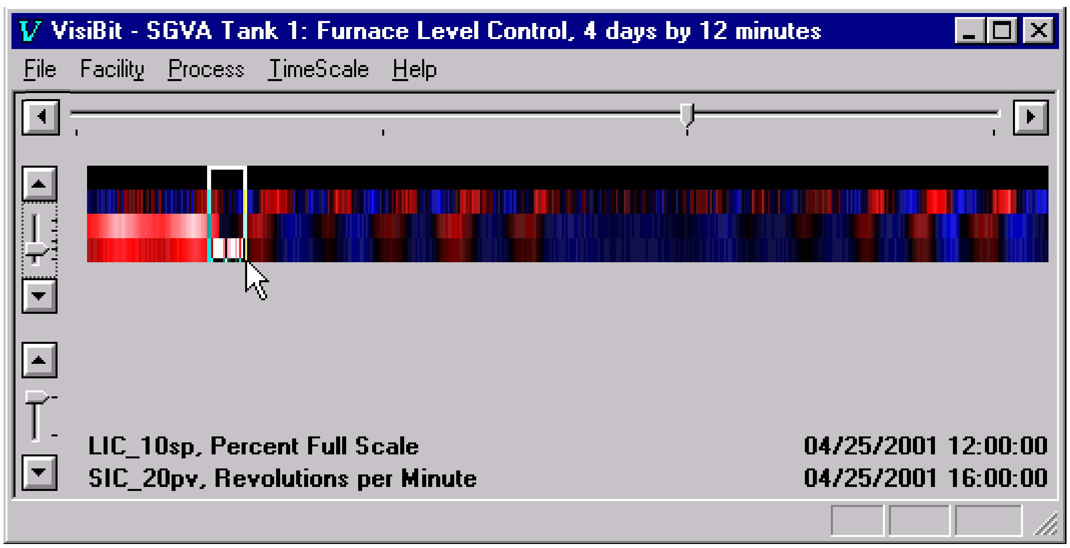

Figure 13 – Abstract Image Showing Two Level and Two Charger Control Loop Variables

The shift of speed control variable data from bright red to dark in the region of interest corresponds to a subtle change easily missed in Figure 9. Wavy level control loop fluctuations, seen in Figures 10 through 12, appear as coincident cyclic changes in brightness and color in adjacent graphic strips in Figure 13.

Figure 14 shows both the disruption of SIC_20PV and the level control loop variability at a higher resolution time scale, sixteen hours of two minute interval data.

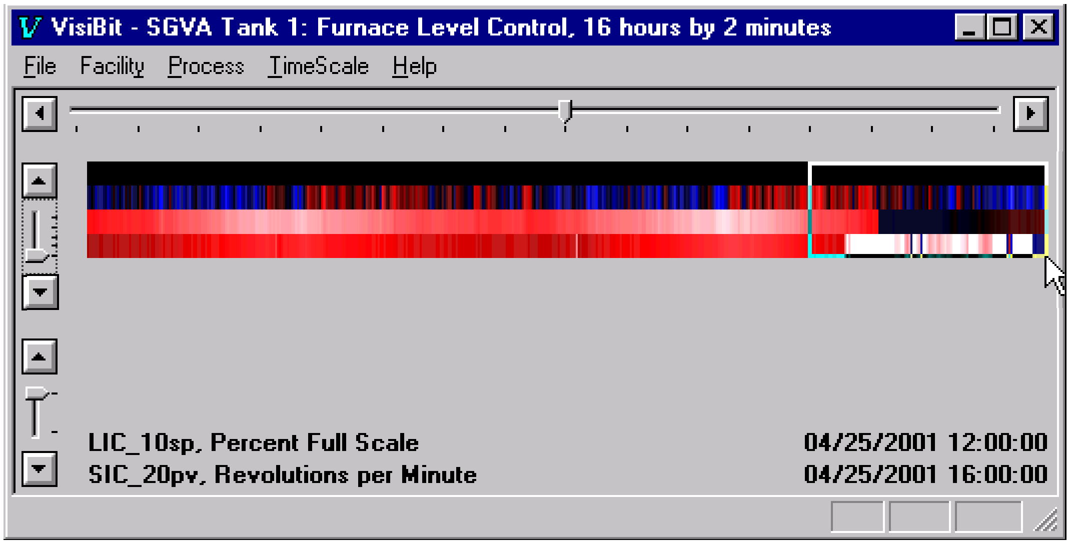

Figure 14 – Abstract Image Showing Two Level and Two Charger Control Loop Variables

CONCLUSION

Abstract presentation of large amounts of process data, regardless of the nature of the underlying data, helps even non-process savvy staff find potential for improvements that can increase company profits.

ACKNOWLEDGEMENTS

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