LAYTON GRAPHICS, INC.
Information Engineering
155 Woolco Drive - P.O. Box 6469 Marietta, GA 30065
Phone: (770) 973-4312 Fax: (800) 367-8192
Internet Address: www.layton-graphics.com

Scanning For The Nuclear Power Industry
A Case Study of Duke Power

Michael Bufkin
Technical Director
Layton Graphics, Inc

Introduction

When Duke Power decided to convert the drawing libraries for its three nuclear power plants from paper to digital, it was faced with more than the usual array of problems. In addition to issues of finding, scanning and indexing hundreds of thousands of drawings, Duke had set itself the goal of doing a formal QA of all resulting images and database records, which meant complying with the very stringent quality requirements of the Nuclear Regulatory Commission. Meeting these goals would be difficult, but there was also a requirement to provide continuous access to all the documents throughout the project, all within a one year completion schedule.

Duke recognized that achieving these goals would require the assistance of an outside contractor, as they had neither the staff, experience or equipment for such a project. They were aware however, that many of the functions needed could not be performed by a contractor, requiring as they did an intimate knowledge of Duke's drawing management system.

Thus the project presented both technical challenges and staffing challenges. As with most such projects, the real challenge was of management.

After a lengthy and thorough process of interviews and bidding, Duke selected Layton Graphics, Inc. of Marietta GA as the project vendor.

Why do it?

To understand a project, it is usually necessary to understand the reasons for doing the project. In Duke's case there were four perceived benefits to conversion from paper to digital.

The first and most visible benefit of scanning was that of quicker access to and revision of drawings. As with all organizations dependent on paper documents, access to drawings required a staff member to gain hands-on possession of a physical item, which was then either copied or revised. Generally only one person could look at the drawing at a time, and that only after going to considerable trouble. With a digital system, in theory the same drawing could be viewed simultaneously by every user on the network.

Of course, once a person had gained possession of a drawing, they had to go through a laborious procedure to update the drawing management data base. With the new system, access could be controlled through a database, and all check out and check in automatically recorded. In addition to improved drawing control, the re-indexing of all drawings in the data base would result in a tremendous improvement in the accuracy of the data base. Every single drawing in the three plants was to be scanned, indexed and QCed.

The final, and unexpected, benefit was an improvement in quality of the image provided to the users. While a black and white scan of a poor quality original is rarely as legible as the original paper, it turned out that it was usually better than the blue printed copies which had been available previously. Re-stated, users received more legible images of the original scans than they had been getting from blue prints and micro film print backs, even though the original paper itself might have been more legible than the scan. The reason for this was that the user had rarely been able to see the original, but only a copy.

These expected benefits were summarized in the basic goal of the project: To provide rapid access for all qualified users to formally QAed plant information.

The Existing Document System

Prior to conversion, Duke power organized its drawings within a database by assigning to each drawing an Electronic Record Number, usually referred to as the ERN. Each drawing revision (including multiple sheets of the same drawing) was assigned a record which contained detail information about the drawing, such as drawing number, sheet number, revision, issue date and title, plus more specific site, discipline and internal information. A typical record in this database might be

ERN	Drawing	Sheet	Rev	Issued	Title
C0001234	C-123-63	002	005	10/19/73	Foundation Plan

The documents themselves were a mixture of manually drawn originals, CAD drawn plots and vendor generated product drawings of unknown origin, all of various materials and in various states of decay. Revisions were made by several means. Good originals were scrubbed and redrawn, some were copied to sepias, washed and redrawn, and CAD files were revised and re-plotted. Except for the CAD drawings, each revision further degraded the quality of the original.

This system was perfectly serviceable for tracking and maintaining drawings so long as it was maintained. The problem was that, while the drawing database was accessed through desktop PCs, the drawings themselves where accessed by physically rummaging through a vast set of flat files, pulling the needed sheets, revising and refiling. When the revision process was completed (days, weeks, ? later) the drawings were refiled and the database updated. To err is human, to maintain a hybrid digital/paper system, divine.

The Conversion Plan

Clearly, the only way to enforce drawing tracking was to control access to the drawings through the same system that recorded drawing data. If the drawings were accessible only as digital images, access control and tracking could be enforced. The conversion to digital would also stop the slow degradation of the physical drawing media.

Getting from the hybrid system to the digital system seemed simple: scan the drawings and enter the ERN number as they were scanned. But the reality was much more complex. There were three major problems

image legibility
index accuracy
throughput

The first two of these were actually aspects of the same problem, that of meeting the quality standards established by the NRC for document accuracy. Put simply, Duke had to be sure that a drawing listed in its database was actually the drawing it was supposed to be and that it was readable. If the drawing failed either of these standards, the db record had to be identified and flagged as not certified for use.

The only practical way to meet NRC quality standards was to employ a vendor who had qualified under the Nuclear Regulatory Commission's 10 CFR 50, Appendix B "Quality Assurance Criteria for Nuclear Power Plants". This is a complex document which among other things sets forth in detail the requirements which vendors to nuclear facilities must meet in order for their products to be used without additional inspection on the part of the owner. Utilizing such a vendor would reduce the time and labor required by Duke to make the data produced by the project available to its users. Unfortunately, no such vendor was available. As a condition of the contract, Layton Graphics agreed to undergo the needed QA audits by the NRC to qualify.

While meeting the quality requirement was an issue of regulatory compliance, the throughput problem was brought on by the requirement that the drawings be available to the users in digital form within a year of startup and be available in physical form at all times during conversion.

To meet these requirements, procedures were developed to locate, prepare, scan, index, check and replace the drawings at a rate sufficient to meet the schedule.

Microfilm Scanning vs. Paper Scanning

Achieving the needed throughput rates while allowing access to the drawings was one of the most difficult aspects of the project. Drawing access required that they remain at the site. Throughput required that they be scanned, indexed and QCed at the rate of 1,500 per day. It was simply not practical to locate enough scanners, indexers and QC staff at the site to achieve this rate.

An alternative approach was to locate a single 35 mm microfilm camera at the site, film the drawings and ship the film to a remote site for completion. This technique was tested thoroughly to ensure that the needed image quality could be achieved. After testing, it was decided that the microfilm approach did not give sufficient accuracy for E size drawings with text sizes less than 3/16”. Consequently a paper scanner was placed on sight for scanning these drawings, which represented about 10% of the total.

All scanning equipment for the project was provided by Intergraph, in the form of two Photmatrix V400 aperture card scanners and one Anatech Eagle SLI 3840 Plus paper scanner. The raster file format used was Intergraph CIT.

Preparing The Documents

For ease of handling, it was decided to process drawings in lots of 250. The old Duke db was used to produce lists of 250 similar drawings, which should have been located together and have similar size and condition. These drawings were then pulled and checked to verify that the ERN number on the drawing matched the list. All drawing preparation was performed by a team of Duke Power staff.

Filming

Filming of drawings was done to ANSI/AIIM standard MS 32, with one exception. A special jig was used to precisely locate the lower left corner of the drawing on the camera bed and to align the horizontal axis of the drawing to the camera bed. This position and alignment was calibrated to that of the aperture card scanner to be used in scanning the drawings so that the images would be consistently located for later cropping and deskewing.

Each day, film was shipped over night to Marietta, GA for processing and quality checking. The film was first developed, then checked for density and resolution, using resolution targets filmed at the beginning and end of each roll. A minimum resolution of 6.3 line pairs per millimeter was required and a density range of 0.90 - 1.20. In addition, 10% of the images in each lot were visually inspected for general quality.

In the event that a lot failed any of the initial quality tests, the site was instructed to re-film that lot. Lots that passed were returned to Duke staff for refiling. The goal was to keep drawings out of the filing area for no more than 3 days. In the event that a drawing was needed during this period, its lot number could be located with the Duke db, the drawing pulled from the lot and copied, and the copy used for scanning.

Indexing

Indexing of the drawings was the most challenging aspect of the project. The difficulty was caused by the fact that the drawing number in the db was not an exact match to the number printed on the drawing. The db frequently contained leading zeros, special characters and leading and trailing spaces not contained on the title block. For example, a database entry for a drawing number listed as

1200.000117002 might be in the title block as 1200-117-2

or 0436-E-GS-004 might be written as 0 -436 E GS-4.

Duke's requirement was that if a reasonable match existed between the title block and the db, then the db record was to be accepted as correct. If not, then the drawing was to be flagged as Not Certified.

Using human operators to compare the two numbers was deemed impractical, due to the natural tendency to recognize two similar strings as the same. What was needed was a fuzzy logic system which would compare the two strings in software and decide if a reasonable match existed. Constructing and maintaining this software became the major challenge of the project.

In practice the number test was done by key entering the drawing number from the title block (along with revision and date). The software then compared this list with the Duke db and generated a list of drawing numbers which failed the reasonable match test. These were then reviewed by indexers to determine whether the software should be overridden, a typo corrected or the db entry marked as Not Certified.

When indexing was complete, the index was used to punch key information on aperture cards and the film mounted in the cards for scanning.

Scanning and Image Quality Checking

If indexing was the most difficult aspect of the project, scanning was among the simplest. The lotting of drawings created batches of 250 aperture cards of similar size and condition, so that scanner setup was minimized. The cards were first scanned, then each image was inspected for legibility. Completely legible images were cropped, de-skewed and de-speckled. Cards which produced images failing the test were pulled for visual inspection. If the original document was found to be illegible, the image was marked as Not Certified, bad original. If the original was legible, the card was re-scanned until a legible image was obtained.

When each lot was complete, a final index list was created, indicating the image file name, its drawing number, revision and revision date and a status. Status was either

Certified -suitable for access by all users
Not certified - access restricted

In addition, for drawings with status Not Certified, a reason for the status was provided. These reasons were generated pragmatically, that is, only certain modes of failure were acceptable. Among these were:

drawing number incorrect in db
revision number incorrect in db
duplicate drawing number in db
duplicate ERN number in db
drawing illegible

These status were used by Duke for corrections and later re-classification from Not Certified to Certified.

Quality Assurance

The production of the scanned images, indexes and status reports was a complex operation involving both software and human judgement. As such, it was subject to the possibility of error. The project goal was to limit the occurrence of these errors to some predictable, small number. This was accomplished in three ways. The first was to ensure that the process used to produce the work was sound and if followed correctly would yield acceptable results. The second was to document that the process was actually followed during production. The third was to inspect at random a sufficiently large sample of the product to detect any patterns of poor work and investigate the causes of the failure. The cause would have to be either in the design of the process or its execution.

The design of the process has been described above. Duke personnel participated in the development of these processes by first specifying in detail the product to be produced, and second, by reviewing with Layton Graphics staff the actual methods to be used, assuring themselves that the proposed methodology was sound.

To insure that agreed upon processes were followed, Duke required that activity logs be maintained at each major process step. These included equipment calibration logs, results of quality inspections, signing off of various activities as completed, and tracking of each drawing by lot. In the event of a quality failure of a particular drawing, all drawings in the same lot could be inspected more thoroughly to determine if the problem was unique or common to all drawings in the lot.

While design of the procedures and the documenting that they are correctly followed are in reality the key to quality assurance, there is no substitute for the human eye in establishing that quality levels are being achieved. For this reason, Duke chose to inspect a random sample of the images and index records as a final check. The procedure was to select at random 33 images and their index records from each batch of 250. Each image was carefully inspected for legibility and the index records were inspected for correctness. If three or more non-acceptable items were found, the lot was rejected and returned to Layton Graphics for re-verification of the entire lot. LGI was then required to determine the cause of the error and report to Duke the steps to be taken to prevent the recurrence of the same errors.

Implementation of the Conversion

As of Sept 1, 1997, Duke Power's Electronic Library is on line to users, with about 75% of all plant drawings available. The library is comprised of about 240,000 drawings for the McGuire, Oconee and Catawba nuclear power stations. Initial user acceptance has been very positive, with most users experiencing the expected benefits.

The greatest single source of dissatisfaction was with a series of civil drawings from which LGI was unable to obtain legible scans. These were primarily mylar sheets which had blue shading on the back of the sheet to indicate poured concrete. After discussions with Anatech, it was discovered that the lamps used in the scanners did not return blue light. A fix was implemented and the drawings rescanned with satisfactory results.

The project was large and complex, the expectations high and the results satisfying to all involved. It was a great project.