THE American Surveyor

A FOOT IN THE PAST… AN EYE TO THE FUTURE

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Applying 3-D Laser Scanning to a Boiler Plant Replacement Project

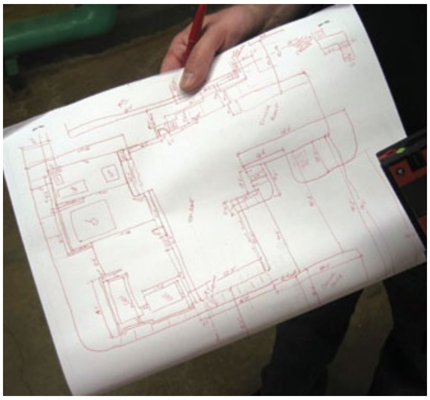
The engineers of Sebesta Blomberg & Associates in Roseville, Minnesota faced a daunting task in documenting existing conditions within the two central boiler plants at North Carolina State University in Raleigh. The Yarbrough facility, built in 1937, contains three large boilers and an intricate network of catwalks, pipes, conduit, ductwork and structural steel supporting the boilers and the auxiliary equipment. Documentation of both the original construction and subsequent renovations put into place since original construction was scant or virtually nonexistent. The Cates plant, constructed in the 1970s, had fairly complete record drawings from which to work, but these were hand-drawn and only photocopies were available. This plant has one large boiler with auxiliary equipment and includes a chilled water facility with cooling towers, pumps and associated piping.

It was required that both of these facilities be completely documented with a high degree of accuracy to facilitate a detailed demolition estimate and to develop a phasing plan for equipment shut-down and replacement. Copies of the original drawings for both plants were sketchy and difficult to read due to the print quality. Electronic files (CAD) were nonexistent, making the task of developing existing condition drawings from the owner-provided documentation extremely difficult. The work at both plants involves extensive renovation. The Cates plant is to undergo a complete removal of equipment and demolition of a portion of the building. The Yarbrough plant will be gutted to house new boiler equipment

>> By Drew C. Bjorklund, AIA, Ed Oliveras, and Damian Lallathin

The right tool for the job... McKim & Creed utilizes high-speed phase-shift laser scanners for industrial and indoor projects. Survey party chief Dennis Batzel operates the scanner in the basement level of the Cates Boiler Plant.

Field measurement requires measuring spaces by hand using a tape measure. Engineers with Sebesta Blomberg estimated that this method would provide good to marginal accuracy.



Using field measurements, engineers develop hand drawings. The data from the drawings is put into CAD to create as-built models.

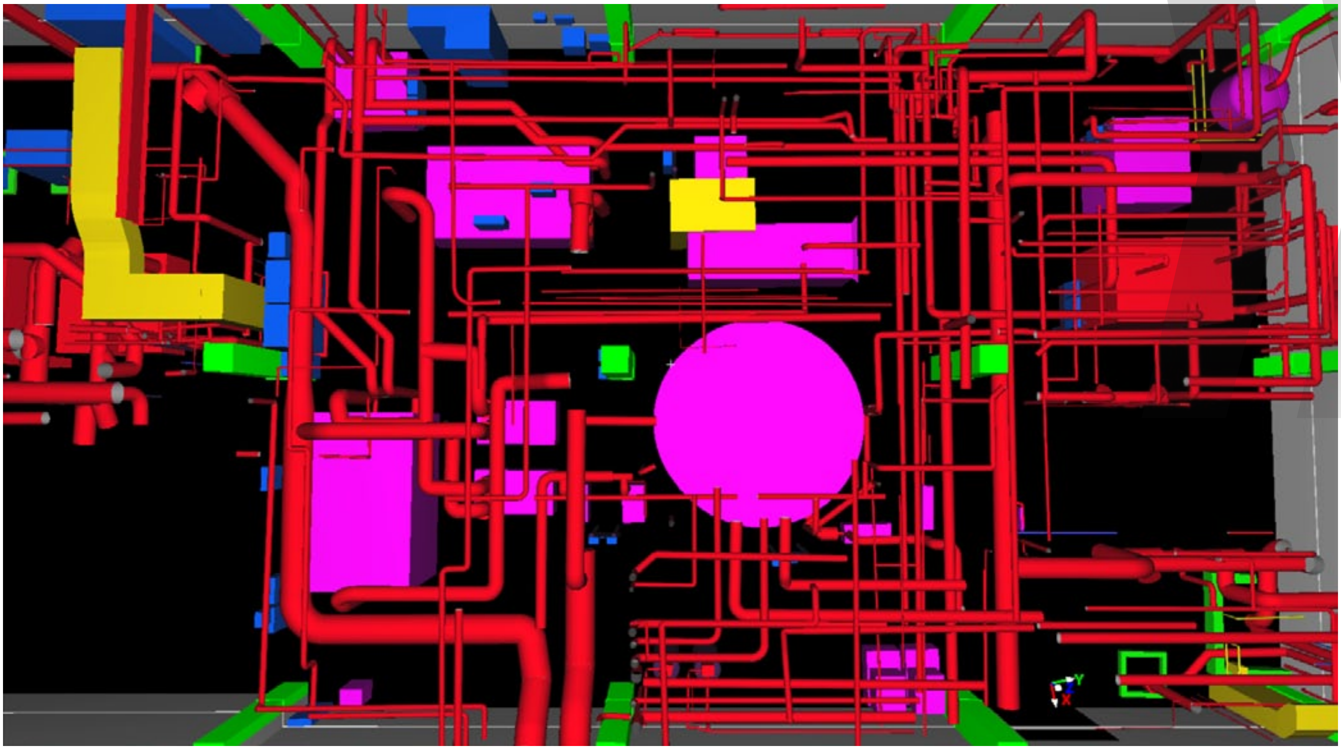
and to restore the exterior shell of the facility through selective demolition and rehabilitation.

Existing condition documentation and new construction design work were time-critical to ensure timely submittals to the owner and state agencies. In addition to the effort to replace the equipment within the two facilities was the importance of preserving the shell of the Yarbrough facility, which is of historical value to the university itself. The architecture of Yarbrough is recognizable by its brick stack and the delicate profile steel-sash windows, indicative of early 1900s-style industrial architecture.

The engineering team developed two scenarios to accomplish the task of documentation: one was to send a team of engineers and technicians to field measure the spaces and the elements within each of these facilities, and the other was to have the spaces documented using phase-based 3-D scanning technology.

The field-measurement approach would require a team of four engineers, one architect and two CAD technicians to work on-site for five days, measuring by hand with electronic and standard tape measures. Anticipated effort for the on-site documentation was 35 staff-days. The expected accuracy of the documentation of the various components was determined as follows: major equipment and structural components–good; minor equipment and ancillary structural components–fair; piping and conduit–marginal. Once the field notes were compiled, the documentation would be converted to 2-D CAD files. The field measurement and CAD conversion process was anticipated to take four to five weeks. Anticipated in-house CAD effort was projected to be 90 staff-days, including coordination sessions with the field engineers.

Scenario two, developed in concert with McKim & Creed (Raleigh, NC), would be to scan the spaces using 3-D laser scanning technology and develop a 3-D model, which could be incorporated into BIM software to create CAD files. All equipment and structural components would be separated onto their proper layers, allowing for 3-D views as well as plan and sectional views. One surveyor, observed by one CAD technician and one estimator, would scan both facilities in five days. One full-time and one part-time modeler would complete the in-house documentation in four to six weeks. The resulting 3-D model would contain a vast amount of information of piping and structural systems, with a resolution showing individual flanges on piping and truss-work steel supports. Accuracy would be (+/-) 1/8 inch, and the cost would be approximately half of the field-measurement approach. In comparison to the field-measured approach, the



A screen capture of a cutaway of the 3-D model shows the complexity of piping networks and structural components that comprise only the basement level. This room took only 3-4 hours to scan using a phase scanner.

actual time in the field was measured as 15 staff-days and the 3-D modeling and CAD production was 45 staff-days.

Assessment

Analysis of both scenarios led the design team to choose the scan technology offered by McKim & Creed. The benefits of 3-D scanning provided the design team of Sebesta Blomberg with a superior package of demolition documents. Key features leading to the decision were:

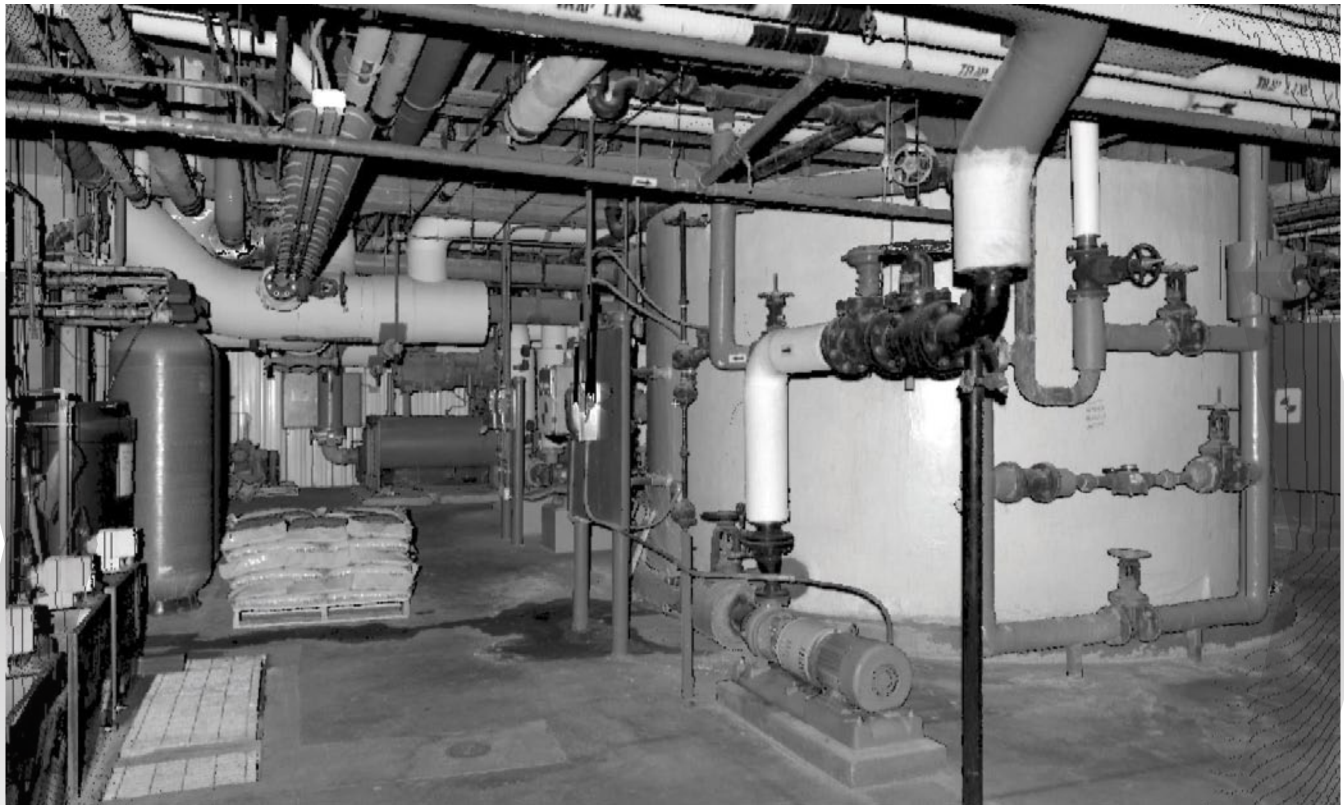
- This method required minor intrusion on plant and personnel operations during the scanning procedure.
- On-site effort was minimized (one CAD technician and one estimator observed the scanning operations).
- Accuracy of the scan files was (+/-) 1/8 inch.
- Equipment, conduit, pipes, ductwork, catwalks and structure would all be separated onto layers in accordance with National CAD Standards.
- Files allowed "walkthrough" views of the spaces at any level.
- Plan and section cuts, as well as 3-D views, could be made at any point within the spaces.
- In-house documentation time was reduced to one-half the planned effort.
- Technology provided photo-quality files, walkthrough views and CAD-file views.
- Files facilitated demolition drawings as well as new equipment and spatial restructuring documentation.
- Scanning technology helped reduce the incidence of unforeseen conditions, facilitating more accurate take-offs and estimating.
- The scanning documentation served to support the bidders' development of the scope of work, resulting in reduced contingencies in the bid proposals.
- Documentation from scanning each space will facilitate identification of, and accounting for elements with recycling content for LEED certification.
- Overall scanning effort shaved 57% off of the originally planned effort of on-site documentation.
- Construction cost estimating proved to be accurate, and project phasing plans were easily facilitated by the versatility of the files received from McKim & Creed.

Process/technology

Laser scanning is a high-speed, non-contact 3-D measurement technology that can be used to create as-built documentation. For this project, laser scans captured existing conditions of the interiors of both central boiler plants and all adjoining rooms.

Each scan creates an image of all it can see from that vantage point; essentially, "If you can see it, we can scan it." Point clouds, which are high-resolution 3-D images of the scene from each scanner's perspective view, are the output of the scans. With the point cloud information, McKim & Creed prepared 3-D CAD models and created fly-through animations using specialized software. The final deliverable was in CAD format and required no retraining for Sebesta Blomberg or specialized software to purchase.

In addition to the 3-D models, an online "TruView" database was created for Sebesta engineers. Leica TruView is a free Internet Explorer plug-in. It allows people to view–from the scanner's perspective–everything that was scanned from a single location, similar to a virtual tour of a hotel or other facility. With TruView, each pixel is a 3-D measurement, and millions of these pixels make



Shown in TruView format, this image is scalable (within the electronic file) and notations can be placed on the file for reference. The image is grayscale, as the scanner records the reflectivity of the object the laser touches. Different surfaces, paints and materials all reflect differently. The system also works at night; the laser emits its own light and doesn't require ambient light. Color scans are accomplished through the use of an external digital camera that is overlaid to the scan data.

up a single scan "image." The user can make basic measurements, markups and notes, and e-mail that information to other colleagues collaborating on the project. The TruView feature provides users–even those who are not adept at using or reading drawing files–with a photo-quality, scalable image of spaces and elements within those spaces.

Owner's Perspective

The owner, being intimately familiar with the intricacies of each plant, did not take for granted the magnitude of the task of documenting the existing conditions. Lacking documentation on successive equipment additions and replacements had been an issue for many years. When the scanning option was presented as a means to document the as-built condition, the owner was pleased to see that the design team made this decision [scanning technology over field measuring] without owner input.

The expectation was that the documents that were developed from the scanning data would be clear and accurate, which would enhance the accuracy of the bid proposals and facilitate demolition and reconstruction scheduling. From the bids received, the contingencies were able to be pared-down since the files provided to the bidders were able to clearly delineate virtually all components within the spaces.

The owner watched the scanning process as it progressed and was able to see a portion of the work that had been scanned while the crew was on-site. From what they saw at that time, and also the resulting bid documentation developed by the design team, the owner concluded that they would be very eager to employ scanning technology, as budgets allow, to future projects where as-built documentation is not on record.

Lessons Learned

The exercise of developing the two scenarios of documenting the spaces (field measurement versus 3-D scanning) proved to be instructive in understanding the magnitude of the work involved, as well as what could be expected in the output. The decision to employ 3-D scanning proved that this technology was the most productive use of time and talent, while also providing accurate and versatile drawing files for the owner's use. Data documented in the 3-D scanning process serves as a historical record of field conditions with the added benefit of being the basis for future design work.

For the design team, the files provided through the scans allowed complete flexibility to develop plans, sections, elevations and perspective views to better understand and document the demolition scope of work. The owner was provided not only with existing condition files, but also with files for new work to be performed in the contract.

Drew Bjorklund participated on the Sebesta Blomberg project team. He is an architectural consultant in Minnesota. **Ed Oliveras** is Director of 3D Imaging and Applied Metrology for McKim & Creed and oversaw the laser scanning portion of this project. **Damian Lallathin** is a project manager with North Carolina State University.