Photo: NRC

The Davis-Besse nuclear power plant, with Lake Erie in the background

Davis-Besse's 20th outage: The "Drive For 25"

As a result of detailed planning, improved communications, and a united effort, Davis-Besse and its contractors achieved their 25-day outage goal—a plant record.

By Mark Kanz

Business as usual" could no longer be the standard at FirstEnergy's Davis-Besse nuclear power plant. The 908-MWe pressurized water reactor in northwest Ohio, about 25 miles east of Toledo near Oak Harbor, had performed successful refueling and maintenance outages in the past, achieving its outage goals, but market forces required the next set of Davis-Besse outage goals to be much more challenging than in the past. The plant's 20th refueling outage in the spring of 2018 would be planned for 25 days—or less. Davis-Besse's "Drive For 25" was under way.

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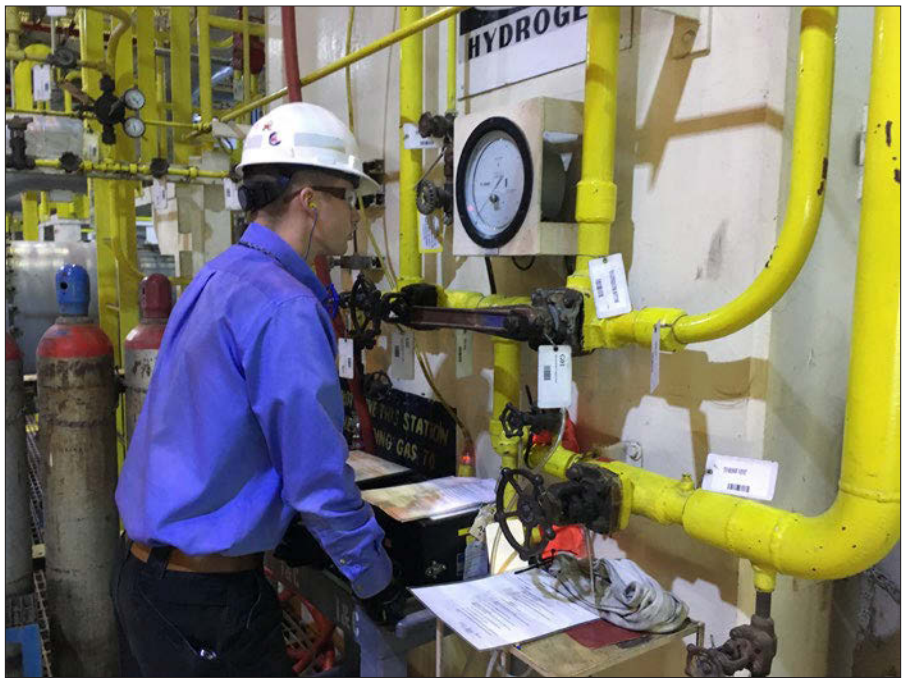
All photos on pp. 44 through 56 are from FirstEnergy, except for the exterior shot (above), which is from the NRC.

Members of the Outage Management team gather at the conference table in the Outage Control Center. From left, Alvin Dawson, John Cunnings, Trent Henline, Brian Matty, Lucas Ring, Bob Howard, and Pat McCloskey.

When Davis-Besse closed the breaker on its previous outage, all major projects required for a 20-year life extension had been completed. The station had previously replaced the reactor vessel head, steam generators, reactor coolant pump motors, and several other components. Major license renewal work was done. Modifications required to implement its FLEX strategies—ordered by the Nuclear Regulatory Commission after the Fukushima Daiichi accident in 2011—were complete, and many other station improvement projects were checked off the "to-do" list. The station objectively was in the best material condition it had been in since its initial construction, and the plant was ready for the prolonged operational life granted by a 20-year license renewal from the NRC—only it wouldn't be that simple.

Market forces were not the only obstacle facing the Davis-Besse team. Three months before the outage was to begin, FirstEnergy made a decision to spin off FirstEnergy Solutions and FirstEnergy Nuclear Operating Company (FENOC) into stand-alone companies. Rumors began to circulate about the company and the plant's future. "When we started planning this outage two years ago," said Doug Huey, performance improvement and day shift outage director, "economics was a major factor, but it became essential that we achieve our outage goals."

With economic uncertainty surrounding the future of the plant, employees were encouraged to focus on the things they could control. "The only thing we can control is safe, error-free, reliable generation," Site Vice President Mark Bezilla told outage workers.



Reactor Operator Chris Hotz monitors plant conditions during shutdown prior to the 2018 spring outage.

The Outage Management team realized that it couldn't do what it had done in the past because it wouldn't achieve the desired result. Employees were challenged to think creatively and to a different level of detail. Contingency plans were also a major focus. The organizational challenge was, "What's the most likely thing that can go wrong and are we prepared for it?"

The outage team was tasked with leading an effort to improve every aspect of Davis-Besse's outage performance. The first challenge was to determine where the greatest gains could be achieved. Davis-Besse outages are broken down into 10 work windows. "We looked at the best times in the industry for Babcock & Wilcox–designed units, how those outage windows were executed, and our previous best performances," said Outage Manager Bob Howard. "The other two FENOC stations—Perry and Beaver Valley—were also leveraged for improvements."

Howard's team needed to find room for nearly 1,250 work orders and more than 7,500 specific activities, from surveillances to preventive and corrective work to a handful of project work orders. He wanted

Crews wait outside the containment hatch to begin inspections at the start of the outage. A 360-degree camera with a fisheye lens was used to take the photo.

Members of the air-operated valve (AOV) maintenance team conduct work on a valve on the turbine deck. The AOV team conducted overhauls, calibrations, packing consolidations and adjustments, and diagnostic testing on 39 different valves during the outage.

control room operators to be able to focus on running the plant without distractions post-outage. Some of the major work scope items included condensate polisher tube replacements, circulating water pipe repairs, steam generator inspections, and the main transformer low-voltage bushing replacements.

"We wanted to make sure we were going after the right work to address plant reliability issues, health report concerns, and operational impacts," Howard noted. One of the biggest challenges was convincing employees that they were capable of executing an outage in 25 days or less because the plant's previous best was almost two weeks longer. "Station personnel had a positive attitude about 1R20 [Unit 1 refueling outage no. 20], but they didn't fully understand the outage improvement initiatives early on," he said. "Supervisors were charged with explaining the 'why' behind the 'what' in the outage schedule."

Despite a lot of moving parts and emergent issues in the first few days of the outage, the Operations department manipulated the plant flawlessly and without incident. "Crews went through a great deal of training, and it really paid off," said Dan Hartnett, assistant operations manager. Part of the secret to success was the just-in-time training the Operations staff received leading up to the outage. Plant operators had the opportunity to practice crucial plant maneuvers in the simulator for several weeks before making the moves for real. "We established plant conditions in the simulator, and it's exactly what they were seeing in the control room," Hartnett said.

Communication and discovery

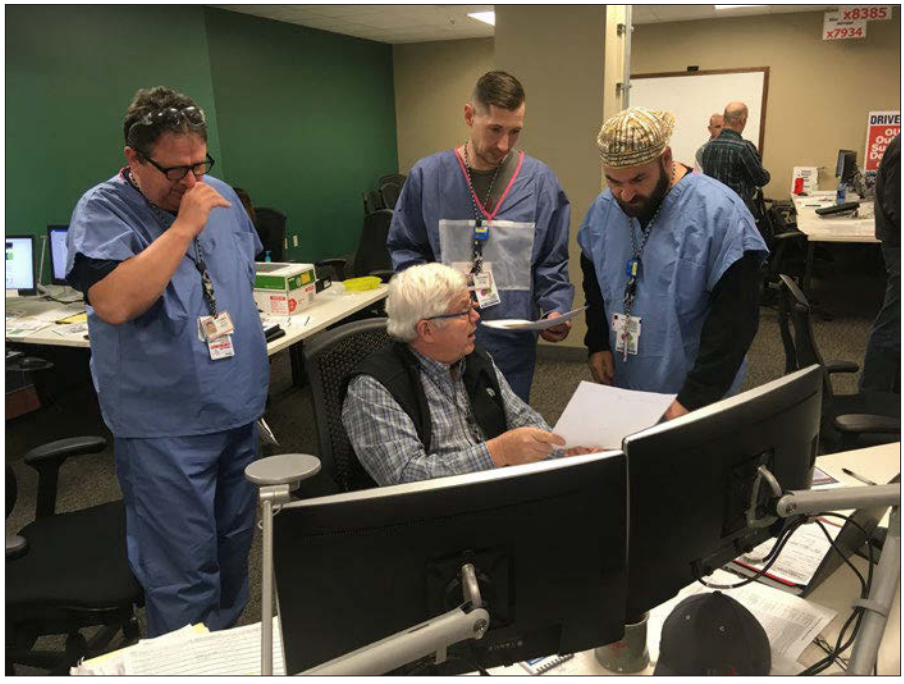
An industry best practice that Davis-Besse borrowed from the Perry plant was the creation of a Joint Work Execution Center (JWEC). "The purpose of the JWEC is to take the three-day schedule and track what the major work groups are doing, including start and stop times," said JWEC Team Lead Chris Chisholm. "We control and track all maintenance activities." The Outage Control Center remains responsible for driving the "big-ticket items" in the outage, focusing on critical path tasks and the 24-hour look ahead.

JWEC staff included representatives from Maintenance, Operations, and Radiation Protection working side by side to improve the handoffs between groups, enhance communication, and ultimately improve schedule adherence by streamlining work, dealing with minor issues, and eliminating delays in the schedule. Equipment clearance orders and Radiation Protection briefings had delayed outage work in the past. The JWEC gave Maintenance direct contact with the two groups that control those areas, providing a clear path for success.

The JWEC's focus was on secondary system restoration, taking the burden off the Operations staff and allowing them to focus on the primary system. "We've seen it work well at top-performing plants and felt it could be the key to trimming a week and a half or more off the typical Davis-Besse outage duration," Chisholm said.

The first 100 hours of every outage are important for discovery, as issues arise and must be dealt with. Some are anticipated and others are not, but they are all emergent and can test an unprepared organization. "We schedule outage activities to get possible discovery items on the table as soon as possible," Howard said.

The Engineering department took great care in laying out the in-service inspection schedule and added some additional manpower to accommodate the compressed outage schedule. "We highlighted some of our discovery items, the high-risk exams that would cause a delay in the outage if an issue were discovered," said Alan Scheanwald, team lead. They conducted



In the Outage Control Center, engineer Dennis Schreiner consults with valve experts on an emergent equipment issue.

The Steam Generator team from BWXT is congratulated by Assistant Dayshift Outage Director Trent Henline, at far right. Team members are, from left, Ted Mitchell, Jimmy Morgan, John O'Neil, and David Howard, who along with the rest of their team set a record for steam generator eddy current inspections safely and under dose estimates.

visual inspections, walked down containment, and tried to identify any problem areas as early as possible.

Issues identified in the first few days of the outage included a valve socket weld leak, malfunctions on two cranes, and a broken throttle on a diesel fire pump. "These types of mechanical issues are going to happen," said Ken Byrd, Engineering director and night shift outage director. "We just turned these challenges into one more work activity, incorporated them into the outage work schedule, and got them done like every other outage activity. The focus was to get out of the analysis phase and get to work to resolving them."

SG team sets record

The consensus opinion at Davis-Besse following steam generator inspection and maintenance activities during 1R19 was, "We can't keep doing what we're doing and expect different results." Numerous challenges caused delays in completing steam generator primary work on time during past outages. The plant had taken a full week to perform steam generator tube inspections, while industry peers were regularly completing similar inspections in about three days.

BWX Technologies (BWXT), the original equipment manufacturer for the plant's current once-through steam generators, was brought in for the outage for the first time. This was viewed as an opportunity to start with a clean slate and dramatically change how steam generator maintenance and inspection activities were handled at Davis-Besse.

BWXT had several years of experience in performing successful outages at plants similar to Davis-Besse, so plant representatives did some benchmarking to see how the vendor coordinated work processes with plant personnel. The lessons learned were incorporated into Davis-Besse's pre-outage planning process, culminating in a three-day meeting with representatives from all affected organizations. An "outage project script" was developed that listed the sequence of events to a far greater level of detail than the outage schedule, handoffs, and the required coordination across the entire work scope. All work groups were on the same page, even during the preliminary equipment mobilization stage.

All of the preparation and planning paid off, as the first outage with BWXT's participation at Davis-Besse was record-setting. The team set an industry record for B&W full-scope steam generator eddy current testing, coming in at just under 62 hours. In addition, the BWXT crew used less than half of the radiation dose it had originally budgeted. All activities were completed ahead of schedule, allowing the rest of the outage to proceed without interruption.

Numerous post-outage lessons learned were documented and will be rolled into planning for the next inspection outage as the BWXT team looks to break its own record. BWXT's steam generator team made a great first impression on Davis-Besse. "They were a first-time vendor here, and they knocked it out of the park," said Trent Henline, site projects manager.

Other scheduled work

Electrical Maintenance Superintendent Brian Walleman's team faced the challenge of fitting 50 pounds of work into a 25-pound bag. "We had multiple motor control centers [MCC] to service, and we had a very narrow window to fit them in," Walleman said.

The MCC team got creative. Environmental qualification testing is required every eight years. This outage required that all 105 MCC enclosures—known as buckets, or cubicles—be tested, a process that had taken a week last time. "Right at the start, we asked which cubicles could be tested on line," Walleman said. They found that the answer was 40. Then they looked for additional efficiency gains and formulated an effective plan for the other 65 cubicles. "We laid these out physically to maximize resource capabilities," he said. "It strategically kept us from bumping into each other or trying to work in the same location at the same time."

The MCC team also looked at upcoming preventive maintenance tasks and incorporated them into the work scope. "We prepared at a level that we've never done before, and the execution was flawless," Walleman proudly said of his team.

A Conco employee conducts feedwater eddy current testing during the outage.

Workers prepare to reinstall the cover on one of the plant feedwater heaters during the outage.

■ Work scheduled on a low-pressure feedwater heater was not only planned to bring this piece of equipment back to life, but also to restore plant efficiency. A water leak in the heater had caused plant operators to bypass it, resulting in a 7-MW production loss during the operating cycle.

"In the past, we would just plug tubes that were leaking," said Project Manager Mark Wymer. "If it got too bad, we'd have to retube the entire heater, and that's a big deal."

A new process brought to Davis-Besse by Framatome (formerly Areva) had technicians identify problem tubes through eddy current testing and then insert sleeves in them. "The sleeves are then expanded for a tight fit," Wymer said. "These eliminate tube flaws and extend the life of the feedwater heaters well into the future." In this effort, several tubes that had been plugged for years were recovered.

■ Davis-Besse's cooling tower suffered the effects of many brutal winters along the shores of Lake Erie. Ice had been falling from the tower and onto the circulating water piping below for four decades, and this problem needed to be corrected.

Project Manager Stevie Darr developed a two-phase plan to protect and refurbish the two concrete pipes that each carry 225,000 gallons of water from the plant to the tower every minute. The first step involved fabricating a rubber and metal

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Technicians apply carbon fiber wrap to the inside of one of the two 108-inch circulating water pipes near the Davis-Besse cooling tower to help mitigate years of damage caused by falling snow and ice.

Project Manager Mark Wymer uncovers a tube bundle staged for replacement in one of the Davis-Besse condensate polishers.

One activity not accounted for in the original outage scope was cleaning and refurbishing the bolts that hold the condensate polishers together. More than 400 bolts had to be blasted and cleaned, and any burrs or irregularities removed. Creative scheduling got this key task included in the outage work.

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bumper to fit over pipe sections that are aboveground. The second phase had crews from Structural Technologies apply a carbon fiber wrap to the inside of the 108-inch-diameter pipes. "It's essentially a new pipe," Darr said.

■ It had been more than 15 years since Davis-Besse's condensate polishers got the kind of attention they received during 1R20. Polishers function like a water softener to filter water and limit the wear on key pieces of plant equipment. As the outage was being planned, questions were raised as to whether work on all four polishers could fit into a 25-day schedule.

"We bought two new frames and tubed them before the outage," Wymer said. "We removed the first two tube bundles and replaced them with the new ones." Then, the two bundles that were removed were refurbished and put into the last two polishers. Maintaining the secondary water chemistry at optimum levels helps ensure the long-term reliability of plant components.

■ Another example of a long-term investment made in the plant and its equipment was the main transformer low-voltage bushing replacement. Six new bushings installed in the outage will have a longer life (20 years) than the previous ones and will perform better under the extreme heat conditions in which they need to operate.

While the transformer was disassembled, a full battery of tests was conducted to ensure its long-term viability and to improve its health. Focused project challenges resulted in the completion of this work in less than nine days, compared to a previous best of 13 days. "The transformer is now in really good shape," said Jim Whitwright, project manager, upon completion of the work.

■ Davis-Besse had 100 integrated control system (ICS) circuit cards in need of replacement grommets at the testing jacks, but the grommets are no longer manufactured for sale. As a result, the plant turned to FENOC's BETA Laboratory to help find a solution. In partnership with Pennsylvania State University, BETA Lab created updated ICS modules using 3-D printing technology.

"Purchasing reverse-engineered cards is costly, averaging $6,800 per card," said Mike Yeager, director of technical and lab services at BETA Laboratory. "We created the grommets in-house at a fraction of the cost. More than $500,000 in savings was achieved."

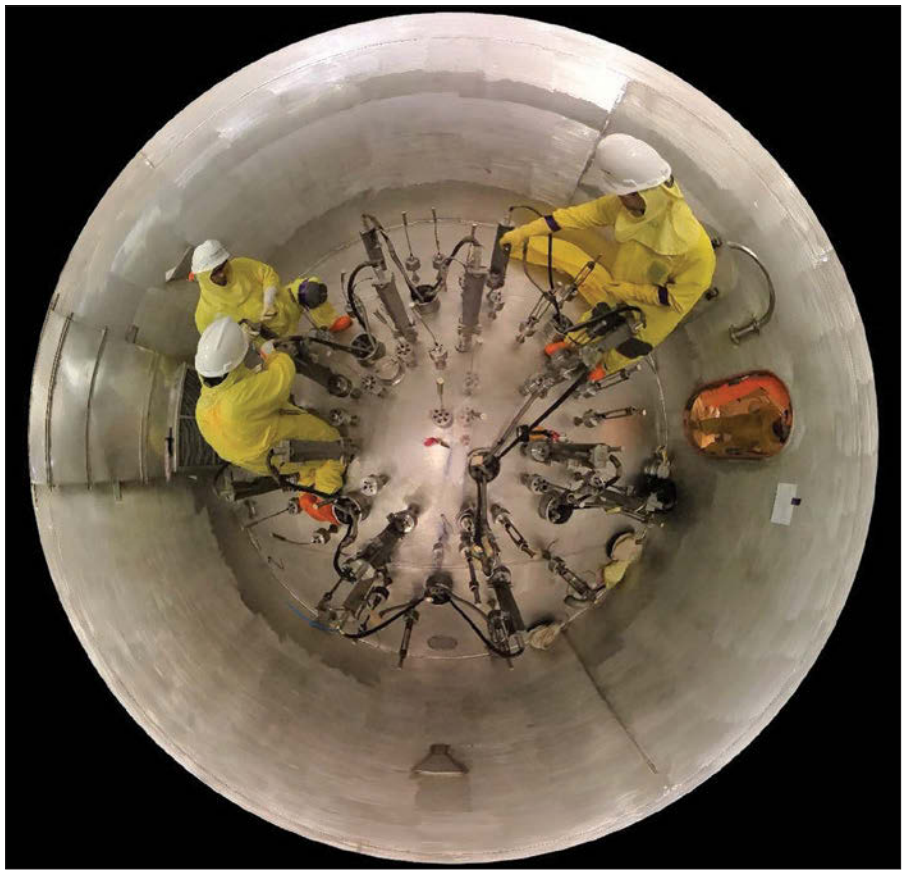
Penn State students gained experience from working on a real-life challenge for a large company, and in return the company benefited from their skills and hard work, as well as the university's institutional knowledge and resources. BETA Lab has already used 3-D printing technology for other applications within the company.

■ The Reactor Engineering group knew that it needed to do its part if the plant was to complete 1R20 in record time. Reactor engineer Shane Rafferty was determined to better the time needed to verify the reactor core, an activity that previously took an entire day and delayed key work required to bring the unit back on line. He benchmarked other plants that use a similar system and trained other staff members on the use of the Newton core verification system. The job was completed in a third of the usual time, helping to push the outage closer to completion.

Involving student interns

Davis-Besse believes in fully immersing its Engineering student interns in outage work. Quinton LeSage, a mechanical engineering student from the University of Wisconsin at Milwaukee, was a boric acid corrosion control (BACC) inspector during the outage. He used a 360-degree camera to create a new virtual tour of the Davis-Besse containment. "I had seen some 360-degree work on the Internet, and it sounded like a cool project," he said. "Pretty much anytime I went out for a BACC inspection, I had that camera with me."

LeSage compiled almost 275 different views of the containment with a dual fisheye lens camera on a tripod. The actual photo takes less than three seconds, pro-



This view inside Davis-Besse's incore tank was taken using a fisheye lens on a 360-degree camera. Workers are making final preparations for the plant's restart.

ducing a view in all directions. The camera combines the views of the two lenses into a single image. Maps of the four main elevations of containment have been posted on the plant's SharePoint site, with dots linked to the panoramic photo shot at that spot. Clicking on the dot opens the photo in an Internet browser. Employees can click, hold, and drag the mouse on the photo to look up, down, right, and left and all around the area.

The virtual tour will increase job safety and efficiency. Workers are better prepared for entry into infrequently accessed spaces, which allows them to work more safely and to complete tasks in less time. Because the photos are plotted on a map, workers can see how to reach the work area and view possible impediments. Radiation Protection staff have used it to show possible problem spots and help workers see exactly what they will be dealing with in the field.

In July, following the outage, an entry into containment was required for online maintenance activities, and the virtual tour proved to be an invaluable asset. Maintenance personnel were able to fully immerse themselves in the work environment prior to doing the actual work. The result was more thorough planning and efficient conduct of the maintenance, saving both radiation exposure and overall cost.

LeSage acknowledged that the nuclear industry is currently going through "a rough patch." However, he added, "These plants are going to be around for years to come regardless, and I want to be a part of the industry." He is thankful for the lessons he learned. "If I gain experience now, I can be ready for a nuclear industry revival."

Plant electricians rack-in the exciter field breaker as Davis-Besse prepares to return to service following its 1R20 outage.

Reflections on 1R20

The "Drive For 25" mission was accomplished with more than nine hours to spare. The official time was 24 days, 14 hours, and 52 minutes. Many plant improvements were completed in three-and-a-half weeks—from March 3 to 27—and, most important, the performance of the outage was safe and event-free. Although the outage got off to a rather inauspicious start with the malfunction of both containment cranes and some issues with fuel handling equipment, the site rallied around those problems and figured out solutions. "We started 18 hours in the hole on day one, and we clawed that back," Huey noted. "I think the staff started to see that this [25-day outage] was possible."

Besides making the duration milestone, a number of other goals were achieved. The plant finished significantly under budget and came in 5.7 rem under its radiation exposure budget. There were no Occupational Safety and Health Administration recordable injuries, no environmental exceedances, no changes in shutdown defense-in-depth, and no site clock resets. The plant has run at 100 percent power since the breaker closed on the outage, further proving that the right work was done and was done correctly. All of these improvements have given the operators a quality plant to run.

A substantial amount of time was spent planning the 1R20 outage and selecting the projects that would provide the biggest benefit to the plant. Barry Blair, general plant manager, credited candid work readiness discussions during Outage Fridays for aiding the process. "We built in a lot of contingencies and held a lot of challenge meetings," he said. "We spent a lot of time digging deep into the schedules."

It worked, as the Davis-Besse team set station best-ever times in six of the 10 outage work windows. Blair's assessment is that pre-outage preparation and emergent issue management made the difference. As planning for 1R21 begins to hit its stride, the Outage Management team is focused on the four windows that did not meet expectations. "There's still room for improvement," he noted. "I think we left some things on the table, but in no way should that diminish the accomplishments of our team."

In previous outages, operators would find themselves trying to start the secondary and primary systems at the same time. The outage team held firm to its schedule, and there was no overlap this time around.

Looking to the future

With the plant arguably in the best material condition it has been in for many years, Davis-Besse now finds itself in a unique situation. While plans for the next outage are well under way, a decommissioning team has also been formed. Just after 1R20 concluded, employees' fears were realized as FirstEnergy Solutions announced plans to deactivate its nuclear

A General Electric technician cleans parts as his group begins to reassemble the Davis-Besse turbine.

fleet unless some type of legislative relief from a flawed market design and weak power prices can be found. Failing that, Davis-Besse will shut down no later than May 31, 2020. On March 31, 2018, First-Energy Solutions declared bankruptcy in an effort to restructure its finances under Chapter 11 of the federal bankruptcy code, further adding to employees' concerns.

Weak power demand forecasts and insufficient capacity auction results make it difficult for a single-unit plant like Davis-Besse to compete in today's competitive market. Davis-Besse and Perry, Ohio-based FENOC nuclear plants, contribute more than $540 million to the Ohio economy annually, and that doesn't include all of the dedicated employees' expenditures on housing, gas, food, and other necessities. Davis-Besse is Ottawa County's largest employer.

Employees try to remain confident that some sort of policy solution will be developed in the Ohio legislature to avoid the deactivation or sale of Davis-Besse, recognizing the importance of nuclear plants and their unique role in providing consumers with reliable, zero-emissions electric power. In the meantime, Davis-Besse continues down the parallel paths of outage planning and preparing for decommissioning, always focusing on the job at hand: to continue safe, secure, and reliable plant operations.

Operator Chris Simpson closes the control cabinet on the DB-34561 output breaker after switchyard work was completed. NN