Windscreens improve performance, reduce O&M cost of ACCs

By Steven C Stultz, Consulting Editor

Air-cooled condensers depend on steady air flow created by a properly designed system of axial-flow fans, normally elevated significantly above grade. Induced by the fans, ambient air then flows vertically through the tube bundles above, condensing the steam within those tubes.

During high winds, the condenser outer shell (wind wall) deflects the ambient air, producing a jet stream below, along the fan inlet region. Jet stream conditions (Fig 1) lead to less air flow (suction starvation), increased pressure, mechanical stress on the fan blades and gear reducers, and increased backpressure on the system, reducing steam-turbine output. An extreme crosswind can mean greatly reduced air uptake, fan stalls, blade damage, and costly motor and gear/drive maintenance and repair.

Although such conditions are both location and time specific, some stations have turned to a system of windscreens (shields) to eliminate, or at least reduce, this jet-stream effect and minimize unfavorable air flow patterns (Fig 2).

Overall ACC performance

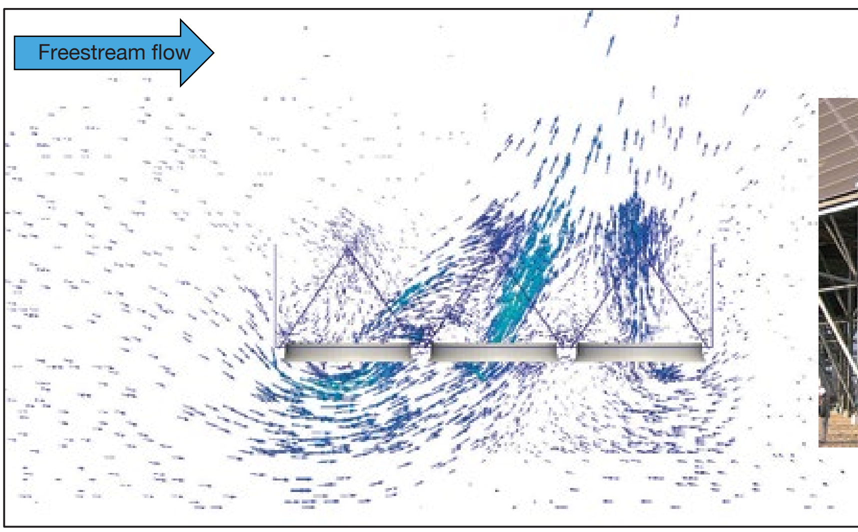
Wind effects vary dramatically from plant to plant, and from season to season. Factors also include ACC orientation onsite, the design sizing of the ACC and fans, and the design of the steam turbine. Nearby buildings, storage tanks, industrial facilities and trees also can have an impact. There is no one-screen-fits-all solution.

If wind is a maintenance or performance factor, the common goal is to design and place screening around the perimeter of the fan system to create uniform air flow into the fans, reduce vibration and stress created by variable winds, and normalize the amperage on the motors driving the fans.

Screens in a cruciform pattern under the ACC will also help enhance air flow into the fans. Balanced and efficient fan operation should then limit equipment damage and improve thermal performance. Service and maintenance should be more predictable.

To date, most windscreen installations are retrofit projects. Many benefits can be measured, but others are still in review. The common parameters studied are:

- Fan performance.
- Blade maintenance.
- Gearbox and motor damage.
- ACC thermal performance.
- System backpressure.
- Steam-turbine output.

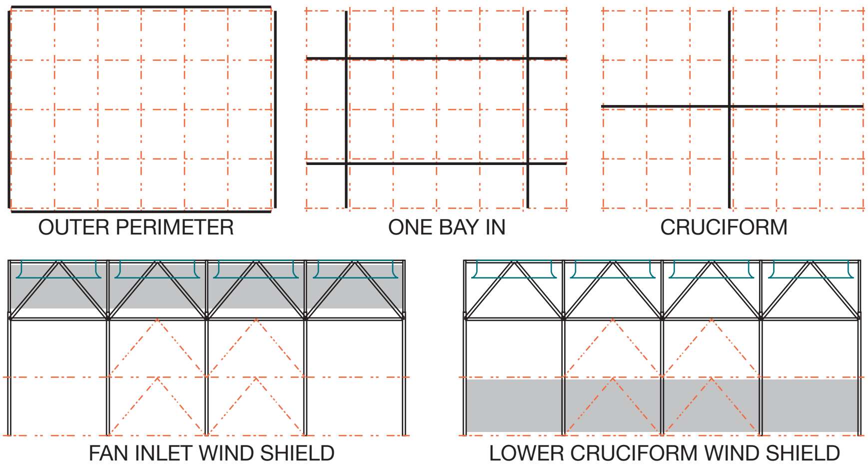


1. Typical impact on ACC of a 9-mph wind without windscreens installed

2. Windscreens and shields are designed to reduce negative airflow patterns. Shown here is an example of a fixed screen

3. Windscreens serving ACCs at a few plants are effective despite being rudimentary. This one was made locally from corrugated sheet steel

4. Mesh screens are designed for specific sites and placement



5. Windscreens come in a variety of arrangements

Perhaps the best summary was presented at the 2015 ACC Users Group meeting in Gettysburg (click on "Presentations" button at www.accusersgroup.org); the core information is included and updated here. Plant personnel know that wind effects on ACCs are drawing increased global attention, and that impacts include thermal performance, fan blade damage, and cell-by-cell fan duty, among others. It is difficult, however, to quantify and measure all thermal performance issues, backpressures, cell-by-cell performance, and other specifics.

But with more than 50 ACCs worldwide already using windscreens or shields, wind-effect experience and knowledge are growing quickly through commercial case studies, smoke tests, CFD analyses, and a variety of field and wind-tunnel examinations.

Materials, options

Windscreen and shield materials vary, including local resources as shown in Fig 3. However, most installations use a fabric system in a permeable mesh format ranging from about 40% to 75% solid, and with a range of pressure-drop coefficients (Figs 2 and 4).

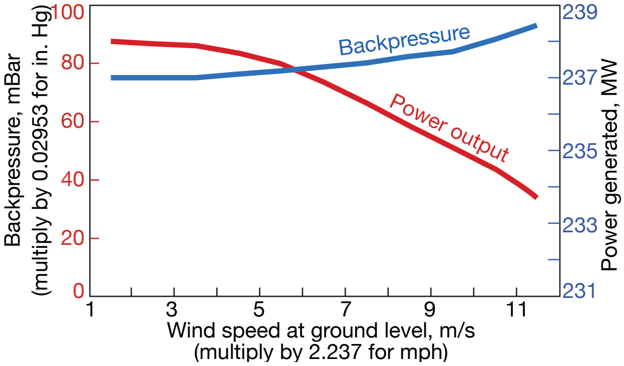
Although screen placement configurations vary, typical installations are shown in Fig 5. The outer perimeter location is the most common, elevated around the fan inlet section of the ACC structure on site-specific sides. Such installations must often allow for structural bracing, pipe work, cable routings, and other interferences, especially for retrofit projects (Fig 6).

Early British tests, results

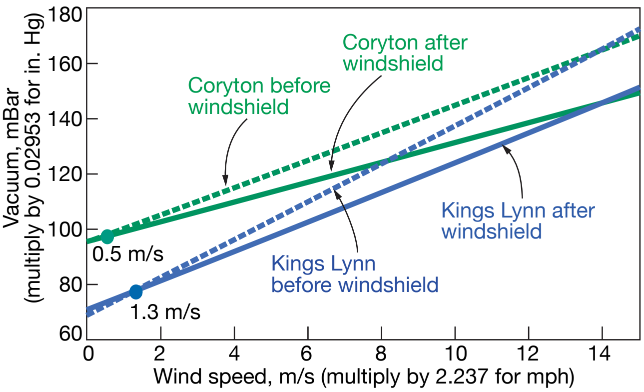
ACC windscreen installations began in 1998, in the United Kingdom at the 360-MW King's Lynn combined-cycle station in Norfolk, now owned by Centrica Energy. This installation, by Galebreaker Group (Ledbury, Herefordshire), is cruciform (cross-shaped) with the screens going from grade up to the fan housing.

Of similar design, the first US installation was in 2003 at Reliant Energy Inc's Bighorn Station (now NV Energy's Walter M Higgins Generating

6. Screens are designed to accommodate services and structures



7. ACC performance falls off as wind speed increases. Results are for a 750-MW combined cycle operating at 50F ambient



8. Impact of wind speed on vacuum at two ACC-equipped UK generating plants

Station)—a 530-MW F-class combined cycle in Primm, Nev, about 40 miles south of Las Vegas.

Early studies in the UK determined that high winds under ACCs increased system backpressure, thereby reducing power output. King's Lynn, commissioned in 1997, decided the following year to install the cruciform screens which were fabricated using 55%-solid PVC-coated polyester mesh.

Operators found that with these screens, ACC vacuum improved when ambient winds increased, because of improved fan performance. Measured in 2006 with average winds of 9.6 mph, vacuum had improved by an average of 0.165 to 0.178 in. Hg. In 2011, perimeter screens were added (with one side motorized).

Also in the UK, personnel at Coryton Power Station, a 753-MW combined cycle commissioned in 2002, determined that high winds under the ACC increased system backpressure and reduced power output (Fig 7). Further research at Coryton included CFD modeling. A major concern beyond wind shear under the fans was the adverse impact on LP-turbine vacuum.

The station added Galebreaker perimeter screens at various heights in 2004. Screen material was identical to that used at King's Lynn. In 2005, based on an average wind speed of 8 mph, vacuum had improved by an average of 0.148 in. Hg (Fig 8).

North Battleford (Canada)

North Battleford Energy Centre, Saskatchewan, Canada, installed screens in 2014—its second year of operation. Battleford is a 1 × 1, 260-MW 7FA-powered combined cycle with an air-cooled condenser arranged in two streets, each with five fans.

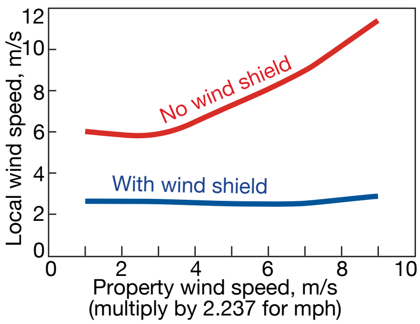
Owned and operated by Toronto's Northland Power Inc, Battleford is part of an overall initiative to deliver baseload power to support Saskatchewan's economic growth, and intermediate on-demand power as needed. The unit has been operating more than 8000 hr/yr at from 50% to 100% of rated output.

During its initial (pre-screen) operation, the unit experienced severe ACC fan and platform vibration with up to 20 trips per fan per day. Wind was believed to be a major contributing factor. All equipment at the site was specified with features based on Northland Power's experience with cold-weather applications and freeze protection.

Average ambient temperature at the plant is 40F with low humidity and normal winds of 8 to 12 mph. Because of freezing potential, all fan drives are variable speed. In winter, half of the ACC can be isolated for protection; fan speed can be reduced, and reversed if necessary.

Northland Power decided to install wind shields and permanent wind monitoring equipment. In May 2014, Galebreaker installed 40%-permeable-mesh perimeter screens able to withstand 90-mph winds.

9. North Battleford, a 1 × 1 combined cycle powered by a 7F.04 gas turbine, relies on perimeter screens for its ACC



10. Influence of wind shield on airflow speed under ACC is dramatic

11. Secondary pinion gear damage suffered at Gateway Generating Station

Screens were *hooked* onto the existing structure, on the north, west, and east elevations (south is protected by the turbine hall). This screen design extends down about 21 ft from the bottom of the wind wall, covering about half the grade-to-deck height (Fig 9). By the end of 2014 the unit was experiencing zero fan trips. Air-flow speed below the fan deck was stable (Fig 10).

Asked recently about these modifications, Richard Pratchler, Battleford's maintenance manager, explained "We did not install windscreens to improve performance of the ACC. We installed the screens to try and eliminate wind-induced fan vibration trips.

"Our fans are driven by VFDs and we can vary the speed from 15% to 100%. At certain rpm and wind conditions we were getting an unacceptable number of fan trips. With a combination of blocked speed ranges and screens, wind-induced fan vibration trips have been eliminated. From this perspective the project was a complete success.

"I do believe that the screens have improved ACC performance," he continued, "but that was not part of the project and we did no testing to determine performance effects." Historically, Battleford has exceeded thermal-performance expectations.

Gateway

Pacific Gas & Electric Co's Gateway Generating Station, Antioch, Calif, achieved COD in January 2009. The nominal 530-MW, 2 × 1 combined cycle, includes a 36-fan ACC (six streets with six fans each), designed for maximum ambient temperature of 104F.

By late 2010, gearbox lube-oil sampling showed metal particulates, and fan vibration readings were increasing on 10 of the 36 fans. When inspection covers were removed, half of those inspected had severe damage to the secondary pinion gear (Fig 11).

All probable causes were reviewed, including:

- Vibration.
- Fan stall caused by wind gusts and high winds.
- Gear-tooth hardness.
- High starting torque.

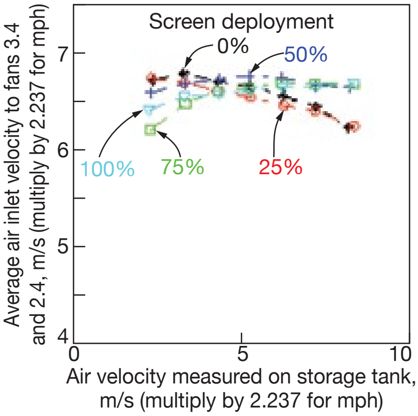
Strong winds are typical at Gateway, and can be accelerated by the venturi effect of the surrounding area. Average annual wind speeds are 9 to 10 mph, but afternoon speeds of 15 to 20 mph are common. Screens were installed in 2011 to break up the winds. They were placed one bay in, extending from the fan deck half way to the ground. Because the screens also extend to the perimeter, each corner cell is screened on two interior sides (Fig 12).

12. One-bay-in screen is installed at Gateway

13. Extensive ACC field tests were conducted at Caithness Long Island Energy Center

14. Caithness screens are shown retracted (front) and deployed (right side and rear)

The screens installed in 2011 have been effective in breaking up the wind. However, any system improvement beyond fan damage has been difficult to measure. Screen design and location were based on existing installations rather than on a concentrated site-specific and unit-specific study (similar to North Battleford). Therefore, the one-bay-in might or might



15. Effects of wind speed and windscreen deployment on the average air inlet velocity to fans 3.4 *and* 2.4 are illustrated in the chart. Note the positive effect of the screen at higher wind speeds and its negative effect at lower wind speeds. Breakeven is about 9 mph (4 m/s). Best results are achieved with 50% screen deployment (up to a wind velocity of 18 mph)

not have been the optimum screen placement.

Caithness

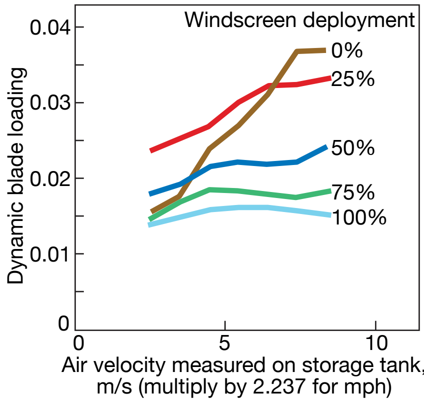
Perhaps the most detailed and long-term windscreen study is ongoing at the 350-MW Caithness Long Island Energy Center, an ACC windscreen retrofit project and analysis that began in 2012. Caithness was first placed into operation in 2009 (Fig 13).

The Yaphank (NY) facility has a 1 × 1 combined cycle with an 18-cell ACC (three streets with six fans each). During the first period of operation, the ACC experienced cracking of fan blades and vibration issues, as well as a few motor-trip problems.

The aerodynamic impact of wind on fan operations was then studied. Early ACC testing, including fan-intake smoke analysis, was a joint effort by Caithness, Siemens Energy, and Howden Group Ltd. GEA Heat Exchangers supported with structural input and reviews.

The site is subject to high winds, explains Siemens Energy's Bill Wareham. "We are located five miles from the south shore of Long Island, with prevailing winds out of the southwest off the ocean. Wind speeds of 10 to 20 mph are fairly common, and we have had two major storms over the past five years (Hurricanes Gloria and Sandy). On a few occasions each year we get wind speeds approaching 50 mph."

Various screen configurations were evaluated. Following these placement tests, Caithness was outfitted with retractable perimeter windscreens by



16. Effect of wind speed and windscreen deployment on the dynamic blade loading of fan 3.4 reflects highest loading at highest wind speeds. Screen deployment reduced dynamic blade loading by a factor of from two to three

Galebreaker, a unique *rolling* feature at time of installation in 2012 (Fig 14). The screens can withstand 120 mph winds by design. Also, during this retrofit the six-blade fans were replaced with nine-blade fans to address vibration and loading concerns.

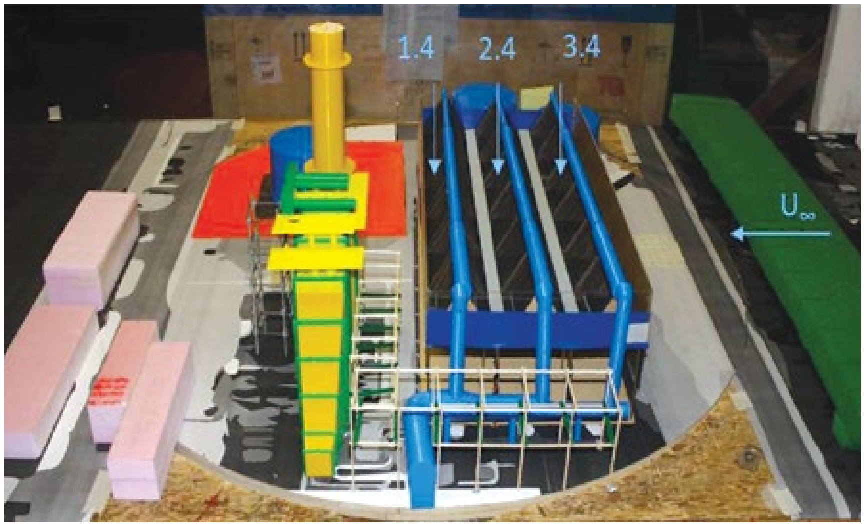
Retractable screens were selected because of the potential hurricane-force winds. With fixed screens in place, such winds could exceed the structural limit of the ACC. Then, because the screens are retractable, the site was selected for in-depth study, and for determining the effects of screens in various deployment conditions. When fully deployed, the screens cover approximately half of the grade-to-deck vertical dimension.

During the next three years, comprehensive research generated a vast amount of data with selected measurable benefits, primarily more uniform inlet velocity and a significant reduction in dynamic fan-blade loading.

Study participants were Maulbetsch Consulting, Galebreaker (windscreens), Howden (fans), Senta Engineering LLC (CFD), University of California-Davis (wind tunnel), and the Caithness Long Island Energy Center (host site and test operations). The study was funded by the California Energy Commission. A few testing specifics follow:

The immediate impact of adding screens seemed to be improved (more uniform) air flow entering the windward-side perimeter fans and reduced stress on fan blades.

Fan data were collected for 18 months. For a period of two months in 2014, data were gathered for two cells (3.4 and 2.4) at full load and with all fans at full power. Fan inlet velocity was then plotted against wind speed



17. A physical wind-tunnel model was developed to advance the depth and breadth of the Caithness studies

measured at the storage tank wind vane (Fig 15). Data sorting parameters included wind direction and screen position (0%, 25%, 50%, 75%, and 100% deployment).

For the two cells combined, at average air inlet velocity:

1. Screens had a positive effect (fan flow rate) at higher wind speeds.
2. Screens had a negative effect (fan flow rate) at lower wind speeds.
3. A wind speed of about 9 mph was break-even.
4. Screen deployment of 50% offered the best results (up to a wind velocity of 18 mph).

Data also were gathered on:

- ACC recirculation (heated plume air back into the inlet stream).
- Steam-turbine backpressure.
- Dynamic fan-blade loading.

For blade dynamics, screen deployment showed significant benefit (Fig 16). Screens reduced dynamic blade load at higher wind speeds by a factor

18. ACC serving the 1 × 1 F-class combined cycle at CCC Saltillo in Mexico currently operates with a combination of sheet-metal wind walls and 60%-mesh windscreens

19, 20. Achieving maximum performance involves thorough inspection and the plugging of the smallest leaks with red gasket-forming silicone (above) and monitoring of fin condition and continually repairing damaged areas (right)

of from two to three. Thermal performance and backpressure benefits were not as clear.

A physical wind-tunnel model (Fig 17) was created at UC-Davis to advance both the depth and breadth of the wind and windscreen studies at Caithness. Study results showed positive correspondence with field data, an accurate physical representation for clarity and understanding, and the ability to explore alternatives. In this case, alternatives were:

- No screens.
- Perimeter screens.
- Perimeter plus cruciform screens.

CFD modeling was created that gave highly detailed representations of the ACC and its surroundings. These models qualitatively showed the upstream complexity of the inlet boundary layer, upstream obstructions (trees and buildings), and the impact of adding a horizontal ledge at the bottom of the ACC wind wall.

Quantitative results under windy conditions were not achieved. However, air velocity entering the fans is now more uniform with the screens, and dynamic blade loading has been significantly reduced. Wareham points out that normal operation is now with windscreens 50% deployed.

Saltillo (Mexico)

Central de Ciclo Combinado Saltillo, a 250-MW 1 × 1 combined cycle in Mexico, began commercial operation in 2001. The ACC has three streets with five fans each.

To combat suction starvation caused by occasionally high wind speeds below the ACC, as well as high ambient temperature, the ACC currently operates with a combination of sheet metal wind walls and 60% mesh windscreens. The first sheet-metal walls were added at grade in 2005 (Fig 18). In 2012, perimeter mesh screens were added on the north side.

To maximize air flow through each fan, Saltillo has experimented with variable-speed drives, changes to the fan-blade pitch angle, and even a concerted effort to plug even the smallest air bypass points within the ACC. This includes pinpoint inspections and red gasket-forming silicone as shown in Fig 19. Sheet metal and pop rivets are added when needed. Fin condition is also monitored for damage-induced bypass to ensure effective use of all components (Fig 20).

Daily recordings of electric-consumption values (per fan) are now compared with both ambient temperature and relative humidity. Fan-blade angle of attack is also correlated with air flow and electric current. These data then are used during the most unfavorable weather conditions to

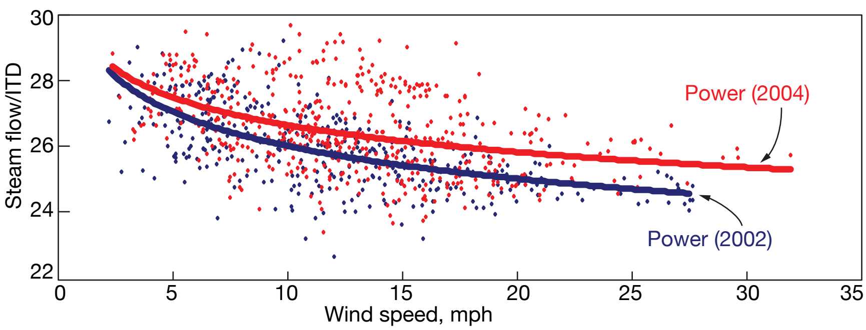
21. Mystic 8's ACC was affected by prevailing southwest winds in summer so the owner installed windscreens on the south and west sides of the unit

22. Obstacles became challenges for south-side screen installation

23. Swing staging was required for some screens

24. Crane assist was necessary for some placements

25. Windscreen porosity at El Dorado varies with the elevation



26. Steam turbine performance is plotted before (blue) and after (red) installation of windscreens at El Dorado, now known as Desert Star

maximize air flow. The worst conditions (coldest air with highest humidity) occur in winter.

With blades properly adjusted, the fans show significant increase in air flow and current. In summer, with less dense air, the ACC operates at maximum condensing capacity.

As Leopoldo Duque Baldaras, O&M manager, explained recently, "at first the condenser encountered loss of vacuum during high wind and high ambient temperature. The Codes N3S-AERO (3D) for aerodynamics and TEFERI (1D) for thermal were used to model with and without wind. As part of that, the plant upgraded its fan motors and gears.

"The combination of sheet metal walls and mesh screens contributes to effective ACC operation," Baldaras said, "and we have a lot of improvement now in steam-turbine backpressure."

Mystic Unit 8

Exelon Generation's Mystic Generating Station is perhaps a poster child for ACC windscreen retrofits, largely because of its unique location in Charleston, Mass. On a typical summer day the site experiences southwest winds exceeding 10 mph, and average temperatures in the low 80s (F).

Mystic Units 8 and 9 are identical 2 × 1 800-MW combined cycles (steam turbines are rated a nominal 300 MW). ACC configuration is nine streets with four cells per street. Fans are a combination of variable-speed and fixed drive.

The Unit 8 ACC is affected by the prevalent southwest winds in summer. Unit 9 is affected by northwest winds, which are less frequent. Therefore, the owner/operator decided to install wind screens on Unit 8, on the south and west sides (Fig 21). The financial incentive was a recurring reduction in summer output with high cost of replacement power. Screens were installed in late summer 2014.

Unit 8 overall performance then was compared for the summers of 2013 and 2015, revealing similar ambient temperatures, relative humidity, wind speeds, wind direction, and unit backpressure. Based on these data, Unit 8 was able to produce an additional 10 to 20 MW with the windscreens in place. Performance measurements for 2016 are awaiting continual hot days with southwest winds.

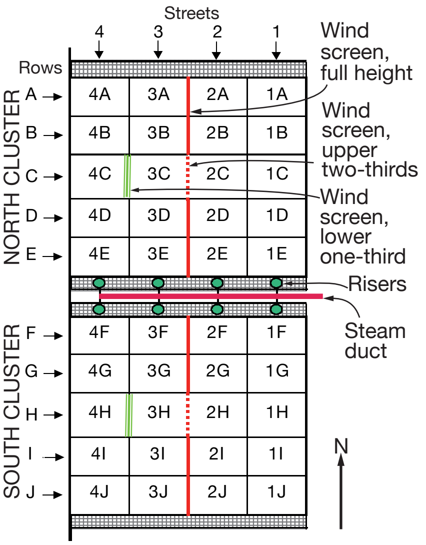
The screens were most effective for wind speeds up to 20 mph. Fan performance has also improved, and long-term maintenance has been reduced.

The Unit 8 ACC retrofit was difficult because of obstacles on the south side. The west side was fairly straight forward. Many obstacles had to be incorporated into the site-specific design to allow for existing cable trays, conduit, small bore piping, and structural attachments (Fig 22).

Space restrictions added to the difficulties, requiring creative solutions to normal aerial-lift platform installation methods.

The middle six columns required a combination of aerial lifts and swing staging, and at times swing staging alone (Fig 23). Wind also was a factor and, with limited space, maneuvering of aerial lifts added time to the schedule. At one point, a crane was needed to position a lift (Fig 24).

Exelon's John Ayyazian says the site is now considering CFD analysis to determine the viability of additional



27. ACC at NV Energy's Walter M Higgins Generating Station has 40 cells, arranged as shown. Note location of screens and their different configurations

screens to further improve performance.

Desert Star, Higgins

San Diego Gas & Electric Co's Desert Star Energy Center, formerly Reliant Energy's El Dorado Energy, began operation in 2000 as a 480-MW combined cycle in 2 × 1 configuration. The plant includes a 30-cell ACC (five streets with six cells each).

Prevailing summer winds (from the south and southwest) often reach 20 to 40 mph, with gusts to 50 mph. Plant personnel were concerned about the high winds in combination with high temperatures, hot air recirculation, and fan-performance degradation caused by non-uniform, crossflow air velocity at the fan inlets.

Screens of porous design from WeatherSolve Structures Inc, Langley, BC, Canada, were installed in a cruciform pattern during the third year of operation. Porosity varies from top to bottom (Fig 25) with the most porous section at the top.

Comparison of ACC and steam-turbine performance before and after screen installation is shown in Fig 26. The performance improvement cannot, however, be precisely characterized because precise field measurements of wind flow patterns and recirculation were not recorded before screen installation.

Higgins began operation in 2004 as Bighorn, as mentioned earlier. The ACC is 40 cells arranged in two 20-cell groups, each with four streets of five cells each.

Screens were installed primarily for aesthetics, as were two wing walls on the northwest and southwest corners (Fig 27). However, detailed measurement of wind patterns in 2005 indicated positive effect for winds not directly from the south. Downwind cells measure some protection against winds from the southeast or southwest.

Dave Rettke, NV Energy mechanical maintenance specialist, explains, "I believe that the windscreens do help our fan and gear reducers in operation. We've never lost a fan blade, and in the highest wind conditions the fans remain fairly stable.

"In most wind conditions," he continues, "the screens help keep the fans stable and well loaded. It is only when we have unusual winds, blowing in gusts against the screens, that I've noted wind-milling issues." CCJ

ACC Users Group steering committee

Owner/operators of ACC-equipped powerplants recognized that critical to solving recurring problems with air-cooled condensers in a timely manner was the sharing of technical information. In 2009, NV Energy and CCJ collaborated on the formation of a user group dedicated to this goal and conducted the first meeting at the utility's headquarters building in Las Vegas. A formal steering-committee structure was put in place shortly after that gathering and today consists of the following members:

Chairman: Dr Andrew Howell, senior systems chemist, Xcel Energy

Dr Barry Dooley, senior associate, Structural Integrity Associates Inc

Oscar Hernandez, manager, corporate engineering, InterGen

Hoc Phung, principal project engineer, PG&E

David Rettke, maintenance specialist, NV Energy