Since 2007, the Nebraska cement market has been seeing increasing strength requirements. As a result, the Blaine fineness of cement produced by first-generation separator finish mill systems has been slowly progressing beyond the capability of these units. Previously, at 3,800 Blaine, the mills could easily outgrind the kilns and satisfy a highly seasonal market. However, the drive to produce Type I/II cement at 4,700 Blaine to meet market demands reduced productivity such that finish mill capacity was quickly becoming a bottleneck to cement production.

This article discusses the details of a project to upgrade the separators at a Nebraska plant from first generation to third generation, thereby enabling the...
plant to regain lost productivity as well as manufacture Type III cement. The challenges of conducting a retrofit project within an existing building and the accompanying hurdles of performing preconstruction while the mills are in operation, working with a short shutdown window, and having the restriction of a 16 ft × 24 ft opening through which to fit materials are detailed.

Addressing Seasonal Variability in Shipments

Ash Grove Cement Company operates a plant in Nebraska that was originally built with wet kiln technology in 1929. The plant was expanded in the 1950s and modernized in 1973 when a semidry kiln with a diameter measuring 15 ft, 5 in and a length of 160 ft was constructed. During this same upgrade, a ball mill with a gas-fired air heater was supplied for raw grinding, and two 4,000-hp ball mills were installed at the facility for cement grinding. In 1980, a kiln with a diameter of 12 ft, 5 in and a length of 164 ft was installed with a calciner kiln system. Following this upgrade, the nominal capacity of the plant was 3,000 short tons per day (tpd) clinker and approximately 4,800 tpd cement.

The cement demand at the facility has been seasonal due to the cold winters in Nebraska (see Figure 1). The finish mills were built with first-generation, 18-ft-diameter mechanical air separators. Even with a highly seasonal market, the plant was not limited by the capacity of the finish grinding systems. A typical annual production cycle is to fill all storage with clinker and cement during the first quarter and then shut down for annual maintenance at the end of the first quarter or early in the second quarter when the weather allows productive work to proceed. The heavy shipping season happens during the summer and fall, when the inventory consequently becomes depleted and the plant runs completely out of its stock. Once the cold weather sets in and shipments drop off significantly, inventories can recover. Figure 1 shows the typical seasonal variability in cement shipments throughout the year. The cement types produced by the plant consist mainly of Type I/II and a flyash interground product that mitigates alkali-silicate reactivity.

Problems with this production schedule began to occur when strength requirements in the marketplace increased, thus broadening the specific surface area (SSA), as measured by blaine, from 3,800 cm²/g to 4,600 cm²/g. As seen in Figure 2, as the blaine value increased in the cement product, a corresponding drop in mill throughput occurred. By the end of this period, the plant’s available excess capacity for sufficient grinding rates to support demand during the busy shipping periods had evaporated. Since the plant was experiencing problems in supporting cement demand during the fall, when inventories were depleted, the plant owner began to investigate how to regain lost production in such a seasonal market.

Technology Research/Scope Development

The evolution of the separator design and its benefits have been well documented [1], [2]. An initial evaluation of the mill systems indicated that replacing the existing first-generation separators with a newer generation of high-efficiency separators (HESs) could increase productivity by providing the needed boost in capacity as well as the capability to achieve better fineness and residue results in the finished product. Since there was a significant change in technology from the original installation of the finish mill systems, the plant owner evaluated the available separator technologies and decided to assess up to four alternative designs to make a technical and financial case for a new separator project.

Technical Work Preparation

The plant owner engaged an engineering firm to assess the capabilities of a new HES installation and provide an initial cost estimate for the project. Concurrently, the owner contacted four equipment manufacturers to provide both commercial and technical quotes for replacing the separators on both finish mill circuits. The initial project review identified several tight constraints. While thought
was given to using a traditionally vented separator with the capability to bleed air into the separator circuit, thereby maintaining low temperatures in the circuit during summer conditions, environmental constraints made it impossible. Limitations on particulate matter emissions at the plant meant that a low amount of gas could be vented from the system. In addition, the tight layout constraints of the building made a large baghouse for venting the separator impossible. Both restraints meant that a system recirculating much of the gas around the separator would be required.

Due to the seasonal nature of production in Nebraska, the installation of a new separator would require a short time window for the shutdown of the mills. To control production interruptions, the schedule would be planned with the goal to have as much equipment installed as possible before the shutdown. This would include a short outage for one mill to be tied in while the other was operated, followed by commissioning the first installed separator and a tie-in period for the second mill system.

The greatest anticipated challenge was installing the new separator through a narrow opening in the building. The design of the existing finish mill building did not allow for the easy removal of roof members or wall cladding. Consequently, nearly all the equipment being added to the system, as well as any demolition material from the two existing systems, would need to be passed through an access point on an upper level of the building measuring only 16 ft $\times$ 24 ft. This would be akin to “threading the eye of a needle with a crane,” as one employee observed.

With these restrictions in mind, a review of the available separator technologies was conducted. Of the four equipment manufacturers evaluated, one option was discarded due to a lack of comparable installations. While a small number of installations had been reviewed in other markets, none of the information provided by the equipment supplier could demonstrate performance at the fineness level required for the new installation. The three remaining systems were evaluated based on not only expected performance but also the constructability of the installations proposed and the overall capital costs. To firm up the cost estimates, contractors were solicited for initial bids to determine the capital costs for the project with greater clarity. The overall payback analysis was presented to factor in the costs of construction and the recovered grinding capacity on the system.

**Technology Selection**

During the review of the specific technologies available, references for separators installed with similar product specifications were solicited. At least three installations with a similar cement type (Portland cement with a blaine of at least 4,500 cm$^2$/g) were reviewed for each technology. Performance data and maintenance costs of the installations were acquired independently of the manufacturers, and interviews were conducted with maintenance and production managers at several installation locations to uncover any recurring issues. While the performance data and operating costs appeared to be similar among the three technologies, one separator showed particular promise. Even though that separator had no North American installations at that time, several installations in Europe were highly touted by reference plant personnel [3], [4], and several items stood out for the owner in selecting this technology.

First, the separator design provided no lower bearing in the gas stream. Most HES designs, including the other two designs under consideration, have a lower bearing that often must operate in a hot and extremely dusty environment, which causes an operating temperature limit as well as a maintenance headache when that bearing needs to be replaced. The design without a lower bearing was highly praised by one of the installation contacts. It was also promoted by the production manager at the reference plant, who favorably compared it with his past experiences working with competing designs.

Second, the cage seal in most HES installations is usually mechanical, requiring adjustments and maintenance to keep the bypass manageable. The cage seal design on the preferred separator, however, had a wide ring with a blower seal, allowing for a positive pressure seal, reducing the likelihood of seal bypass, and giving the best possible cut on a particle size distribution (Figures 3 and 4). The
ring also enabled any vertical adjustment to the cage to tighten or loosen the blower seal gap.

Third, the preferred design offered the possibility of proceeding with modular construction. The restrictions on building access and lifting capacity meant that the unit could not be assembled on the ground and lifted into place; it would need to be assembled in place. The design of the preferred separator allowed the cage, bearing, pulleys, and motor to be installed from above in a somewhat similar fashion to a Russian nesting doll. Finally, the standard design options for this separator allowed for either a traditional air-swept circuit with a baghouse or an air-swept circuit with up to 100% of a recirculation circuit using cyclones and a dirty air fan (Figure 5).

Capital Case
A capital case was compiled based on the following improvements:

1) **Regain lost productivity:** The seasonal nature of the market means that the mills need to overgrind the kiln by significant amounts in the summer months and grind product for storage in the winter months. By installing an HES, the target product SSA was expected to be cut by approximately 300–400 cm²/g (blaine), and thus regain the productivity lost by needing to make a high blaine Type I/II cement product.

2) **Power consumption savings:** With the additional productivity, the specific power consumption could be reduced by approximately 10%.

3) **The ability to manufacture a Type III cement product and grow the market:** The plant has a small Type III cement market that had been shipping in product from another plant within the owner’s organization. The existing first-generation separators were capable of making a Type III cement product. However, switching to this product type required a mill shutdown to modify the existing separator so a full deck of whizzer blades required for a Type III cement campaign could be installed. Following this production run, another shutdown would be required to remove the blades to return to grinding a Type I/II cement product. With a grinding schedule requiring full production capacity in the summer months, this would be difficult to accomplish efficiently.

4) **Stopping the addition of retarder to the product:** With the first-generation separator product, retarders were used for a set time control due to the particle size distribution in the cement. With the amount of superfine material minimized in the final product as a result of a tighter partial size distribution with the new HES, retarder usage was envisaged to be eliminated with a corresponding change in production costs.

5) **Additional side benefits of an HES:** On the product quality side, there are several benefits to cement produced in a mill circuit with an HES. While some have a measurable financial payback, others that are more difficult to quantify but give benefits to the end user are recognized by the customer in the competitive marketplace.

**Project Management**
On larger projects such as this, the plant owner prefers to execute these with an original equipment manufacturer (OEM) using a traditional design build; turnkey; or engineer, procure, and construct a project model. In these project models, the OEM is the main contractor who either self-performs the project engineering or contracts it out, supplies the equipment, and manages the installation by selecting and managing a construction contractor.

Following the feasibility study and the selection of technology for this project, it was obvious that executing it under the traditional model would not be feasible. The plant owner decided to embark on a self-managed project by having separate contracts with equipment vendors, the engineer, and the construction contractor. Contracts were drawn up with the OEM and the engineer to start the project.

Weekly conference calls for project updates were scheduled and held for the duration of the project. The core personnel remained the same, but others transitioned in and out as the project progressed from design to construction. Ground rules were established to keep these meetings useful.
and on task. The meeting length was restricted to a maximum of 30 min. A discussion was held detailing key progress points, action items for the short term, and any action items that could cause project delays. Bullet-point minutes were issued the same day of the meeting and used as agenda items for the next week’s meeting. As tasks were completed, they were removed from the list. If any issues surfaced that required further discussion and clarification, then separate meetings were scheduled with only the relevant parties involved. Originally, it was envisioned that these meetings would last for the engineering phase only, but they carried on throughout the timeframe of the project. Ongoing communication was the key to success for this project.

**Engineering**

The engineering stage was completed as a two-phase approach to provide a precise scope due to the complexity of retrofitting machinery equipment within an existing building. The layout of the separator and auxiliary equipment was completed during the first phase of engineering. At that time, a shutdown period of fewer than 40 days per mill was anticipated. During the engineer's first plant visit, he concluded that the initial layout, the construction plan for removing the old unit, and the installation plan for the new separator and cyclones in the space left by the old unit were not feasible. Observations in the field identified that this approach would result in a long shutdown period (estimated to be 50–63 days per mill) as well as the need to vertically convey cement from the separator discharge up to the cement coolers.

These obstacles could have halted the project. However, in discussions with the engineer, the OEM noted it had previously upgraded a finish mill system in Europe by installing the separator, cyclones, and majority of the equipment within the building while the mill was running. Thus, a short shutdown would be needed to tie in the old equipment to the new equipment. That installation had been performed within a three-day outage window. The layout for the Nebraska facility was more complicated than the European reference plant, but the concept was similar. Due to the complexity of such an installation, as part of the first phase of engineering, a three-dimensional (3-D) scan of the building was performed to document the actual locations of all equipment, the plant structure, its piping, and the conduit systems and to allow for a more easily planned 3-D layout of the new equipment (Figure 6).

At the conclusion of the first phase of engineering, the project plan was to install the new separators, air-gravity conveyers, and fans inside the building while the mills were running. There would be a shorter shutdown time to demolish the existing separators, install the new cyclones, and complete the tie-in of the equipment. With this new approach, the shutdown times were estimated to be 38 and 43 days, respectively, for the plant's two mills. With the selection of this new installation approach and a 3-D scan in place, the second phase of engineering began with avoiding interferences with existing structures and a detailed plan of construction to allow components to be maneuvered inside the building. The engineer provided equipment specifications tailored to the needs of the plant. The equipment (air-gravity conveyors, reject flowmeters, bag filters, fans, and so on) was procured based on these specifications, and the engineer

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**FIGURE 5.** The circuit design options: (a) recirculation using cyclones or (b) the traditional bag filter system. (Image courtesy of Christian Pfeiffer product literature.)
detailed the installation procedure and final layout with the equipment drawings received. The engineer also created a bid package for the construction contract.

Retrofitting machinery equipment within an existing building created some interesting issues. For example, one of the most time-consuming tasks was identifying wiring within the conduit runs in areas to be demolished, assessing its criticality, and what needed to be moved or rerun prior to the shutdown. Several short shutdowns were planned throughout the year to reroute conduit and wiring runs that would have interfered with the project to minimize the main shutdown time. As detailed engineering was being finalized, a bid package was sent to three contractors. A site visit was set up for the prospective contractors to assess the project and complexity of the construction. Following the bid evaluation and clarifications, a contractor was selected. The selected construction contractor believed he could perform the shutdown work within 28 days per mill, and a schedule of 28 days of construction with ten days of commissioning per mill was contractually agreed on with a target date of 19 January 2015 to commence the back-to-back shutdowns. The plant owner desired a ten-day period for the start up and commissioning of the first mill before taking down the second mill.

**Construction**
As the second phase of engineering was being completed, the construction bids were finalized. Surgical demolition would be needed as well as an Erector Set-style construction. All equipment to be installed had to be brought in through the 16 ft × 24 ft access door via a jib crane. A temporary work platform was built by this door so that equipment could be preassembled before being lifted into place (Figure 7). The roof could not be removed to aid in construction due to the presence of both pretensioned concrete roof panels and overhead crane beams within the building. Consequently, an overhead crane and additional crane beam installation had to be used.

The construction contractor mobilized to the site in September 2014 and started the surgical demolition of redundant equipment and the installation of the work platform. The new HES would be built in the location of two old shell and tube in-line product coolers that had been replaced with newer style coolers but not removed. These were the first items demolished, and structural steel for the new platform was installed. Separator construction and installation followed along with the system recirculation fan platform, pedestals, and fan throughout November and December 2014. The installation of the separators was supervised by an engineer from the equipment supplier in December 2014 (Figure 8). During this period, all of the dry commissioning was completed, making a second visit during the planned shutdown in January unnecessary.
The electrical contractor installed starters for new equipment and variable frequency drives (VFDs) for the system fans in the electrical room and installed all wiring and additional programmable logic controller input/output boards. The majority of this work was also performed prior to the shutdown, but final terminations could only be performed when the whole mill system was shut down. The main work during the mill shutdown was to remove the existing nuisance dust collector, install the twin cyclones and associated material transports, and install the new dust collector (Figure 9) and associated fan and ductwork. It was also necessary to tie in the new separator feed air-gravity conveyer and the new spitzer trap to the existing elevator (Figure 10).

**Staffing**
A full-time project manager was stationed at the plant throughout the project. He worked closely with the plant staff to ensure that conflicts interfering with construction around operating equipment were minimized and plan for short shutdowns when needed. This allowed the plant to continue with its regular operations and main shutdown schedule. Throughout most of the construction phase, a representative sent by the engineer was also on site to review any potential issues, including installation problems, to maintain the construction schedule.

The project manager, engineer representative, and contractor’s site manager were fundamental to ensuring that the construction proceeded smoothly and any interferences and fit issues were worked out efficiently. These three people met daily, sometimes multiple times. Even when there was interference and rework was needed, because of this constant communication, work could be quickly redirected while the issue was being reviewed and rectified. The contractor started working a five-day schedule and then staffed up to a 24-h, six-day-per-week schedule with two crews through the latter part of the construction period. This transitioned to a 24-h, seven-day schedule throughout the shutdown periods.

**Project Timeline**
Approximately 25 months elapsed from the completion of the feasibility study to the end of construction. The key project milestones are shown in Figure 11. From
FIGURE 11. The project timeline.
project approval following the phase one engineering, the entire project took 15 months to complete. The cooperation of the OEM, engineer, and plant owner in monitoring construction activities was instrumental to the success of the schedule expectations being achieved with time to spare. Mill 2 was started up eight days earlier than planned. This allowed for mill 1 shutdown to begin three days earlier than had been expected. This success, in turn, allowed for mill 1 to start up nine days earlier than scheduled.

**Commissioning and Start Up**

Since the separators were installed in December, dry commissioning by the OEM's representative (e.g., inspection/lube checks and the freedom of rotation) was completed before the end of 2014, well ahead of the planned shutdowns in January and February 2015. This first mill to be commissioned was complete to a point where checkout and dry runs of the equipment could be started on 11 February 2005, just 23 days after the shutdown commenced. The more formal commissioning model of 28 days construction/handover/ten days commissioning was somewhat adjusted, and the equipment was dry commissioned and run as it became available. A tagging system was put into place so that the signal check, rotation check, safety walkdown, and equipment run-ins could be performed as soon as possible.

Commissioning meetings involving all parties were held twice daily (at 8:00 a.m. and 3:30 p.m.), and a whiteboard was updated with the activities and plans (Figure 12). This was a low-tech approach but worked for the group. Instead of updating a Gantt chart, printing it, and distributing it to everyone, each party could take a photograph of the current day's whiteboard on his or her smartphone and have the plan in hand. Once equipment had passed through the tagging system, it would be run during the day under no load and bearings and lube checked. Sequence checks were performed offline with the control system vendor's representative, and all sequences and trips were field verified before the mill was ready to run.

Feed was introduced to the first mill to be commissioned (mill 2) on 17 February, 30 days from the mill shutdown. It ran for 2 h and was shut down to allow personnel to tighten belts and assess product quality. A second 4-h grind was performed on 18 February followed by three runs on 19 February. During these runs, various items were being tuned and troubleshooted (in particular, the VFD for the separator). This time was also used to detect operating parameters that would produce satisfactory products. The mill was put into 24-h operation on 20 February with material being sent to the silos.

Traditional control points for a cement mill are Blaine fineness and the residue on a 325-mesh sieve. The product produced with the new separator consistently showed greater than 99.5% passing this sieve size and, as such, would not be adequate as a control point. An alternative control point would be needed. An air-jet sieving machine was purchased, and new control points were established based on a 450-mesh sieve (32 μm) for the Type I/II cement and the flyash interground cement and a 635-mesh sieve (20 μm) for the Type III cement, which was found to be much more responsive with regard to evaluating product quality.

On 17 February, once the plant was satisfied with the performance of mill 2, it released mill 1 to the contractor, three days ahead of schedule. The second shutdown went much more smoothly than the first, as the contractor had learned lessons from the first installation. The commissioning model was copied and the “start up achieved” certificate was signed 32 days from the commencement of the shutdown. This could have been 30 days had it not been for some other shutdown conflicts that were beyond the project's control.

**Results**

For mill 1, the media charge was topped off before the shutdown, and a baseline audit was performed. The charge was not changed during the shutdown, so the only alteration made to the mill system was the HES upgrade. Productivity increased by approximately 10% while grinding Type I/II cement and approximately...
15% while grinding the flyash inter-ground cement. Upon start-up, the production was cross-checked by grinding to an empty shipping silo and calculating the sum of the truck weights shipped from the silo. Plant personnel were satisfied with the performance and ultimately chose not to enact a formal guarantee test, as is the option in most contracts.

Tromp curves for the Type I/II cement produced by finish mill 2 before and after the project are shown in Figure 13. Bypass was drastically reduced, and the slope increased significantly as expected. The product passing through the 325-mesh sieve increased to greater than 98% for the Type I/II cement, approximately 99.5% for the flyash inter-ground cement, and greater than 99.5% for the Type III cement. This led to the control points used to review the operation being adjusted to a 450-mesh sieve on the flyash interground cement and a 635-mesh air-jet sieve for the Type III cement.

With the Type I/II cement, a 10% reduction in SSA was achieved, providing similar mortar cube strength at all ages (one, three, seven, and 28 days). The use of set time retarders was eliminated with the new separator. With the flyash interground cement, a similar 10–15% reduction was also seen in the SSA. While the early mortar cube strength (one and three days) held similar levels to the previous product, the later strength (seven and 28 day) increased approximately 7% and 13%, respectively.

Conclusions

The project was executed on time and met its productivity and quality objectives. Plant records were used to demonstrate productivity gains instead of a formal production guarantee test. The high-level improvements that were observed included the following:

- a system reliability of 95% or higher
- the blaine reduced by at least 10%
- a mill production rate increase of 10–15%
- a Type II cement set time of 5 min (with no retarder)
- a % passing a 325-mesh sieve (45 mm) from 94% to roughly 99%
- a % passing a 450-mesh sieve (30 mm) from low 80% range to more than 90%
- similar early mortar cube strength
- an improved strength gain of the flyash interground cement on both seven- and 28-day cube break samples.

By all measures, the project successfully achieved its goal of allowing the continued use of the existing ball mill systems so that the plant owner could meet the demands of his clients. The honest and open communication among all parties involved was the key to the success of this project.

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References