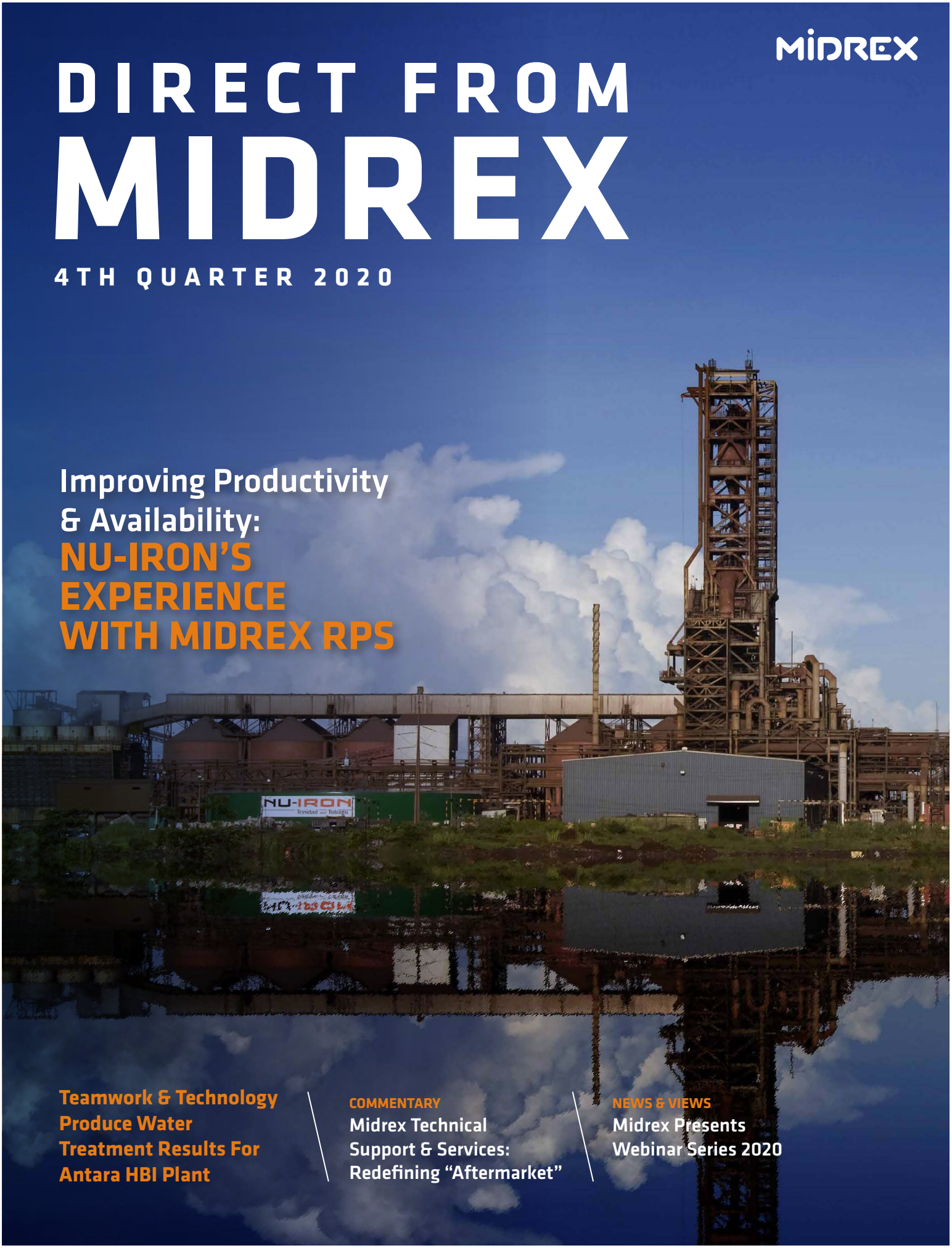
MIDREX

DIRECT FROM MIDREX

4TH QUARTER 2020



Improving Productivity & Availability: NU-IRON'S EXPERIENCE WITH MIDREX RPS

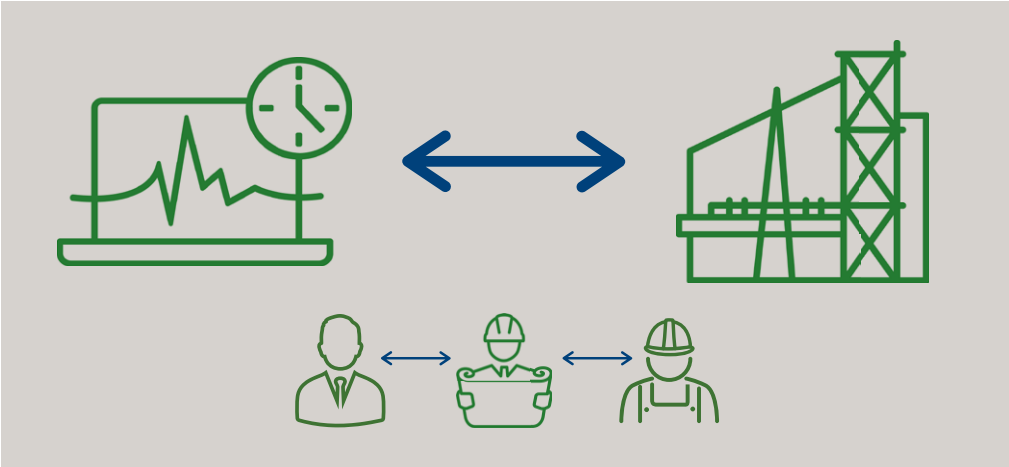
Teamwork & Technology Produce Water Treatment Results For Antara HBI Plant

COMMENTARY
Midrex Technical Support & Services: Redefining "Aftermarket"

NEWS & VIEWS
Midrex Presents Webinar Series 2020

COMMENTARY

MIDREX TECHNICAL SUPPORT & SERVICES: REDEFINING "AFTERMARKET"



By John Linklater
Services Program Manager, Midrex Technologies, Inc.

Midrex made a commitment to collaborative technology transfer even before the first full-scale MIDREX® Direct Reduction Plant was built in the early 1970s. Now, almost 50 years later, with more than 90 modules located around the world, we are providing our customers with innovative, essential, and effective technology-based processes and systems and the services and support to ensure they receive the highest return on their investments.

Each plant is unique in its staffing, mission, and operating conditions. Depending on time, location, and circumstances, the service requirements can be very different, even for the same plant. Therefore, an effective service provider must have the skills, ingenuity, and experience to create custom solutions – and the consistent presence and relationships to gain the trust and cooperation of the customers.

We don't regard customer support and services in the traditional "aftermarket" sense because Midrex is actively involved in all aspect of a plant – design, supply, operation, and maintenance – a seamless transition from plant supply to plant operation services and support. Our all-inclusive approach to support and services is based on:

- **Two-way technology transfer**
- **Collaborative technical support**
- **Digitally-based advanced solutions**

Organizationally, Midrex has two groups devoted to customer support and services: Technical Services and Global Solutions. Technical Services is the main point of contact for Midrex with operating plants and provides support under the provisions of the MIDREX Process License in the form of:

COMMENTARY

- responding to technical inquiries from Process Licensees
- collecting operational/production data for preparing the annual MIDREX Plants Operations Report and to facilitate benchmarking
- organizing the technical program of the annual Midrex Operations Seminar and/or webinars
- identifying plant improvements and improvements needed
- coordinating plant visits
- supervising the preparation of Technical Bulletins and Instructions (TSBs and I&Is)

Global Solutions supplies spare parts and provides engineered solutions and the services to implement them. Engineered solutions include plant audits, debottlenecking studies, process automation upgrades, adapting equipment for local conditions, and incorporating new technologies, such as Adjustable Carbon Technology (ACT™). Services range from reformer management to field-based support, such as refractory replacement and mechanical or operations advice, as well as Integrated Plant Solutions (IPS), a custom-tailored suite of services to match specific client needs.

The most recent Midrex service offering is complete DRI-to-EAF optimization through our partnership with AMI Automation. This partnership allows all MIDREX DRI-EAF integrated facilities to achieve the lowest cost of liquid steel produced from iron oxide by optimizing the DRI plants and the EAFs as a single unit. Therefore, all decisions are based on the effect on liquid steel produced and not the performance of the individual operations.

Supplying, supporting, and servicing technology for direct reduction-based steelmaking is our business – our only business – and Global Solutions is the only plant services provider that can guarantee the solutions it provides are designed and manufactured to exact Midrex specifications.

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This issue of *Direct From Midrex* features two services-related articles by Midrex Gulf Services (MGS) and Nu-Iron Unlimited. The Antara HBI article reviews the planning, implementation, and first year's results of its water treatment management system; the latter article describes the improvement in productivity and availability achieved by Nu-Iron with the assistance of Midrex RPS (Remote Professional Services).

IMPROVING PRODUCTIVITY & AVAILABILITY:

NU-IRON'S EXPERIENCE WITH MIDREX RPS

NU-IRON Trinidad and Tobago

By NIGEL NOEL and RONNIE DABIDEEN,
Nu-Iron Unlimited

INTRODUCTION

In September 2004, Nucor acquired the physical assets of American Iron Reduction (AIR), a 1.2 million ton per year cold DRI (CDRI) plant utilizing MIDREX® Direct Reduction Technology. Nucor relocated the plant to Point Lisas, Trinidad and Tobago, in 2005, and increased the capacity to 1.6 million metric tons per year. The new plant, Nu-Iron Unlimited, commenced DRI production on December 30, 2006. The company is the largest shipper of CDRI in the world and has produced more than 19 million tons of cold DRI since start-up, which have been successfully shipped to and melted in Nucor mills in the USA.

Nu-Iron established a Direct Reduction Engineering and Technology (DRET) Team in 2011 to address productivity and availability issues. Its primary focus was to keep the plant running at optimum performance, improve product quality, and minimize downtime. In 2017, the efforts of the DRET produced a 10% increase in annual production and an 11.5% improvement in operating hours (both in comparison to 2016). To further build on the success of the DRET Team, Nu-Iron entered into a long-term agreement with Midrex for Remote Professional Services (RPS). This would be a collaboration to find ways to enhance or improve operations by combining the operational expertise of Nu-Iron with the multi-disciplined Midrex team and supporting proprietary software.

BACKGROUND

Following acquisition of the idled AIR plant, Nucor signed a contract with Midrex Technologies, Inc. in April 2005 for upgrading the plant's capacity to 1.6 million tons per year (t/y) by adding reforming capability and gas compressor capacity. The first cargo of DRI was shipped to Mobile, Alabama, on January 21, 2007.

With no on-site steelmaking capability, Nu-Iron ships all DRI it produces to four ports in the USA: Charleston, South Carolina; Mobile, Alabama; New Orleans, Louisiana, and Morehead City, North Carolina. The product is further transported via barges to Nucor steel mills in Berkeley County, South Carolina; Tuscaloosa, Alabama; Decatur, Alabama; Memphis, Tennessee; Hickman, Arkansas, and Hertford County, North Carolina.

The Nu-Iron plant is shown in ***Figure 1***, with the shaft furnace in the center of the photo, the DRI storage bins behind it to the left, and the receiving and the shipping docks in the background.

FIGURE 1. *Nu-Iron Unlimited, Pt. Lisas, Trinidad and Tobago*

CREATION OF THE DRET TEAM

With the latest and most productive DRI technology in use at the Point Lisas site, Nu-Iron sought to push the DRI technology and plant performance even further. To see where they could go, Nu-Iron began benchmarking their operations and comparing themselves to other MIDREX Plants. They determined that there was room for improvement.

The company had goals of setting new standards and breaking internal and external records. With a clear vision set, next came creation of a team empowered to make changes. In 2011, Nu-Iron established a Direct Reduction Engineering Technology (DRET) Team, with an initial focus of planning and process analysis. Professionals from the plant's mechanical and electrical engineering staffs were added in 2014, and the Team was further expanded from 2014-2017 to include members drawn from process engineering, a refractory specialist, a control systems engineer, senior technicians and specialists, and a mechanical engineer from Midrex, who functioned as an onsite liaison.

The DRET Team takes a broad view of various aspects of plant operation in order to define realistic and achievable goals. Once defined, strategies are systematically outlined and implementation procedures are established to attack the challenges. The Team's responsibilities include major shutdown planning, creating and maintaining a 5-year "living document" for plant maintenance and operations, conducting root cause analysis investigations, developing equipment preventive maintenance procedures, and implementing the Management of Change process.

With the leadership of the DRET Team, Nu-Iron embarked on ways to improve operation through minimizing unscheduled downtime. Thermography and vibration analysis technologies were adopted to enhance the preventive maintenance programs. Thermography and oil and vibration analysis are used to effectively monitor the health of vital equipment, to reduce wear, predict maintenance needs, and limit the number of unscheduled plant stops.

The effectiveness of the DRET Team was obvious in the results achieved in 2017. Annual production was increased by 10% to almost 1.6 million tons ***(Figure 2, next page)*** and plant annual operating hours were increased by 11.5% to 7,860 as a result of decreasing plant stops by five-fold ***(Figure 3, next page)***.

NEED FOR CONTINUAL IMPROVEMENT

Although the results achieved in 2017 were in keeping with Nucor's relentless quest for excellence, it was felt there was room for further improvement. Nu-Iron had achieved great success from the DRET Team's efforts, but there was a need to continue evolving in order to keep improving.

In 2018, Midrex approached Nu-Iron with a proposal for a suite of services that included the ability for Midrex's engineering personnel to observe the operation of Nu-Iron's plant remotely from their RPS control room in Charlotte, NC. Although in the current structure, Midrex and Nu-Iron interact with a ticketing system to identify items to work on, the original RPS proposal included:

- Review of plant start-up and shutdown operations
- Review of plant operations during upset conditions
- Analysis of "pain points" with proposed solutions
- Real time monitoring of plant conditions during start-up from cold conditions
- Investigation of special requests made by Nu-Iron

Two of the "pain points" identified by Nu-Iron and Midrex were possible furnace channeling and material plugging in the proportioning hopper.

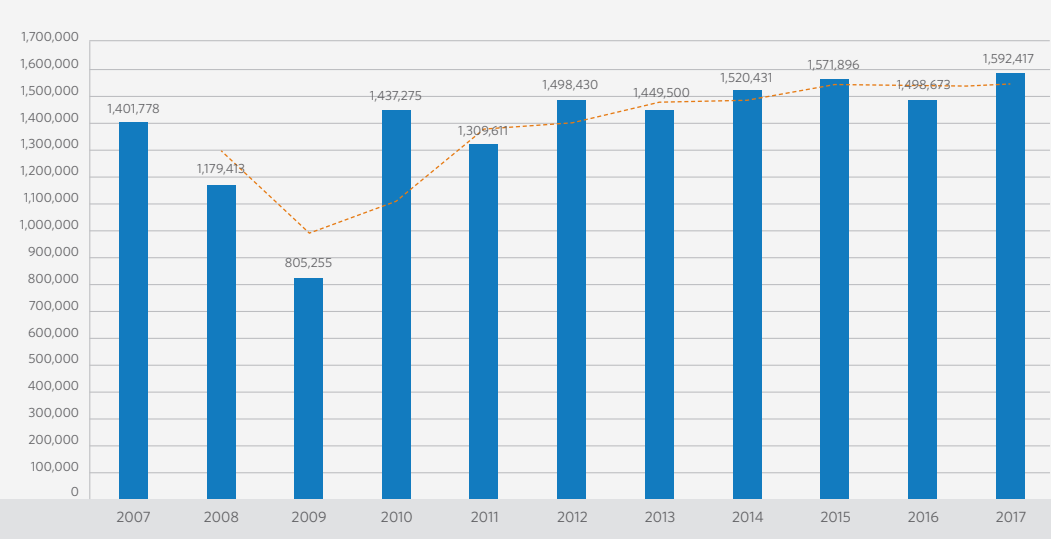


FIGURE 2. *Annual CDRI Production (2007-2017)*

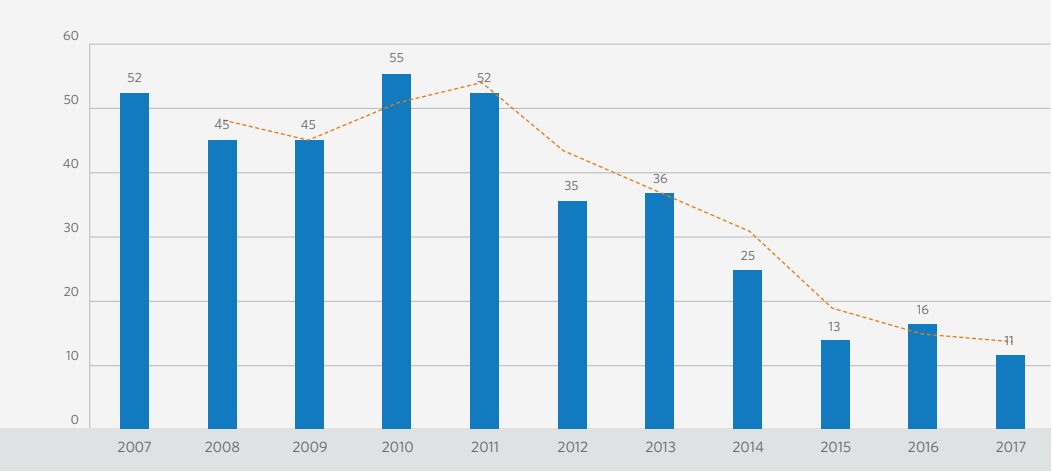


FIGURE 3. *Number of Plant Stops (2007-2017)*

FURNACE CHANNELING

Nu-Iron was aware of erratic bed temperatures from their analysis ***(Figure 4)***, which suggested erratic behavior of the bed at higher discharge rates. A higher standard deviation in metallization was noticed (approximately 0.8%), and other parameters showing response to bed temperatures (such as process gas CO_2) confirmed that some instability in the material flow was occurring.

With Nu-Iron focusing on the day to day operation, Midrex RPS was able to focus on identifying all possible causes, or potential operating improvements.

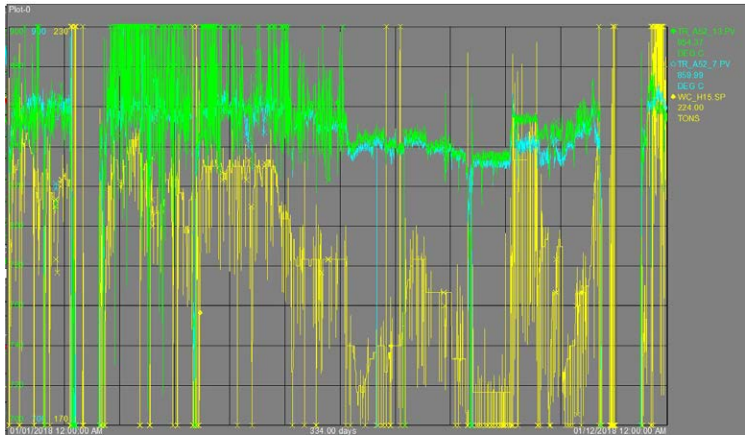


FIGURE 4. *Nu-Iron Analysis of Bed Temperature Fluctuations*

When looking at solutions or trying to identify root causes, the teams frequently developed a cause-and-effect diagram. This required both teams to work in unison, with many of the required verifications or checks done on-site. To develop a cause-and-effect diagram, Nu-Iron and Midrex prepared a list of all possible causes with suggested actions. An example for finding a solution for erratic bed flow is shown in TABLE I.

One of the possible causes involved material fluidizing. Using proprietary software, Midrex used the size distribution data provided by Nu-Iron of their various oxide pellet suppliers to check the material fluidization. This study showed the current feed mix blend to be susceptible to fluidizing. A new blend was suggested to reduce this potential. Once implemented, the results of the efforts from both teams were obvious with the increase in production shown in TABLE II. It should be noted that achieving this increase in production was not a result of any one change or adjustment, but rather a combination of many mutually agreed changes or adjustments by both Nu-Iron and Midrex RPS.

POSSIBLE CAUSE	SUGGESTED ACTION	COMPLETED	COMMENTS
Asymmetric and incomplete stroke of UBF, MBF and LBF	Adjust stroke to match that of design. Design 45 (MBF) and 30 (LBF) resp.	May 2018	Unable to make changes to UBF
Some feed materials have higher fluidization potential	Operate plant with feed mix with lowest fluidization potential	Not done	Ore supply constraints
Significant roughness of furnace walls (Damage to refractory)	Remove refractory down to insulating layer and restore circumference through shotcrete	Nov 2018	Every TAR we shotcrete and scrape affected area
High fines in furnace	Install new primary oxide screens	Nov 2018	New Screens have reduced the amount of fines in the furnace
Worn teeth on Burden Feeder shafts	Replace worn teeth	Nov 2018	This action was done due to wear of MBF and LBF shafts at pad ends

TABLE I. *Possible Causes for Furnace Channeling and Actions Taken*

PROCESS CONDITIONS	PRODUCTIVITY MTPH	BUSTLE TEMP DEGREES C	PROCESS GAS FLOW *1000
Historical Best	217	980	205
Pre Nov 2018 Shutdown	212	980	200
Post Nov 2018 Shutdown	225	960	205
Post Nov 2018 Best (Ore Limitation)	230	940	210
Post Nov 2018 Best (with mix provided)	242	958	205

TABLE II. *Results of Actions Taken*

PLUGGING IN THE PROPORTIONING HOPPER

In November 2018, Nu-Iron changed the proportioning hopper and furnace feed legs. Alignment of the legs to the hopper was checked visually, and only reversed ledges were present. Vibrators were installed on all the feed legs to function on timer sequence during operation. High fluctuations in top gas temperature were observed 1-2.5 months after starting up following cleaning of the hopper, as shown in ***Figure 5***, indicating possible blockages in the charge hopper. No significant loss of productivity was noticed; however, it could become a reason to stop the plant if left unresolved.

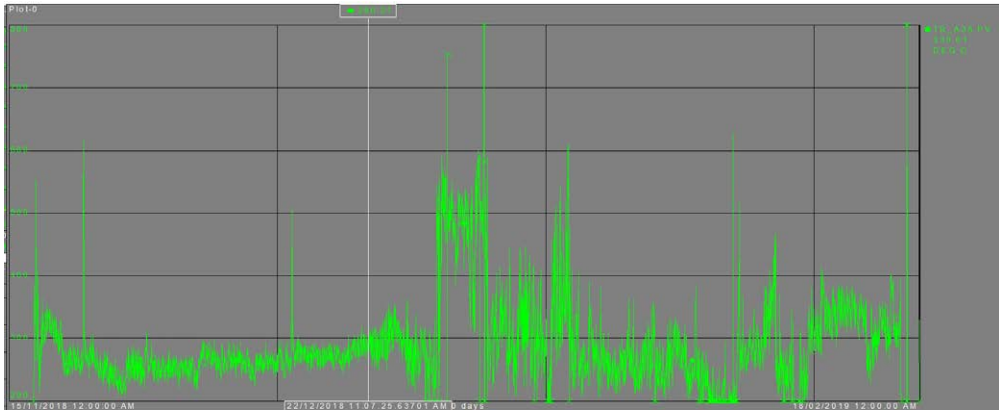


FIGURE 5. *Nu-Iron Analysis of Top Gas Temperature Fluctuations*

Nu-Iron and Midrex developed an extensive list of possible causes and suggested actions from analysis of the plant data and RPS monitoring **(TABLE IIIA and IIIB).** Each possible cause was checked and eliminated from the list if it was determined not to be contributing to this effort.

The plant was restarted in November 2018, after a planned maintenance shutdown and operated 1-1.5 months before high fluctuations in top gas temperature were observed. When Nu-Iron brought the plant down in February 2019, the proportioning hopper was cleaned and inspections were conducted. Similar behavior was observed 2-2.5 months after the plant went back into operation. The plant was shut down in June 2019 for scheduled maintenance, at which time the hopper was cleaned and inspected and some areas were polished. Upon restarting plant, Nu-Iron stopped operation of the vibrators.

In early September 2019, the plant was shut down to change a motor. No irregular and/or high swings in the top gas temperature were observed up to this point. The hopper was inspected and build up similar to that before was found, which led to the following conclusions:

- The DRET Team had never considered that the vibrators could possibly aggravate the hopper plugging problem, as they are seen as useful in promoting material flow.
- The input and discussion with the Midrex RPS team has helped identify possible causes.

It must be noted that although this problem has not yet been successfully resolved, it highlights the benefit of both teams "brain storming" in an effort to successfully resolve an issue.

CAUSE	ACTION	COMPLETED	COMMENTS
Excessive fines	Change primary screens	Nov 2018	Screen is working well
Ledges or nucleation points	Inspect alignment	Nov 2018; Feb 2019	Mainly reverse ledges exist where build up is happening
Excess or improper coating	Continue slurry monitoring and lime discharge tests	Ongoing	Typically issues with coating manifests itself in many areas before the proportioning hopper
Excessive moisture in seal gas	New seal gas dryer installed	Nov 2018	100% our seal gas is dried. Also wet seal gas leads to plugging at insert region
Vibrators installed on sequence during operation could lead to segregation of fines	Stop the vibrators	Jul 2019	The suggested action was very logical and fell into that category of what was changed. The Nu-Iron team only viewed the vibrators as a benefit to promote material movement

TABLE IIIA. *Possible Causes for Hopper Plugging and Actions Taken*

CAUSE	ACTION	COMPLETED	COMMENTS
Vibrators creating magnetic field resulting in sticking of fines	Stop operation of vibrators	Jul 2019	Thinking outside of the box suggestion. However action was easy to do
Drying of fines in hopper region	Add spray water to charge hopper and/ or E08	Not done	Last action as this is a plaster to the cause of recent rate of plugging after Nov 2018
More fines being delivered to furnace	Remove ceramic lining in chutes or allow build up of fines external from furnace	Not done	Risk vs Reward interaction of humans in cleaning in chutes on daily basis and we have never shut down the plant as a result of this plugging
Material changes	Analysis of build up	Sept 2019	Sent sample to Midrex for guidance and testing
Material used in lining or installation of lining has characteristic resulting in fines sticking	Material analysis and installation of ceramic coating in areas of build up	Jan 2020	Investigating of actions needed to prepare surface and reach etc.

TABLE IIIB. *Possible Causes for Hopper Plugging and Actions Taken*

REDUCING OPERATOR ERRORS DURING PLANT START-UPS

One of the consequences of increased availability and less plant downtime was that new DCS operators were not getting practical experience in restarting the plant. In the past, before a new DCS operator would get confirmed in his position,

he needed to have three successful plant start-ups; however, it was no longer possible to wait on three plant start-ups to confirm DCS operators. DCS operators were being confirmed based on "explained knowledge" of a plant start-up as opposed to "displayed knowledge". This resulted in an increase in "operator errors" during plant start-ups.

Nu-Iron and Midrex developed three main ways to address this issue. These three approaches have allowed Nu-Iron to reduce the number of "operator errors" during plant operation and plant start-up and improved the efficiency of the restart to reduce the time to achieve prime production and reduce the amount of remet generated.

1. Review by the Process Engineering Team of plant start-ups and stops due to "operator error".

The Process Engineering Team reviews every plant start-up and generates a report that includes the following:

- Summary of the plant start-up
- Positive observation during the start-up
- Potential opportunities for improvement

A report is also generated whenever there is a plant stop due to "operator error". The report identifies the following:

- Actions taken by the operator
- Root cause of the error
- Corrective actions to prevent reoccurrence

These reports are discussed with all DCS operators. The valuable feedback from the process team and the discussion it engenders is used to help improve the start-up actions of the DCS operators, as well as review of Nu-Iron's start-up procedures. This has recently been further enhanced by having the Midrex RPS team also review plant start-ups to provide further insights that may be missed by the Nu-Iron Process Team.

2. Real-time oversight of plant start-up by Midrex RPS team when restarting from a planned outage.

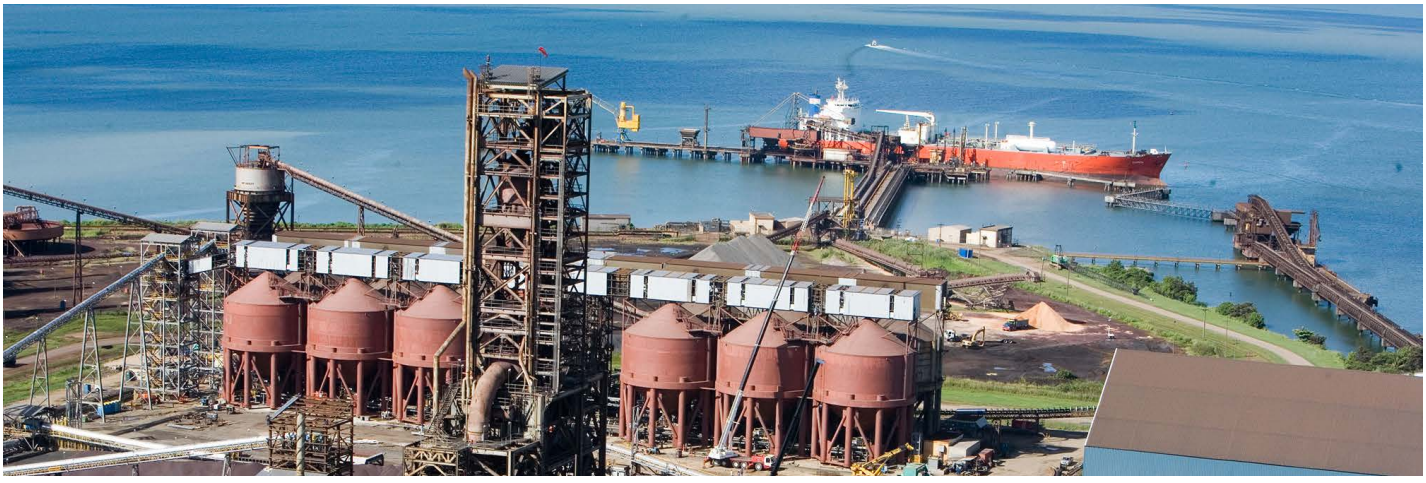
Once Nu-Iron has a plant start-up from a planned outage, Nu-Iron engages the services of the RPS team to observe the plant restart remotely and communicate with the process engineering personnel on site during the start-up. This oversight has provided guidance to the process team in real time and has helped to further improve Nu-Iron's plant start-ups.

3. Development of an Operator Training Simulator (OTS).

Nu-Iron, Midrex, and a third party signed an agreement in 2017 to develop an Operator Training Simulator to simulate a plant start-up from idle to completion of reforming. The simulator currently focuses on the gas circuit (and not the shaft furnace). This project took over two years to complete to ensure that the simulator mirrored the "feel" of an actual plant start-up. The simulator was delivered to Nu-Iron in late 2019, and Nu-Iron started using it with experienced DCS operators to ensure that they felt it replicated the plant restart experience.

The feedback from the experienced DCS operators has been extremely positive, and Nu-Iron have has started using the simulator with less experienced DCS operators. Nu-Iron is in discussion with Midrex and the 3rd third party to develop further modules to the OTS.

As a result of the cooperative efforts of the Nu-Iron DRET Team and Process Engineering Team and the Midrex RPS Team, production in 2019 reached an all-time high ***(see Figure 6, next page)*** and several availability records were set.



SUMMARY

The Nucor culture inspires high performance and results-driven operations that stresses safety and teamwork. The DRET Team embodies core Nucor values and the spirit to improve, looking to push technology and performance further while creating a safe and prosperous work environment. Nu-Iron has been able to improve productivity and availability by creating the DRET Team to focus on root causes of plant issues and implementing prompt, effective corrective actions.

In 2018, Nu-Iron engaged the services of the Midrex RPS team in response to the challenge to continually improve. "Pain points" that Nu-Iron's operations and maintenance personnel were wanting to manage are being eliminated with the integration of Midrex into the Nu-Iron operations team. The collaborative efforts of the Nu-Iron DRET Team and the Midrex RPS team have established new goals and set new standards for direct reduction ironmaking, resulting in the Nu-Iron plant setting numerous production and availability records in 2019 and performing beyond design ratings:

- **Producing more than 1.7 million tons of CDRI *(Figure 6)***
- **Averaging 224 t/h in January 2019**
- **Averaging 96.1% metallization and 2.66% carbon**
- **Operating in excess of 8,000 hours by maintaining a low number of overall plant stoppages, as well as a low level of stoppages due to operation**

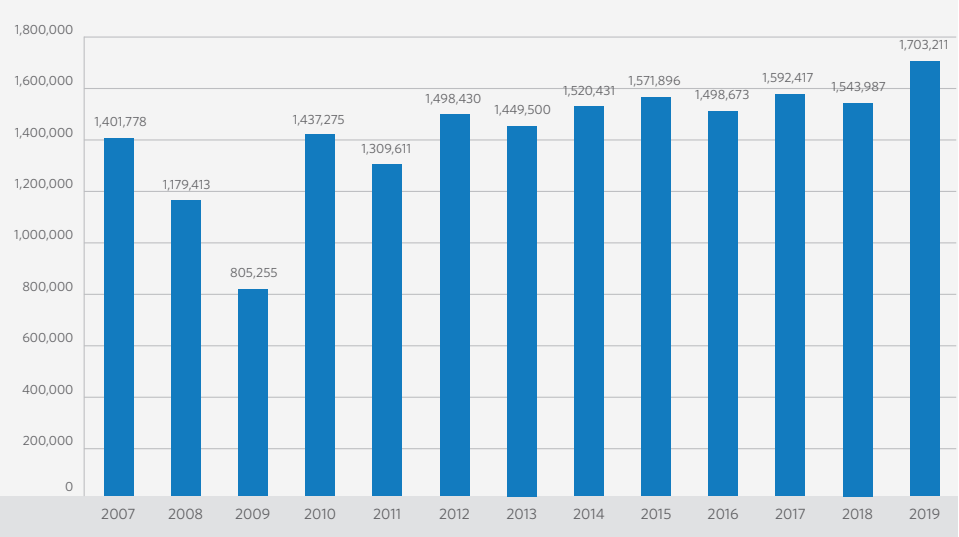


FIGURE 6. *Annual CDRI Production (2007-2019)*

"90% of issues can be solved through internal focus, but 100% can only be achieved through external inclusion"

- Ronnie Dabideen

NU-IRON Trinidad and Tobago

As a key part of Nucor's ore-based metallics (OBM) strategy, the Nu-Iron plant is one of the world's most advanced DRI operations. It is based on flexibility, inclusion, and performance. Nu-Iron delivers world class DRI product quality while maintaining a safe and productive work environment. The plant has a DART rating of 0.0 (DART is a safety metric that stands for "days away, restricted or transferred"). Nu-Iron's DART is well below the national industry average of 1.67.

Typical Nu-Iron DRI has metallization greater than 96% with carbon content of 2.6% or higher. Their product specs exceed the standards of many other operating DRI facilities. In fact, any DRI produced with met lower than 96% is considered "remet" by Nu-Iron. Although "remet" does not have an industry standard definition for metallization percentage, typically anything under 89% is considered "remet"; therefore, Nu-Iron's "remet" would be considered acceptable product by most DRI plants throughout the world.

Teamwork & Technology Produce Water Treatment Results For Antara HBI Plant

By Faycal Finnouche and David Oswald,
Midrex Technologies Gulf Services FZCO

INTRODUCTION

Midrex has a long history of aftermarket support for our Process Licensees and a strong desire to introduce technologies and enhancements that benefit their operations. One of the newer Midrex initiatives to expand our service model was to establish an agreement with ChemTreat, Inc., which enables us to offer water treatment and technical solutions for the water systems of MIDREX® Plants. The agreement was announced in December 2018, and by early 2019, Midrex had signed its first water treatment contract with Antara Steel Mills HBI to provide services following their scheduled annual maintenance shutdown.

This article reviews the cooperative efforts of the Antara utilities team and the Midrex water services team prior to start-up and the activities in preparation for product introduction. Additionally, it reviews the activities following start-up and compares the first year's results against historical data. Lastly, some future efforts which have wide range application to the DRI water process are introduced.

BACKGROUND

Antara HBI plant was commissioned in August 1984. Current capacity is approximately 570,000 tons per year (t/y), with a production rate of 100 tons per hour (t/h). The plant manufactures hot briquetted iron (HBI) with a metallization rate of 93-94%. Located on the Island of Labuan off the north coast of East Malaysia, they have a deep-water port to ship all of their production to overseas clients.

→ Antara HBI Plant

→ Evaluating Treatment Scenarios

The plant typically takes an extended maintenance shutdown every 18 months. During these periods, the plant conducts normal repair and maintenance activities for the entire facility and specifically for the water system, focusing on cleaning the cooling tower fill and basins along with the scrubber packing and fouling in the pipework. These shutdowns normally take 30-45 days to complete.

Prior to negotiating the final program recommendations, the Midrex team visited the plant to understand the current state of the water circuits and treatment strategy being deployed by Antara. Based upon this information and discussions with ChemTreat, we developed a treatment strategy which would provide performance improvements to plant operations. In order to implement these enhancements, additional dosing points and pump skids would be required.

POST-CONTRACT SIGNING ACTIVITIES

Following the execution of the contract, the Midrex water team visited the plant to discuss the location of the additional dosing skids and to review the treatment and dosing strategies necessary to execute the program. Additionally, we evaluated a number of treatment scenarios for the Process Cooling Water (PCW) system to ensure that the program would achieve a significant reduction in total suspended solids (TSS) in the system. The goal was a 50% reduction from historical levels. Using the current treatment protocol and evaluating multiple combinations of flocculants and coagulants, we were able to determine the right program for Antara's water. With these results, the "guess work" for the PCW system was eliminated.

During the next several months, we focused on constructing the dosing skids and shipping them to Labuan, where the Antara team built-out and fabricated a storage area for each of the systems.

We also delivered all the required inventory for start-up and worked with the Antara team to develop a delivery schedule to ensure uninterrupted supply. One of the more practical

→ Covered storage for new dosing skids

→ Dosing skid & 1m³ product tote *(close up view)*

solutions was to supply all products in 1m³ totes so plant-side inventory always was ready for treatment. We were well aware of the effects of poor system management, which stems from inadequate supply of on-site chemical, so the decision was mutual to use totes for each dosing station.

PRE-START-UP ACTIVITIES

Just prior to the HBI plant restarting in September 2019, we visited the site to have final meetings with the Antara utilities and laboratory team to answer final questions and to set up treatment for each of the systems. The first priority was to commission all the dosing pumps and establish dosing curves for each product with each skid. With Antara's assistance, this was completed and feed rates were calibrated and verified.

The next step was to set up the analytical software program – CTVista+ – from ChemTreat and build-out desired upper and lower control limits for all systems. The software package can be customized for the need of each client, and with Antara's historical water treatment data "dumped" into the software, laboratory teammates and Midrex customized the reporting protocol to meet Antara's expectations. One of the big changes which CTVista+ enabled the client to do, is provide a daily dashboard for the critical variables. This information is available to all responsible plant personnel and remotely to Midrex.

The last major activity prior to commissioning was to conduct a general training session for the responsible departments. While Antara has a very strong process control culture and is competent to conduct almost any test required from their laboratory or troubleshoot the systems with precision, collectively, Antara and Midrex wanted to go through some of the critical changes which were involved with the new program. Over two days, we reviewed each system and treatment program and discussed how it would be managed for optimal results.

YEAR 1 RESULTS

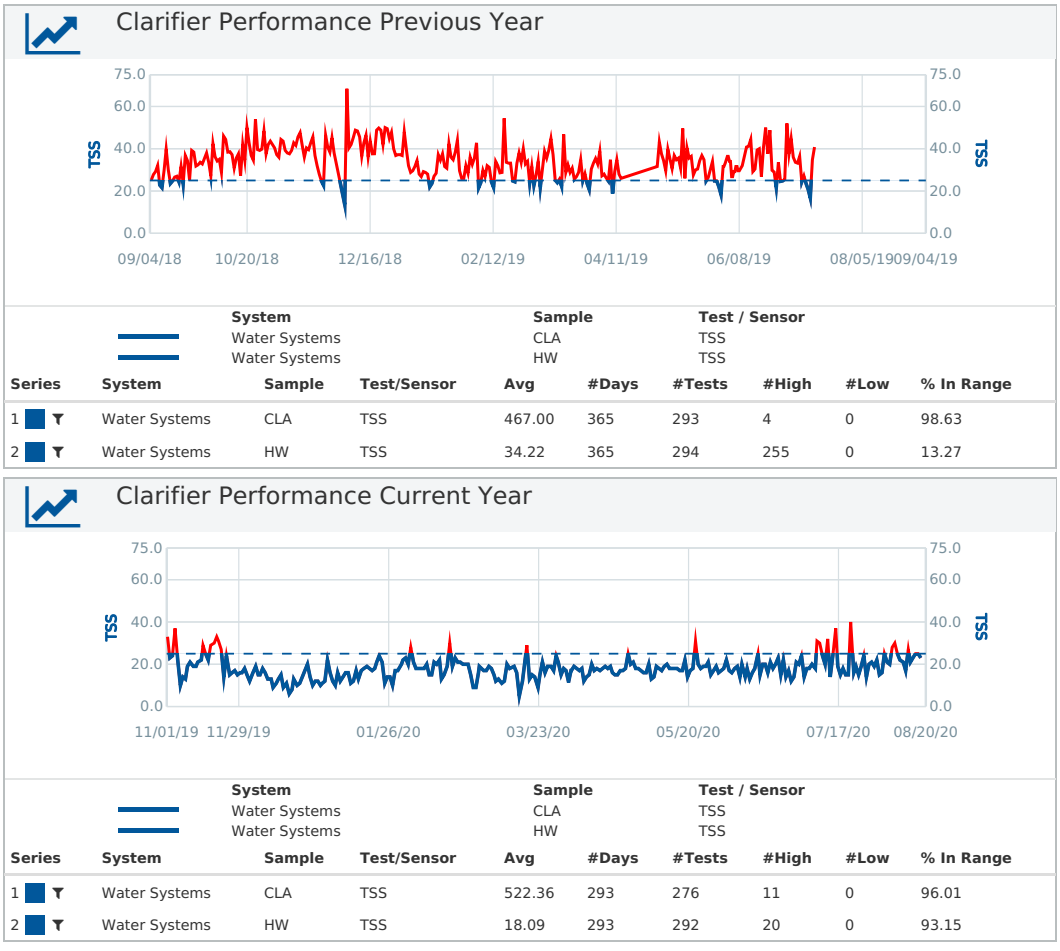
Start-up began without many issues from a water treatment perspective. Initially, the clarifier had lower turbidity readings and TSS levels were 50% lower than historical changes. After two weeks of on-site management with the Antara utility team, we determined that all pumps, feed rates, and performance parameters were as expected and returned to our office. The plan was to visit the plant regularly

CTVista+ Trend Chart Display

and have routine conference calls to ensure results were maintained. Unexpectedly, our strategy was interrupted by the COVID-19 global pandemic. The last on-site visit was in early February 2020, but conference calls have continued through today. We have seen in the CTVista+ data that results have shown solid improvement from historical data. ***(Figure 1)***

Probably, the most significant result has been the improvement in the PCW system relative to water clarity. Historically, the incoming TSS average was 467 ppm. Following the shutdown, the incoming TSS has averaged 522 ppm – a 12% increase. Even with this trend, water clarity going to the hot well (over the weir) was reduced to 18.1ppm TSS from 34.2 ppm TSS – a 53% average reduction. From a historical perspective, the percentage in range readings increased from 13.3% with the prior treatment program to over 93% in range. While Midrex water teammates were present in early February and working alongside the client, minor adjustments to the treatment of the clarifier resulted in very low TSS – 10-14 ppm. Based on these results, we are confident that further optimization is possible and will be one of the future studies that we run. By any standard, the improvements realized are significant and will help extend the Antara plant's operational window because fewer solids are returning to the process.

Further data from the PCW cold well indicates that scale formation is not evident after coupons were removed from service ***(Figure 2)***. Top and bottom sides of the scale coupons only exhibit soft, lightly fouling surface residue, which is easily removed with a minor wipe. No hard scale formation is evident. Furthermore, these results are important because the PCW does not have a blowdown valve so cycle management is very difficult. Normally, scale growth will be exacerbated as the cycles increase. Effective treatment is enabling the system to run "clean".



Series	System	Sample	Test/Sensor	Avg	#Days	#Tests	#High	#Low	% In Range
1	Water Systems	CLA	TSS	467.00	365	293	4	0	98.63
2	Water Systems	HW	TSS	34.22	365	294	255	0	13.27

Series	System	Sample	Test/Sensor	Avg	#Days	#Tests	#High	#Low	% In Range
1	Water Systems	CLA	TSS	522.36	293	276	11	0	96.01
2	Water Systems	HW	TSS	18.09	293	292	20	0	93.15

FIGURE 1. *PCW System Performance Comparison*

FIGURE 2. *PCW Cold Well Scale Coupons*

System	Coupon Photo	Metallurgy	Days Exposure	Corrosion Rate (MPY)	Best in Class MPY rating
MCW		Cu	105	< 0.1	< 1.0
MCW		MS	105	< 0.1	< 0.1
CCT		MS	105	2	< 3.0
CCT		Cu	105	< 0.1	< 0.5

TABLE I. *Corrosion Coupon Results*

Numerous other metrics show each of the circuits improved from historical levels. The Machinery Cooling Water (MCW) circuit had approximately 20% less iron in the system, indirectly demonstrating that corrosion rates were lower. The corrosion coupons for the same system show that the corrosion rates for mild steel and copper coupons are excellent, meeting standards considered "best in class".

Likewise, the Clean Cooling Tower (CCT) circuit has demonstrated better than "best in class" performance for both mild steel and copper metallurgy. See TABLE I for other circuit metrics.

Overall, each of the dashboard metrics established by Antara have been consistently within established limits ***(Figure 3, next page).*** The only reading outside the established maximum limit has been the total iron in the cold well. But from a historical perspective, the prior treatment regime average iron was ~ 15.5 ppm, and the Midrex average has been 10.6 ppm (a 32% reduction). This improvement proves that the increased solids (TSS) capture in the clarifier is positively impacting the cooling tower and settling basins.

FUTURE WORK – TECHNICAL EXPANSION

As mentioned earlier, visits to the plant have not been possible since early 2020. Even so, we continue to work with Antara to evaluate new instrumentation which will enable better monitoring and subsequently control of critical variables to the process. Since April of this year, evaluation of a robust pH monitor has been ongoing, and two patents have been applied for that use this technology to improve the process and monitor the scaling tendency for the system. We have some other ideas for additional monitoring techniques, which once the technology has been verified, we will be introducing to MIDREX Process Licensees. The ideal situation is for these monitoring protocols to be integrated into the plant DCS system to enable operators to make real-time decisions. Additionally, these monitors can be integrated into the Midrex RPS (Remote Professional Services) technology so our engineers can remotely provide feedback on system variations. The overarching principle behind these efforts is to build-out process smart technology today for the smarter plants of tomorrow. In doing so, our licensees will benefit from process improvements and Midrex will continue to be the leader in global ironmaking technology.

Without question, the results achieved in no small part are to the

credit of our teammates at Antara. As mentioned earlier, they have a strong quality control, operational control, and best practice mindset and constantly strive for the very best results for their plant. As the Midrex water team continues to work remotely with the Antara team, we want to acknowledge their dedication and hard work and willingness to consider different strategies to help achieve the results discussed.

ChemTreat® CTVista+

Water System Log

Log Sheet

Test	CO2 Stripper out	TGS	CLA	HW	WW	CW	MCW	MU	JKR	Soft	CT
pH	7.25	6.38	6.35	7.24	6.58	7.99	8.06	7.39	7.32	7.83	8.49
Limits										7-8	
Alkalinity				148	148	143	98.6	19.8	19.2		181
Limits				250 max		250 max					
Tot Hardness (ppm as CaCO3				154	153	153	32.7	37.8	36.9	1	219
Limits				250 max							
Cal Hardness				144	145	143		29	28.2		190
Limits				170 max		170 max					
Mg Hardness				9.7	7.8	9.7		8.8	8.7		28.4
Limits				80 max		80 max					
Chlorides	24.96	25.71	24.77	24.71	24.92	24.1	13.1	4.72	4.51	4.76	49.92
Limits	50 max	50 max	50 max	50 max	50 max	50 max				10 max	
Iron	296	230	322	13.58		12.82	1.29	0.2			50
Limits						6 max	2 max				
TSS	430	362	439	21	18	16		1	0		8
Limits	800 max	800 max	800 max	25 max	25 max	25 max					
TDS				230	230	230	900	50	50		500
Limits											
Turbidity				40.2	47.7	54.9	15.3	1.27	1.19		24.9
Limits				100 max		100 max					
Nitrate							470				
Limits							300 - 800				
Cond. (µmhos)	392	402	399	385		379	1.241	80	80		679
Limits											
Phospho. (ppm)						1.12					7.92
Limits											
ORP	24	1.1	4.3	20.9							

FIGURE 3. *Complete Water System Log Sheet*

Midrex News & Views

Midrex Presents Webinar Series 2020

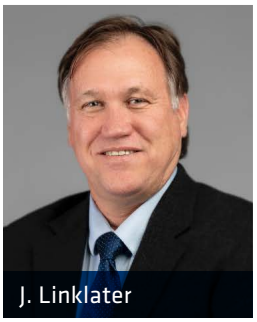
The 2020 Plant Operations Seminar for MIDREX® Process Licensee and Construction Partners was one of the casualties of the global COVID-19 pandemic. This annual meeting is an opportunity for Midrex and its plant supply partners to exchange ideas, experiences, and new developments with the operators of MIDREX Plants.

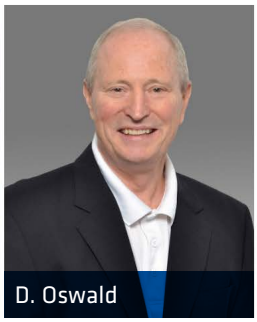
In lieu of the seminar this year, Midrex created a series of four webinars on topics determined to be of interest to plant operators, one of which was presented each month from August-November.

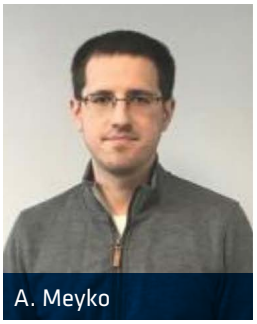
Moderator

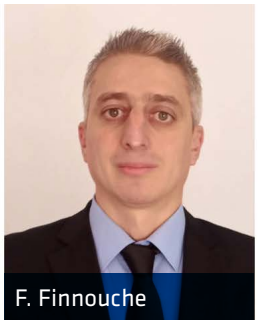
Host & Coordinator

MIDREX PRESENTERS









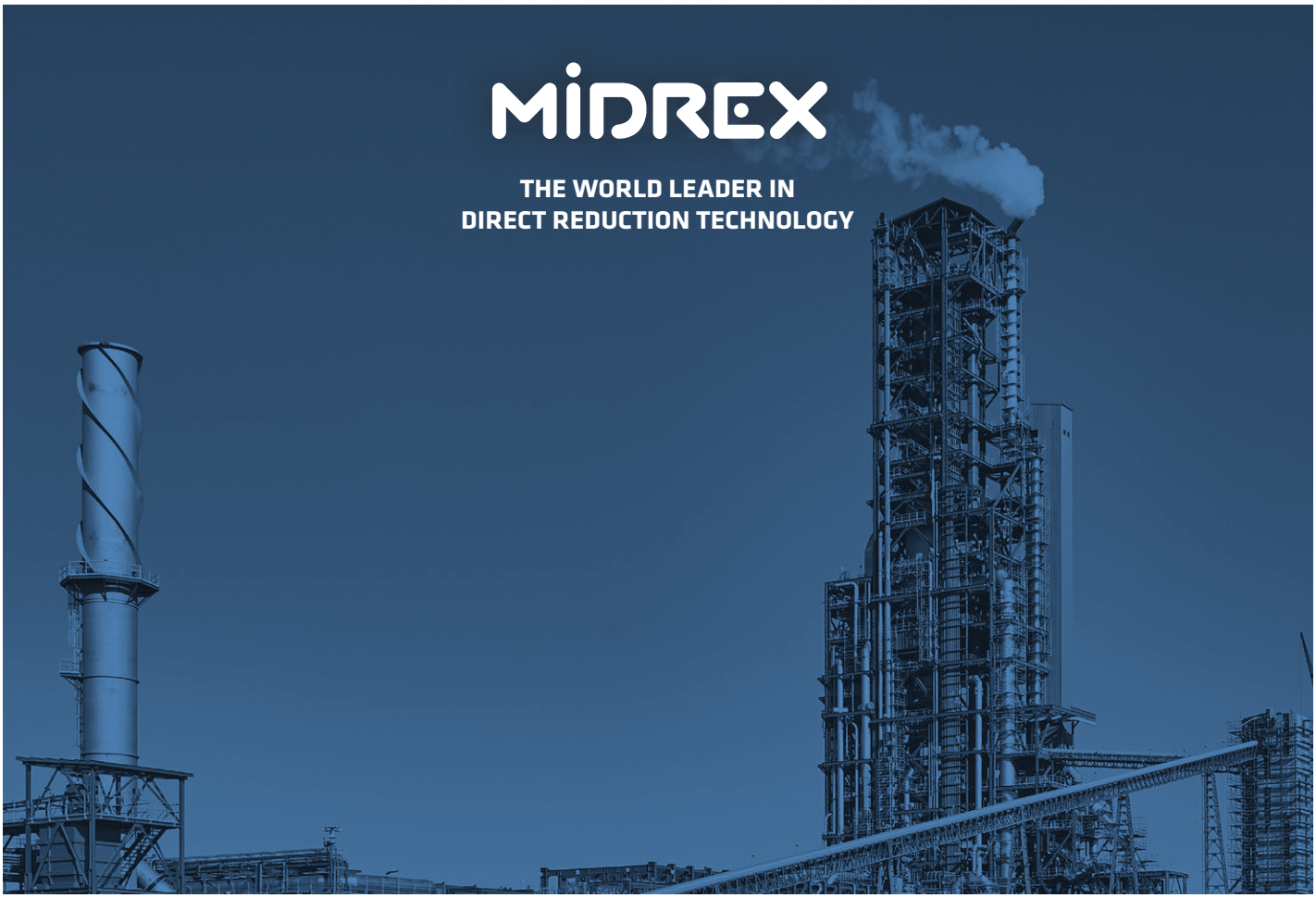
MIDREX WEBINAR SERIES

August 12, 2020
OPTIMIZATION OF RAW MATERIALS FOR THE MIDREX® PROCESS
by John Linklater and Rainer Schulze, Midrex Technologies, Inc.

September 9, 2020
RECENT DEVELOPMENTS IN OXYGEN INJECTION FOR THE MIDREX® PROCESS
by Geoff Wallwork and Anatoliy Meyko, Midrex Technologies, Inc.

October 21, 2020
INNOVATIONS AND IMPROVEMENTS IN PROCESS WATER TREATMENT IN MIDREX® PLANTS
by David Oswald, Mark Jernigan, and Faycal Finnouche, Midrex Technologies, Inc.;and Briant & Jack Wilder, ChemTreat, Inc.

November 11, 2020
TESTING THE MIDREX REFORMER TUBES & DETERMINING THE REMAINING LIFE
by John Linklater, Midrex Technologies, Inc.; Valton B. Fowler, US Thermal Technology, Inc.; and Peter Sachs, Magnetische Pruefanlagen Gmbh



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