MIDREX

DIRECT FROM MIDREX

4TH QUARTER 2022

H2 Green Steel Story:

THE QUEST FOR EARTH'S SUSTAINABLE FUTURE

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COMMENTARY

MIDREX INNOVATION
"CYCLES OF LEARNING" FOR SUCCESS

> "The power of what you have learned enables you to do the next thing, and it enables you to do the next thing better."
>
> – Jonathan "Jony" Ive,
> *former Apple designer*

By Jim Lewis, P.E.
Innovation Team Process Coach
Midrex Technologies, Inc.

Midrex is a company built upon knowledge learned through years of applied research, engineering, and plant experience. Our Innovation Process, launched in 2017, builds upon that knowledge legacy by continual learning through **PDSA (Plan-Do-Study-Act)** cycles, which are the core work of Innovation Engineering (IE).

PDSA cycles ask the following questions:

- What does success look like?
- What are some ideas to achieve success?
- Which idea is most meaningful and unique?
- What would kill the idea?
- How can you test the "death threats" and the idea itself?
- What did you learn from the test?

When confronted with any kind of problem, innovators first define "what is a successful outcome?" and ***Plan*** an activity (experiment, research, measurement, or conversation – anything to gain data) to try to reach that outcome. Next, they ***Do*** the activity, taking care to gather as much data as possible. Learning occurs as the innovators ***Study*** the data to extract meaning. Finally, innovators ***Act*** on the meaning learned, which could be to revise the activity and repeat it, seek another idea path, or solve the problem. Each PDSA iteration is a "Cycle of Learning," which increases knowledge through a consistent refinement of data and its interpretation.

IE is a methodology for growing a culture of never-ending innovation through increased speed (up to 6x faster) and decreased risk (30-80%). IE defines innovation as "meaningfully unique" ideas in which people are willing to invest their time, energy, and money. The process to create ***meaningfully unique (MU)*** ideas can be shown as:

$$MU = \frac{S^D}{F}$$

COMMENTARY

Meaningfully Unique Ideas Process

- Explore **Stimulus (S)** – good ideas can originate from any kind of stimulus to our thinking
- Leverage **Diversity (D)** – tapping into the knowledge & experience of others generates an exponentially greater number of ideas
- Drive Out **Fear (F)** – fear of what others think, fear of loss or change, fear of rejection, fear of the unknown, and fear of exposure

At Midrex, we train innovators in this process to gather in ***Diverse*** groups (Create Sessions) to ***Stimulate*** idea creation intended to solve a specific, defined problem. Our Innovation Team, comprised of Green Belt certified Innovation Engineers, drives out ***Fear*** by identifying ***Death Threats*** (issues that could kill an idea) and uses PDSA cycles to resolve the threats. Once the threat(s) to an idea are successfully resolved, it is promoted as a Technology Development activity. However, if the threat is upheld, work on the idea is ended, thus saving further expenditure of financial and human resources.

INNOVATION

"We are pioneers in our industry. We think creatively—and act boldly—in service of our mission and vision."

MIDREX
CORE VALUE

In the first five years of Midrex Innovation Engineering, almost 300 ideas have been generated by a diverse group of innovators from throughout the company. Every technology development activity in the pipeline today is a result of the IE process, notably:

- **Decarbonization of Ironmaking** – MIDREX Flex™ and MIDREX H2™ technology, market confidence studies (five programs)
- **Higher Value Metallics** – enhanced DRI-based metallic product quality and value-in-use (six programs)

We also use PDSA cycles to continually improve our work processes. For example, in our 2022 Innovation Team activities, we developed better metrics for ranking ideas by their MU score (meaningfulness and uniqueness) so we can better prioritize our workload. In its 2nd iteration, we now have a data-driven ranking tool that we will continue to sharpen via PDSA cycles.

In pursuing our core value to Innovate, we at Midrex share the challenge to continually learn. And we learn best when we define success and systematically grow our knowledge through "cycles of learning," with the results being better work performance. I look forward to training team members in India in the Innovation Process so Midrex can broaden the diversity of its pool of innovators.

(Editor's note: Jim Lewis is transitioning to his new assignment as General Manager – India Engineering. See ***News & Views*** *in this issue for more information.)*

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This issue of ***Direct From Midrex*** features an article by H2 Green Steel that introduces this pioneer of fossil-free steelmaking, describes their immediate plans for a DR-EAF facility in Boden, Sweden, and their broader mission to decarbonize hard-to-abate industries. In the second article, IIMA discusses the proposed IMSBC Code schedule for DRI (D) (By-product fines with moisture at least 2%), which will make DRI fines safer to ship. News & Views includes the contract awarded by H2 Green Steel to Midrex and Paul Wurth for the first commercial-scale hydrogen direct reduction plant, the decision to set up an engineering center in Midrex India, and MIDREX® Plants with fourth quarter anniversaries.

H2 GREEN STEEL STORY

THE QUEST FOR EARTH'S SUSTAINABLE FUTURE

By DURGESH GUPTA
Senior Vice President – DRI, H2 Green Steel

INTRODUCTION

In 2014, Vargas Holding, the founder and largest shareholder of H2 Green Steel, was established for the purpose of facilitating the transition to a more sustainable future by transforming sectors of society to emit less carbon. The mission of Vargas is to build new, sustainable companies from the ground up, free of legacy commitments, populated by people who share a passion for creating change.

Polarium, a firm that provides battery backup solutions for the telecommunications sector, was the first business established by Vargas in 2014. As Polarium grew, it became increasingly clear to management that sole-sourcing battery cells from Asia was an unsustainable business model for a company headquarted in Sweden.

To determine the viability of constructing a greenfield giga-scale lithium-iron battery manufacturing facility in Europe, Vargas Holding reached out to Pete Carlsson, formerly the Head of Supply Chain at Tesla Motors, and Northvolt was established. Located in northern Sweden, Northolt began manufacturing battery cells and made its first commercial sale in April 2022.

With Volkswagen as a major stakeholder, the automaker's goal of achieving full decarbonization of the industry inspired Northvolt to explore the green steel market. Its business strategy calls for collaboration in product development, process technology, recycling methods, and logistics. The knowledge and expertise gained through the creation of Northvolt were instrumental in the founding of H2 Green Steel.

H2 Green Steel (H2GS AB) was established in 2020 with the ambition to accelerate the decarbonization of the steel industry using green hydrogen. The company's main purpose is to radically reduce CO_2 emissions in hard-to-abate industries. And because the steel industry is one of the world's largest carbon dioxide emitters, we made the decision to start with steel.

H2 GREEN STEEL – THE FIVE-STEP PROCESS

Production of steel is responsible for up to 9% of global CO_2 emissions and 14% of Sweden's total CO_2 emissions. The European carbon market has involved steel companies since the carbon market began in 2005. However, steel companies have free carbon allocations due to the heavy industry feature, but free carbon allocations for steel companies will be dismissed by 2030 due to the "Fit for 55" plan.

The steel industry is confronted with extraordinary decarbonization challenges.

7~9% **5%** **14%**

steel industry's share of total CO_2 emissions

1,900,000,000 tonnes steel produced per year
3,500,000,000 tonnes of CO_2 emitted every year

To achieve net zero CO_2 emissions by 2050, total global emissions must be reduced 37% by 2030. Achieving this target will take more than just increasing material or process efficiencies. It will require new technologies to be deployed at scale for the Industry Sector to contribute 13% of the emissions reduction in 2030.

As it stands now, steelmakers have three options:

1. Do nothing,
2. Invest in carbon capture and storage solutions, or
3. Transition to cleaner production processes, such as hydrogen-based steelmaking starting with the direct reduction process.

Decarbonization of steel is not just about electrification to make hydrogen. It requires unique solutions to deal with emissions both from traditional blast furnace-based iron reduction process due its reliance on coal, as well as from high-temperature combustion based on natural gas.

H2GS is pursuing a 5-step process to achieve green steelmaking *(see sidebar for H2GS's definition of "green steel"):*

Step 1: Giga-scale Electrolysis-

Using fossil-free electricity to decompose water into hydrogen and produce enough hydrogen to make 5 million tonnes of high-quality steel annually by 2030.

Step 2: Hydrogen-based Direct Reduction-

Using green hydrogen instead of coal or natural gas to react with oxygen in iron oxide pellets to produce highly metallized direct reduced iron (DRI) for steelmaking with steam as the residual, thus reducing CO_2 emissions by more than 95%.

Step 3: Electric arc furnace (EAF) Steelmaking-

Using fossil-free electricity to heat DRI and steel scrap to create liquid steel, with contained carbon in the slag playing an important role in lowering electricity consumption and enabling the transformation of iron to steel.

Step 4: Continuous Casting and Rolling-

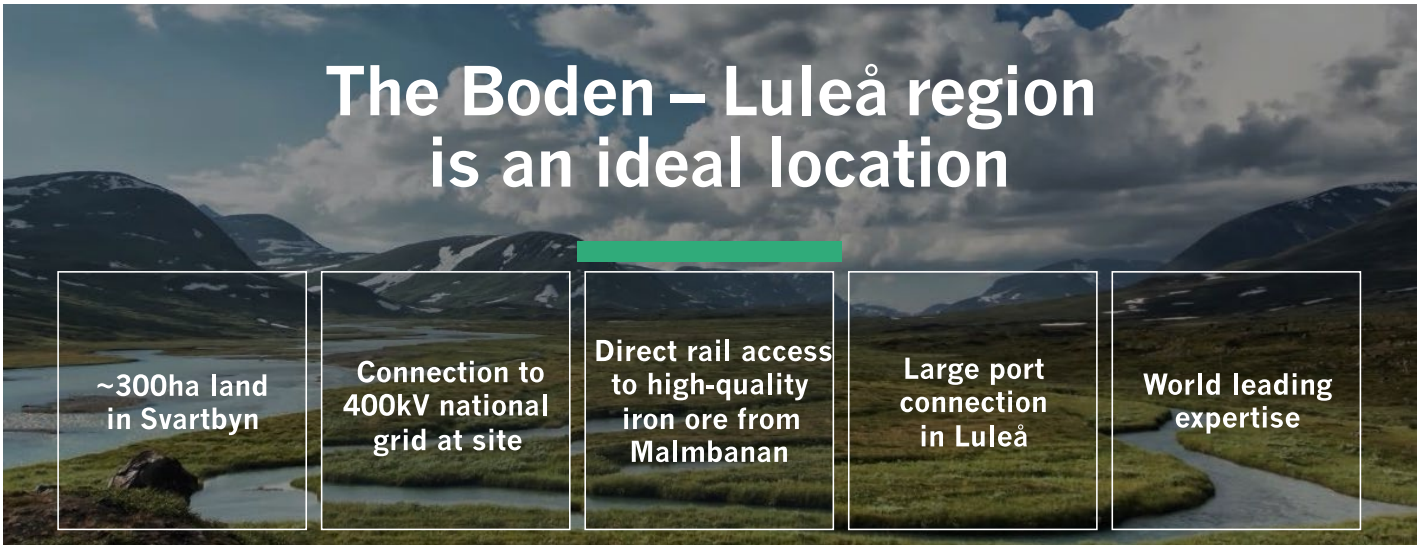
Allowing energy consumption to be reduced 70% and replacing natural gas in the traditional process.

Step 5: Downstream Finishing Lines-

Cold rolling, annealing, and hot-dip galvanizing for adjusting steel thickness, creating desired mechanical properties, and protecting against corrosion, respectively.

WHY CHOOSE BODEN

H2GS is building its first factory in Boden, a town 45 miles south of the Arctic Circle in the north of Sweden, in an area with one of Europe's lowest energy costs. Green electricity is one of Boden's biggest enablers and makes up about 90% of the energy mix. The cost of electricity is at a level that helps make steel produced with hydrogen DRI competitive. The site will include



one of the biggest green hydrogen electrolysers, at 800MW, a MIDREX H2™ DRI plant, and a downstream steel mill supplied by the SMS Group.

Work is underway at the site, with the intention of installing roads and building temporary office space and housing for construction workers before the onset of winter 2022. A direct rail line will connect the Boden site to Luleå port, which will be able to accommodate ships equipped for icebreaking to ensure year-round operations. The steel mill will have 1,200-1,400 employees to produce 2.5 million tonnes of steel products.

Boden will be H2GS's first lighthouse project. We see our project as equally an investment in green steel and as a building block for a green society, making the Norrbotten region a world-leader in fossil-free steel production.

A TRANSFORMATION COMPANY WITH STEEL AS A PART OF IT

H2GS's initial notion was that its steel project would only target vehicle makers since the auto sector was ready to pay a green premium. However, since then the company has expanded its horizon, as the impact and influence of decarbonisation continues to take hold globally.

What we do and strive to comprehend is not just the customer and the customer's business but also the customer's customer. And this is something that we are incorporating into our work with green steel as well. So, yes, the customers are on board and quite a wide range of customers, too. They are not just automotive and vehicle manufacturers, but also white goods & industrial equipment manufacturers that are prepared to pay a higher price for green steel for the future of our planet.

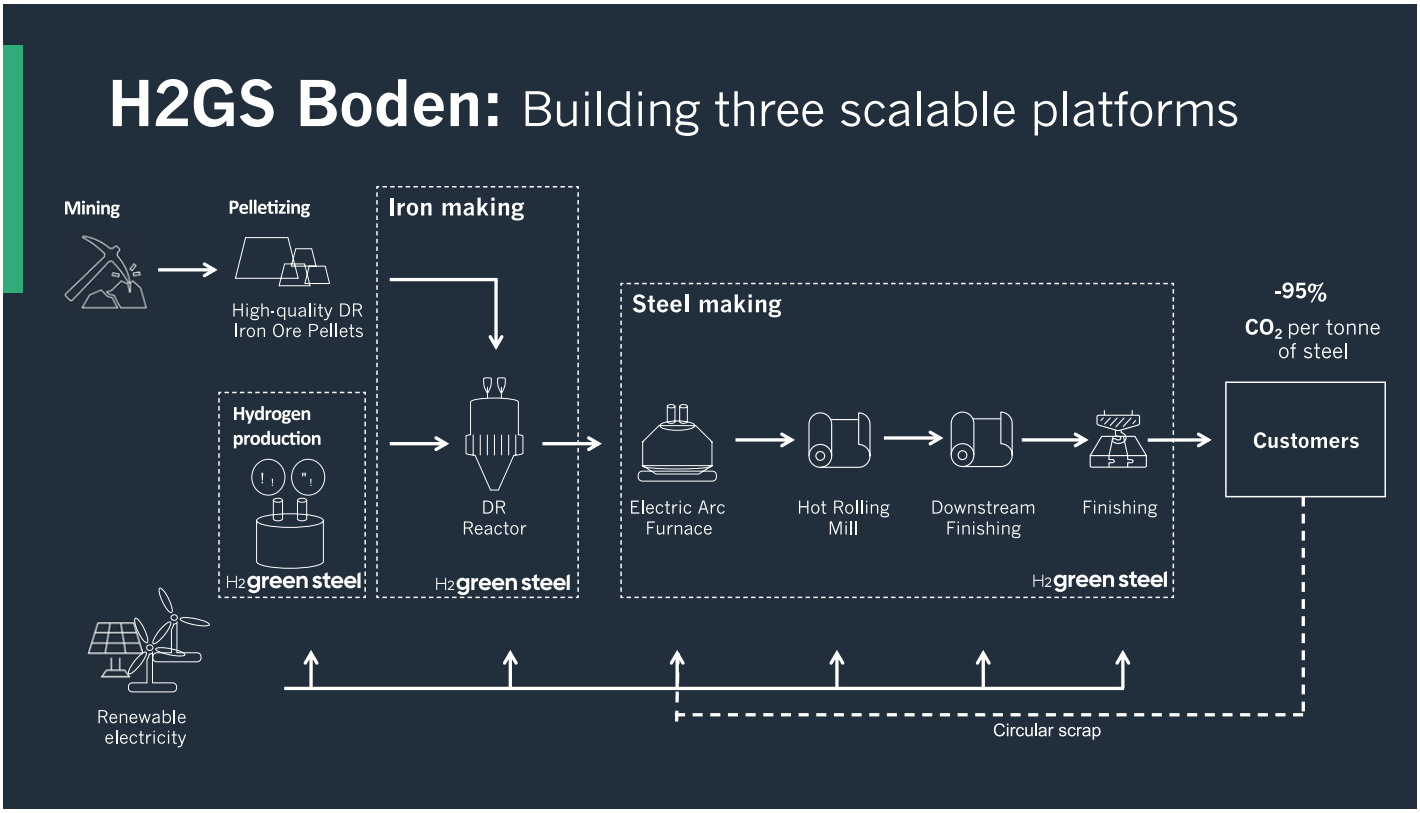
As a clear sign of a strong customer demand for green steel, H2GS has already signed long-term offtake supply agreements for over 1.5 million tonnes of steel that we will produce from 2025 onwards.

Pre-sold green steel

1,5 mt

Customers include:

- Adient
- BE Group
- BILSTEIN GROUP
- BMW Group
- Electrolux
- Kingspan
- Klöckner & Co
- Lindab
- Marcegaglia
- Mercedes-Benz
- Miele
- Mubea
- Purmo Group
- Roba Metals
- Scania
- Schaeffler
- Welser
- Zekelman Industries
- ZF Group



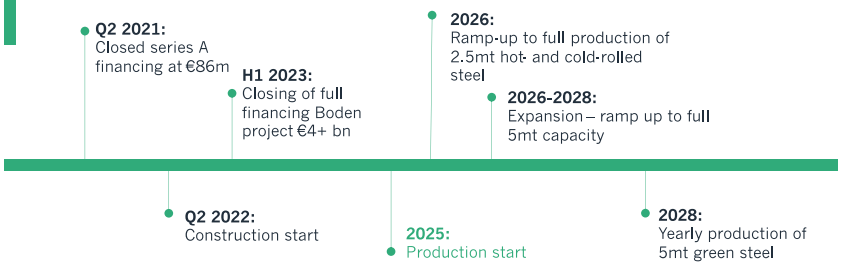
STRENGTHENING THE VALUE CHAIN

To establish a clean hydrogen-based steel ecosystem, the creation of a value chain is crucial. The ecosystem also requires the efforts of renewable energy, clean hydrogen, and technology solution providers, as well as the downstream consumer side to further reduce costs and develop markets.

Hydrogen-based steel production, especially with green hydrogen, is one of the most promising solutions for steel industry decarbonization, considering both clean efficiency and technology maturity. This route has nearly full potential of decarbonization and has been piloted by several steel companies.

The H2 Green Steel site will be a close to 300 hectares greenfield project in Boden in the Swedish Norbotten region. The plant is expected to produce green steel by 2025, ramping up volumes in 2026.

Ramp up to 5mt of green steel by 2030



H2 Green Steel recently announced a signed agreement with Midrex Technologies, Inc. (Midrex) and Paul Wurth, an SMS Group company to supply the world's first commercial 100% hydrogen direct reduced iron plant. MIDREX H2 is ironmaking technology for the new era, which will utilize green hydrogen produced from renewable energy to reduce iron ore. The DRI plant will have a yearly production capacity of 2,1 million tonnes of hot DRI and hot briquetted iron (HBI), which will feed the production of initially 2,5 million tonnes of green steel.

We are H2 Green Steel

H2 Green Steel will build a 5 Mtpa green steel production facility in Boden, Sweden…

…powered by a 800MW electrolyser producing green hydrogen

The facility will produce steel with a ~95% lower CO2 footprint

2.5Mtpa Phase I production	2025 start of production	Close customer partnerships

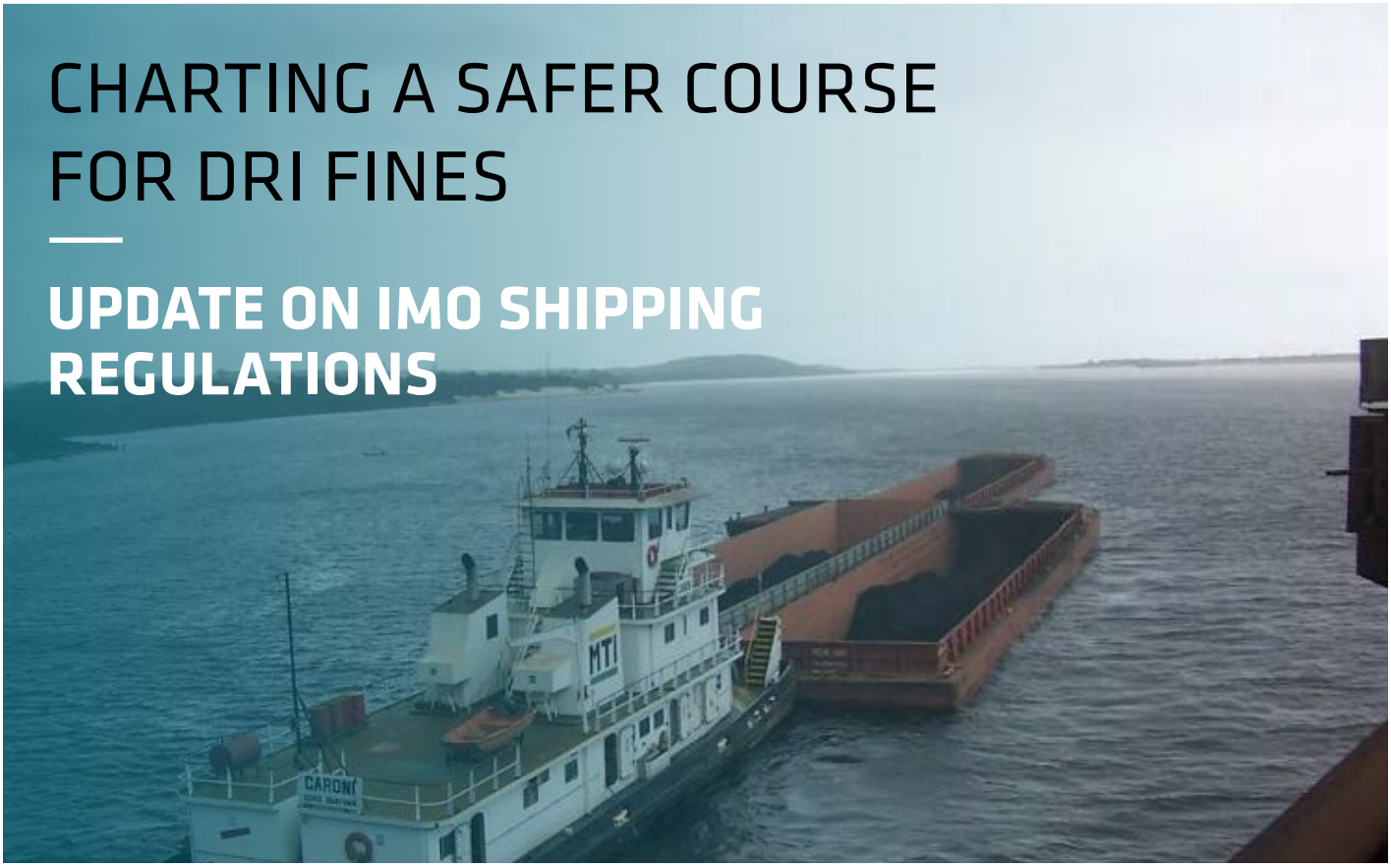
SMS Group will supply process technology for the world's first large-scale green steel production plant including an electric arc furnace (EAF) melt shop, continuous casting and a hot rolling plant, as well as an advanced cold rolling and processing complex for the production of advanced high strength steel and automotive steel grades.

H2 GREEN STEEL'S DEFINITION OF GREEN STEEL

"Green Steel must be produced from a combination of a significant amount of green virgin iron and scrap in a production process which uses electricity from renewable energy sources. The total emissions in such a process must be more than 90% lower than that of traditional steelmaking [using] a blast furnace [for the ironmaking step]."

CHARTING A SAFER COURSE FOR DRI FINES

UPDATE ON IMO SHIPPING REGULATIONS



By CHRIS BARRINGTON, *Chief Advisor, International Iron Metallics Association (IIMA)*

INTRODUCTION

The 3Q2021 edition of DFM included my article, "The IMSBC Code: Regulatory framework for international shipment of solid bulk cargoes," which first of all provided background information about the International Maritime Organisation (IMO) and the International Maritime Solid Bulk Cargoes Code (IMSBC Code) and then explained the IMSBC Code's relevance to the various forms of DRI:

- Direct Reduced Iron (A) Briquettes, hot-moulded
- Direct Reduced Iron (B) Lumps, pellets, cold-moulded briquettes
- Direct Reduced Iron (C) By-product fines

Of the three forms of DRI, DRI Fines have been the most actively discussed in recent years, currently included in the IMSBC Code only by the largely unrepresentative schedule for DRI (C). Therefore, this article will present the current state of this discussion and the solution that has been accepted in principle, i.e. the proposed schedule for DRI (D) (By-product fines with moisture at least 2%), which will provide a mandatory legal instrument governing international maritime shipment of DRI Fines and ensure shipment in the safest manner possible.

CURRENT IMSBC CODE DRI (C) SCHEDULE

→ **DRI (C):** A porous, black/grey metallic material generated as a by-product of the manufacturing and handling processes of DRI (A) and/or DRI (B). The density of DRI (C) is less than 5,000 kg/m^3. A loading requirement for DRI (C) is that the moisture content shall not exceed 0.3%.

CURRENT IMSBC CODE DRI (C) SCHEDULE

→ **Hazard:** Temporary increase in temperature of about 300 C due to self-heating may be expected after material handling in bulk. There is a risk of overheating, fire and explosion during transport. This cargo reacts with air and with fresh water or seawater to produce hydrogen and heat. Hydrogen is a flammable gas that can form an explosive mixture when mixed with air in concentrations above 4% by volume. Cargo heating may generate very high temperatures that are sufficient to lead to self-heating, auto-ignition, and explosion. Oxygen in cargo spaces and in enclosed adjacent spaces may be depleted. Flammable gas may also build up in these spaces. All precautions shall be taken when entering cargo and enclosed adjacent spaces. The reactivity of this cargo is extremely difficult to assess due to the nature of the material that can be included in the category. A worst-case scenario should therefore be assumed at all times.

ONGOING DEBATE OVER DRI FINES

With respect to DRI Fines, it is important to note that the vast majority of shipments of this material contain moisture content greater than the maximum 0.3% required for carriage of DRI (C), typically 5-6%, but less than the Transportable Moisture Limit, (TML). For such material, the principal hazard is evolution of hydrogen rather than self-heating. Therefore, shipments have for many years and continue to be covered by exemptions in accordance with Section 1.5 of the IMSBC Code which permit the higher moisture content and require mechanical surface ventilation as the principal measure for dealing with the hydrogen hazard, a practice safely employed by the industry for many years.

The debate at the IMO about DRI Fines dates back to 2006, and despite attempts by the industry to introduce a schedule for DRI Fines with moisture content higher that 0.3%, the decision of the then Sub-Committee on Dangerous Goods, Solid Cargoes & Containers (DSC, now the Sub-Committee on Carriage of Cargoes and Containers [CCC]) was that DRI Fines should be treated in the same manner as DRI (B). Hence, the DRI (C) schedule was adopted with self-heating as the principal hazard and inerting cargo holds, usually with nitrogen, as the principal mitigation measure.

For the last 10 years or so, further attempts have been made at the IMO to introduce a new IMSBC Code schedule for DRI Fines with higher moisture, embodying mechanical surface ventilation as the principal mitigation measure. Concerns about the effectiveness of ventilation have been raised, as underlying this process are long memories of past incidents with DRI Fines, notably the tragic loss in 2004 of six lives and the M/V Ythan, a bulk carrier enroute from Venezuela to Asia with a full cargo of DRI Fines.

Industry, working collaboratively through IIMA since 2014, has co-operated with key national IMO delegations and affiliated NGOs (non-governmental organizations) in trying to find a workable solution, culminating in an agreement in principle in March 2022 to an updated draft schedule, designated DRI (D). This new schedule will be included as part of Amendment 07-23 to the IMSBC Code, which was referred to CCC and, in turn, to the subsequent E&T (Editorial & Technical Group) meeting for finalization. It is gratifying that the DRI (D) schedule survived this process intact and amendment 07-23 will be referred to the Maritime Safety Committee (MSC) for final approval.

Amendment 07-23 including the DRI (D) schedule, will become mandatory from 2025.

DRAFT SCHEDULE FOR DRI (D)

DIRECT REDUCED IRON (D)
By-product fines with moisture content of at least 2%

DESCRIPTION
Direct reduced iron (DRI) (D) is a porous, black/grey odourless metallic material generated as a by-product of the manufacturing and handling processes of DRI (A) hot-moulded briquettes and/or DRI (B) lumps, pellets and cold-moulded briquettes, which has been aged for at least 30 days prior to loading.

CHARACTERISTICS

Physical properties			
Size	Angle of repose	Bulk density (kg/m³)	Stowage factor (m³/t)
Fines and small particles with an average size less than 6.35 mm, particles larger than 12 mm not to exceed 3% by weight	Not applicable	1,850 to 3,300	0.30 to 0.54
Hazard classification			
Class	Subsidiary hazard(s)	MHB[2]	Group[3]
Not applicable	Not applicable	WF and/or SH	A and B

The basics of the schedule have not changed significantly during the process; i.e., the principal hazard being evolution of hydrogen, with the principal mitigation measure being mechanical surface ventilation. However, in order to move it forward, a number of generally value-added changes and modifications were introduced, the most significant of which are described below (the entire draft schedule runs 11 pages and can be downloaded from IIMA's website **https://www.metallics.org/logistics-guides.html.**

INTRODUCTION OF MINIMUM MOISTURE CONTENT OF 2%

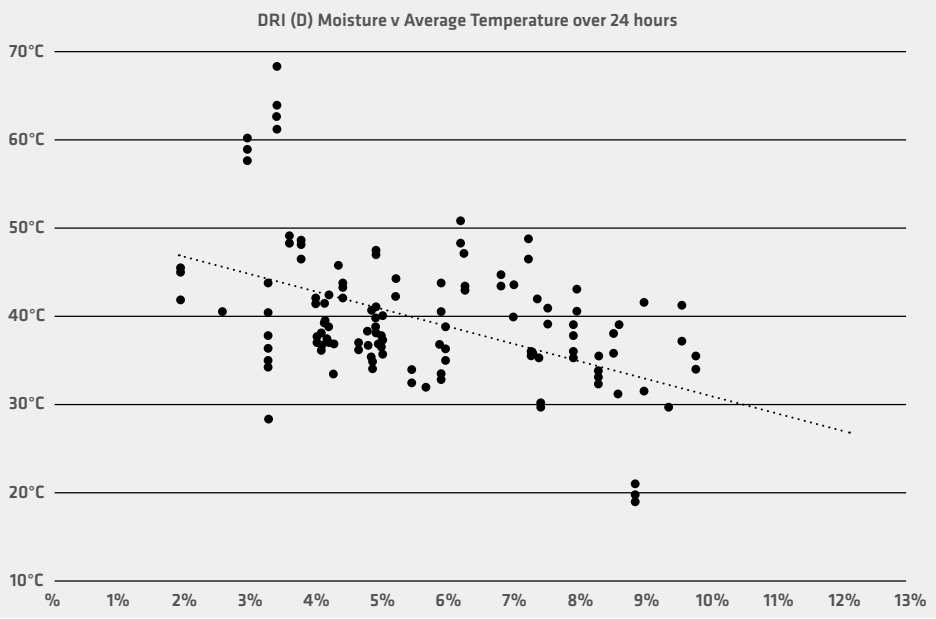
Behind this development was the premise that moisture contained in DRI Fines has an inhibiting effect on self-heating (as described in a paper submitted to DSC by IIMA , entitled "The effect of the seawater on DRI (C) hydrogen gas generation and on the self-heating of this cargo," based on experimental work in Venezuela). This premise occupied more than a little time at subsequent CCC/E&T meetings.

IIMA analysed a data base of actual shipments made between October 2016 and September 2018, which included:

- shipments totalling 1.085 million tons of DRI Fines
- moisture contents ranging from 2.0% up to 12.1%
- temperature measurements in 134 holds during 47 voyages on 18 different vessels
- average voyage length of 16 days (range 8 to 42 days)
- origins including Venezuela, Trinidad and Tobago, US, and Egypt

The results of this analysis with the following charts were presented to CCC in July 2020 with the following conclusions:

- There is a relationship between temperature and moisture content with a reduction in temperature as the moisture content increases.
- The analysis supports the proposed minimum moisture content of 2%.



REQUIREMENT FOR CERTIFICATION THAT THE CARGO DOES NOT MEET THE CRITERIA FOR CLASS 4.2 MATERIALS

The draft schedule requires this certificate to be provided by a competent person to the master of the vessel prior to loading a cargo. A class 4.2 material falls under the description "dangerous goods," Class 4.2 being a substance liable to spontaneous combustion (materials, other than pyrophoric materials, which in contact with air, without energy supply, are liable to self-heating). DRI (D) as currently shipped is not Class 4.2 (the relevant test being N-4 from the UN Manual of Tests and Criteria, Part III, Section 33.4.6)[6].

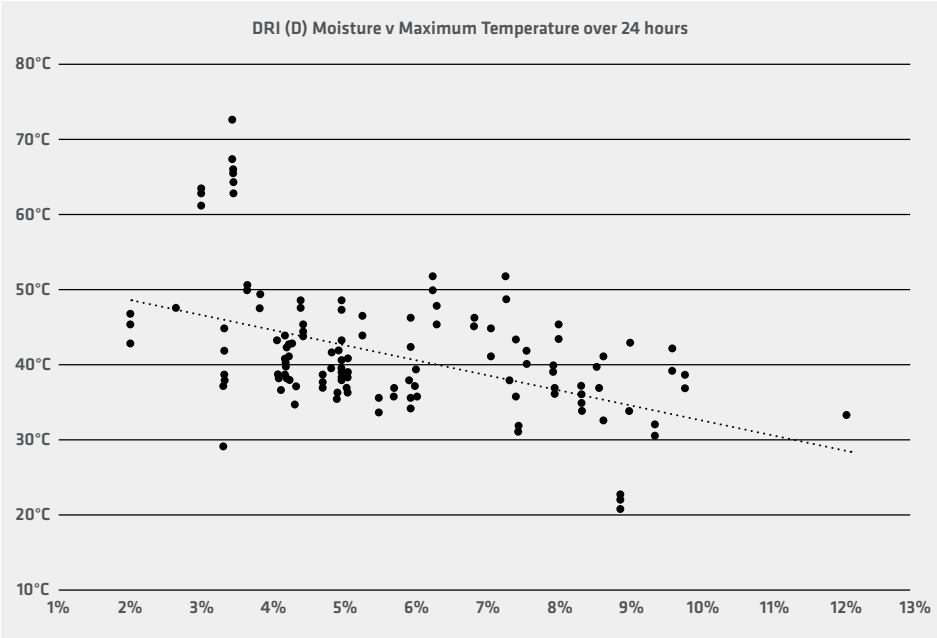
This addition to the draft schedule was a compromise with several member states whose concern was that, whilst the DRI (D) schedule is appropriate for DRI Fines as currently shipped, the material properties might change in the future such that the material becomes Class 4.2.

Shippers will need to find a practical, non-onerous means of providing the required certification.

ASPECTS OF DRI (D) SCHEDULE

Cargo Technician

It has been standard practice and indeed a requirement of exemptions to the IMSBC Code that an experienced cargo technician be on board the vessel during loading and throughout the voyage in order to assist with cargo monitoring and to provide advice as needed by the master of the vessel and crew. The mandatory requirement for a cargo technician was strongly opposed by some for various reasons and in the end, it was agreed that it would be recommendatory rather than mandatory.



IIMA regrets this development, which in effect is a compromise in the interest of progressing the draft schedule, and still strongly supports the appointment of a cargo technician. In the absence of appointment of a cargo technician, the master or a designated representative shall seek advice from the shipper or other competent person.

Risk assessment

Prior to loading, the shipper shall provide the master of the vessel with comprehensive information about the risk of hydrogen evolution and the factors which affect the rate thereof. This risk assessment may include expected weather conditions, available information on the rate of hydrogen evolution for the cargo in question, vessel speed, availability and accessibility of ports of refuge enroute, and distance to the port of discharge.

The risk assessment, voyage plan, and weather routing, if adopted, shall be updated frequently during the voyage as updates on the weather, as well as actual hydrogen evolution rates, become available.

Ventilation requirements

The updated schedule requires that in order to minimize the possibility of the introduction of oxygen and moisture into the cargo holds, periods of surface ventilation shall be limited to the time necessary to remove hydrogen which may have accumulated in the cargo holds and to maintain the hydrogen concentration below 1% by volume (25% of the lower explosive limit, LEL). Previously, continuous mechanical ventilation was required.

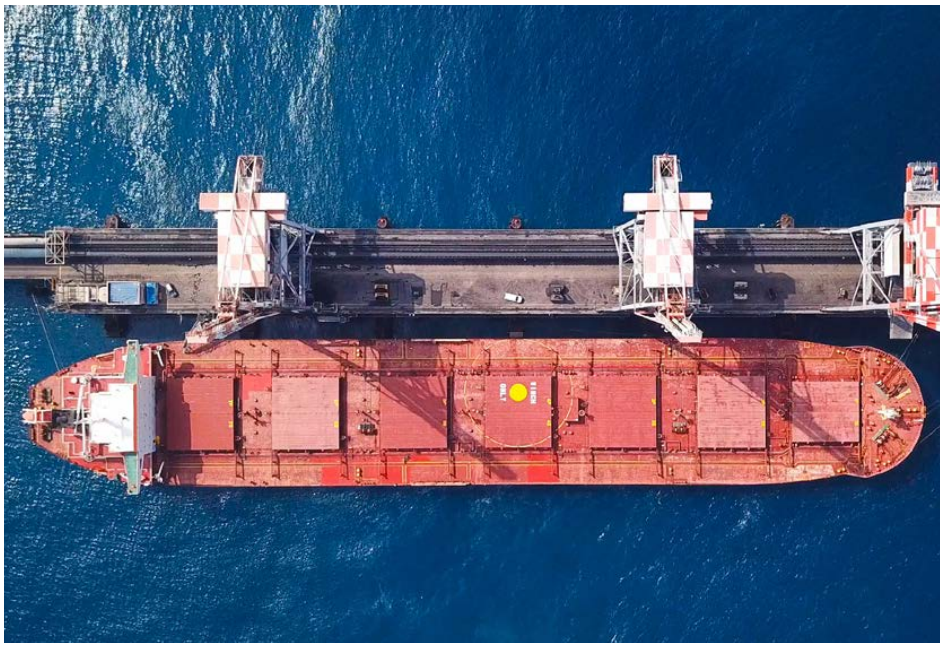
The operating period and frequency of the ventilation system shall be determined based on the measured hydrogen concentration and the indicated rate of increase/decrease thereof over time. Therefore, it is very important to establish a time-based gas prediction curve. Such curve shall be first determined prior to sailing and,

recognizing that conditions can change, updated from time to time during the voyage as may be appropriate, for example in the case of seawater intrusion into a hold carrying this cargo.

In order to develop such a curve, a cargo hold shall be ventilated until the hydrogen concentration falls to or below 0.2% by volume (5% LEL), then ventilation (both natural and mechanical) to such hold shall be stopped, and the hydrogen concentration measured every 2 hours thereafter for at least 24 hours or until it reaches 1% by volume, whichever occurs first. If the concentration reaches or exceeds 1% by volume, the respective cargo holds shall be ventilated and measurements continued to ensure that the concentration of hydrogen has stabilized and remains sustainably at or below 0.2% by volume (5% LEL).

CONCLUSION

With one more step to go in the IMO process, i.e., approval of amendment 07-23 to the IMSBC Code by the Maritime Safety Committee at its 107th meeting in June 2023, this particular task is nearing its conclusion. In 2025 the amendment will become mandatory (with voluntary adoption from 2024) and as such will (a) provide a global legal instrument governing maritime shipment of DRI Fines with at least 2% moisture and (b) obviate the need for exemptions. IIMA has long championed the need for such a mandatory instrument and the need for global compliance – the industry can ill afford the reputational damage that would result from another unfortunate incident.



The DRI (C) schedule will remain in the IMSBC Code in order to provide a basis for the very rare shipments of DRI Fines with moisture content of up to 0.3%.

The question then arises about how to deal with DRI Fines with moisture content above 0.3% and less than 2%. The short answer to this is that maritime transport of such material will not be legal without an exemption and should better be dealt with by producers through improved in-plant storage measures, etc.

Whilst recycling of DRI Fines by the producer is an ideal solution, this is not always an economic proposition and maritime shipment will certainly continue and even grow as production of DRI increases along the pathway to decarbonization of steel production.

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Author's note (cbarrington@metallics.org):

I would like to acknowledge the enormous contribution of IIMA's DRI Fines team, comprised of DRI producers, shippers, cargo technicians, and other experts, shipping companies, etc. I also want to acknowledge with grateful thanks the assistance, advice, and co-sponsorship of the DRI (D) schedule from Belgium, Canada, the United States, and the NGOs – BIMCO, ICS, Intercargo, and the International Group of P&I Clubs.

Midrex News & Views

The full news articles are available on **www.midrex.com**

Midrex and Paul Wurth Selected by H2 Green Steel

100% green Hydrogen to produce 2.1 million tons of DRI per year

Midrex and Paul Wurth, an SMS Group company, have signed an agreement with H2 Green Steel to supply the world's first commercial 100% hydrogen-based direct reduced iron (DRI) plant. The 2.1 million tons per year MIDREX H2™ Plant will be located in Boden, northern Sweden. H2 Green Steel will produce green steel, reducing CO_2 emissions by up to 95% compared to traditional steelmaking by replacing coal with green hydrogen produced by renewable electricity. Water and heat are the primary emissions from the plant, which is expected to begin production in 2025 and ramp up during 2026.

H2 Green Steel DRI plant rendering, Boden, Sweden

Midrex News & Views

The full news articles are available on **www.midrex.com**

MIDREX® Plants with 4th Quarter Anniversaries

Midrex is known for designing, engineering, and servicing reliable direct reduction plants, as well as for making certain that these plants have long and successful operating lives. This issue of ***Direct From Midrex*** recognizes the start-ups of Hadeed B (Saudi Iron & Steel Company) in Al Jubail, Saudi Arabia (40 years), OEMK IV (Oskol Electrometallurgical Kombinat) in Stary Oskol, Russia (35 years), LISCO 3 (Libyan Iron & Steel Company) in Misurata, Libya (25 years), LGOK HBI-2 (Lebedinsky GOK) in Gubkin, Russia (15 years), and DRIC I (Direct Reduction Iron Company) in Damman, Saudi Arabia (15 years).

Hadeed B (Saudi Iron & Steel Company)

Started up 40 years ago in the 4th Quarter
Location: Al Jubail, Saudi Arabia
DR plant: MIDREX® (I of 4 modules)
- Start-up: December 1982
- Flowsheet: MIDREX NG™
- Product: CDRI
- Capacity: 0.4 M tons

Hadeed (Saudi Iron and Steel Company) is a fully-owned affiliate of Saudi Basic Industries Corporation (SABIC). It began operating in 1979 and added two MIDREX® DR Modules in 1982-83 (Hadeed A & B), a third in 1992 (Hadeed C), and a dual discharge HDRI/CDRI module (Module E) in 2007.

Although originally rated at 0.4 million tons/year, Hadeed B has averaged more than 0.6 million tons/year in its 40 years of operation. Two reformer bays were added in 1997, and thin wall refractory was installed in the shaft furnace in 2011.

Read more about Hadeed at:
http://www.hadeed.com.sa/

Oskol Electrometallurgical Kombinat Module IV

Started up 35 years ago in the 4th Quarter
Location: Stary Oskol, Russia
DR plant: MIDREX® (I of 4 modules)
- Start-up: December 1987
- Flowsheet: MIDREX NG™
- Product: CDRI
- Capacity: 0.4 M tons

Oskol Electrometallurgical Kombinat (OEMK), one of the world's largest direct reduction/electric arc furnace (DR/EAF) steel mills, is located in Stary Oskol, Belgorod Region, Russia, 600 kilometers south of Moscow near Kursk. The first of four MIDREX® Direct Reduction Modules owned and operated by OEMK was started up in December 1983, followed by Module II in December 1985, Module III in January 1987, and Module IV in December 1987.

Through 2021, OEMK IV has produced more than 18.5 million tons of DRI, which is an annual average of almost 528,600 tons by a module originally designed for 400,000 tons per year.

OEMK is owned by Metalloinvest, the global leader in merchant HBI production and Russia's largest iron ore company. Read more at:
https://www.metalloinvest.com/en/business/steel/oemk/

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MIDREX® Plants with 4th Quarter Anniversaries
(continued)

LISCO 3 (Libyan Iron & Steel Company)

Started up 25 years ago in the 4th Quarter
Location: Misurata, Libya
DR plant: MIDREX® (I of 3 modules)
- Start-up: November 1997
- Flowsheet: MIDREX NG™ with hot briquetting
- Product: HBI
- Capacity: 0.65 M tons

Libyan Iron & Steel Company (LISCO) owns and operates two MIDREX Modules that have a combined annual rated capacity of 1.1 million tons of cold DRI (CDRI) and LISCO 3, which is rated at 0.65 million tons/year of HBI. LISCO 3 was the first HBI plant to be built in North Africa and has become an important supplier to Western Europe and Turkey.

The integrated DR-EAF works began production in September 1989 and produces a wide variety of steel products including bars, rods, large & medium sections, and hot & cold-rolled strip.

Read more about Libyan Iron & Steel Company (LISCO) at:
https://libyansteel.com/

Lebedinsky GOK HBI-2

Started up 15 years ago in the 4th Quarter
Location: Gubkin, Belgorod Region, Russia
DR plant: MIDREX® (I of 2 modules)
- Start-up: October 2007
- Flowsheet: MIDREX NG™ with hot briquetting
- Product: HBI
- Capacity: 1.4 M tons

Lebedinsky GOK (LGOK) is located astride the Kursk Magnetic Anomaly (iron ore naturally containing 60% iron), in Gubkin, Belgorod Region, Russia. LGOK operates three HBI plants: two MIDREX® Process and one HYL ENERGIRON. The MIDREX Plants were started up in October 2007 (HBI-2) and March 2017 (HBI-3).

Through 2021, LGOK HBI-2 has produced almost 21.1 million tons of HBI with metallization averaging 94.1%. In late 2021, Metalloinvest awarded a contract for Lebedinsky HBI-4 to Midrex and its construction partner, Primetals Technologies.

Read more about Lebedinsky GOK at:
https://www.metalloinvest.com/en/business/steel/lgok/

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MIDREX® Plants with 4th Quarter Anniversaries
(continued)

Direct Reduction Iron Company (DRIC 1)

Started up 15 years ago in the 4th Quarter
Location: Damman, Saudi Arabia
DR plant: MIDREX® (1 of 2)
- Start-up: December 2007
- Flowsheet: MIDREX NG™
- Product: CDRI
- Capacity: 0.5 M tons

The two modules owned and operated by Direct Reduction Iron Company Ltd. Were first started up in 1979 for British Steel Corporation in Hunterston, Scotland. The modules were relocated to Mobile, Alabama, USA, in 1997 for Tuscaloosa Steel. The Al-Tuwairqi Group acquired in 2004 and relocated the two module plant to its current location in Damman, Saudi Arabia.

DRIC 1 produced 5.7 million tons of DRI in 2021, and with DRIC 2, which began operation in May 2007, have produced 11.6 million tons.

DRIC is a subsidiary of Arab Steel Company, which is part of Al Ittefaq Steel Company (ISPC). Read more about DRIC and Arab Steel Co. on the Al Ittefaq Steel Co. (ISPC) website: **https://www.ispc.com.sa**

Midrex Establishes Engineering Center in India
Jim Lewis Named General Manager

JIM LEWIS

With the increased interest in direct reduction as the preferred ironmaking process for decarbonizing steel production, Midrex is setting up an engineering center in India. The strategic objective is to position Midrex engineering resources globally to better serve the growing demand for MIDREX® Plants. The engineering center will operate from the offices of Midrex India near New Delhi.

Jim Lewis, who rejoined Midrex in 2019 as a Senior Research Engineer at the Research & Technology Development Center, has been chosen to lead Midrex India Engineering as general manager. Prior to returning to Midrex, he owned and operated Coastal River Engineering, PLLC, a multi-disciplinary engineering company that provided mechanical engineering services for several Midrex projects including LGOK HBI-3, Lion, and Qatar Steel 2 and field commissioning services for the ESISCO, JSPL Angul, Lion, Shadeed, Tosyali I, and TSM (Tuwairqi Steel Mills Ltd.) MIDREX Plants.

Lewis, who serves as Process Coach for the Midrex Innovation Team, will look to establish a similar team in the Midrex India Engineering operation.

(Editor's note: See the Commentary in this issue by Jim Lewis on the benefits of Innovation Engineering within Midrex Technologies)

Lauren Lorraine: **Editor**

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The processes and equipment depicted in this material are subject to multiple patents and patents pending in the U.S. and internationally.

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