CANADIAN
CONSULTING
ENGINEERING
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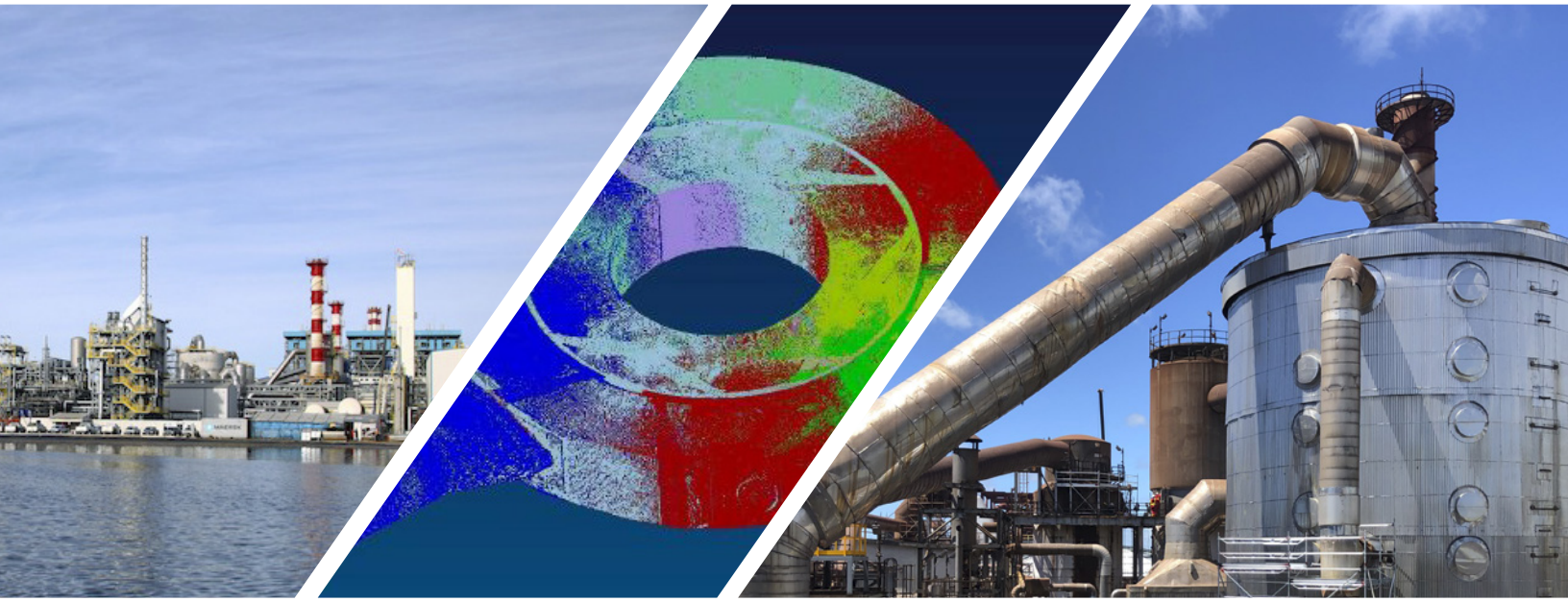
CATEGORY
NATURAL RESOURCES, MINING,
INDUSTRY AND ENERGY

# INNOVATIVE REFURBISHMENT OF ACID PLANT CONVERTERS

**Client : Ambatovy**
Major Industrial Operation Mining
and Refining Nickel and Cobalt in Madagascar



NORDA STELO
COLLECTIVE INGENUITY

## PROJECT SUMMARY

Ambatovy is a large-scale nickel and cobalt mining operation on the East coast of Madagascar. When the two converters at their acid plant suffered heavy damage in 2016, Ambatovy engaged Norda Stelo to engineer repair solutions that would minimize down time. By analyzing the structural behaviour of the equipment and understanding the damage mechanism, Norda Stelo implemented solutions allowing not only to maintain the converters in operation, but to extend their lifespan.

# INNOVATION

## AMBATOVY RUNS A "CONTACT PROCESS" ACID PLANT WHERE SULPHURIC ACID IS PRODUCED FOR PROCESSING NICKEL AND COBALT ORE.

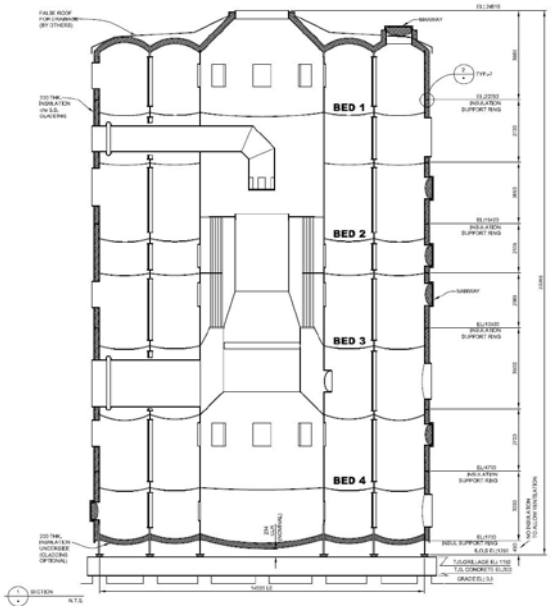
In this three-step process: sulphur combustion produces $SO_2$, which is then converted to $SO_3$ (through a gas converter), which reacts with water to create sulphuric acid. Each converter is therefore critical, and consists of a stainless-steel vessel, 25 m high, 14 m diameter, with complex internals and multiple ducts. In 2016, the roof posts of the two converters failed under thermal and pressure constraints, putting the whole plant operation at risk.

After assisting for immediate temporary repairs, Norda Stelo presented an action plan for solutions permitting uninterrupted operation of the converters at a minimal cost.

Rather than opting for the straightforward but costly solution of replacing the entire roof, Ambatovy retained Norda's engineering approach with the aim of repairing and extending the converters' lifespan.

Norda's innovative proposition was to undertake applied studies combining asset integrity assessment processes with innovative technologies and methodologies. Consisting in a series of subsequent steps, the engineering primarily focussed on understanding the reasons and mechanisms for failure; prior to identify, design, model and verify solutions.

We first conducted a Root Cause Failure Analysis (RCFA) based on construction documents and operation data. This revealed conceptual and material selection errors, making the roof unable to withstand design stresses. A digital model of the converter was created and used to perform a Finite Element Analysis (FEA) based on the undisturbed roof structure, which showed an unexpected stress distribution pattern. On this basis, the design of the temporary repairs was improved for implementation at earliest shutdown, allowing operation until a secure permanent solution could be identified.

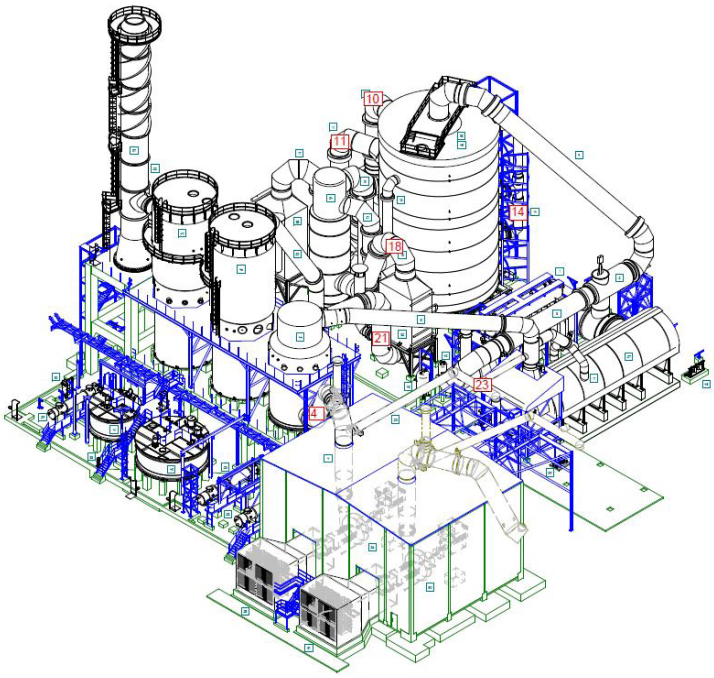



Converter Cross-Section

During shutdown, samples of the failed posts were collected for metallographic analysis, and a 3D laser scan of the roof was executed, allowing completion of the RCFA with the validation of both stress distribution and failure mechanism. This scan was used to create a digital model of the damaged converter, for which another FEA verified the operability, providing the posts were reattached.

We then designed secondary posts to secure and reinforce the deformed converter's roof, extending its lifespan. Additional FEA and simulations of stop/start scenarios verified impacts of modifications and ensured converter integrity.

Our permanent solution was refined with Ambatovy for constructability and was successfully implemented in one converter in 2021.




Acid Plant with Converter (#10)

Damaged Converter (2016)

Restored Converter (2021)

# COMPLEXITY

THIS PROJECT INVOLVED STABILISING AND IMPROVING A CRITICAL PROCESS EQUIPMENT WHILE RESPECTING THE CONTINUITY OF OPERATIONS AND LIMITING MAJOR INTERVENTIONS TO PLANNED SHUTDOWNS.

With the aim of keeping the roof of the converters for future operation, Norda Stelo needed to gather accurate information about the altered structure, in order to proceed with the verification of both its structural functioning and its structural integrity.

Norda Stelo resolved the problematic by undertaking what could be qualified as a "digital reverse engineering process".

Taking the opportunity of a shut down on one of the two converters, Norda Stelo performed a 3D laser scan of the deformed roof level.

The rendered point cloud was then processed to create a digital model of the damaged converter. This model permitted to execute a realistic Finite Element Analysis (FEA), with several simulations factoring in mechanical and thermal constraints. The results allowed us to evaluate and validate the optimal repair solution, and eventually confirmed that the roof did not need to be replaced.

Another challenging aspect of the project was the geographical dispersal of the project stakeholders and the need to facilitate collaboration across multiple time zones.

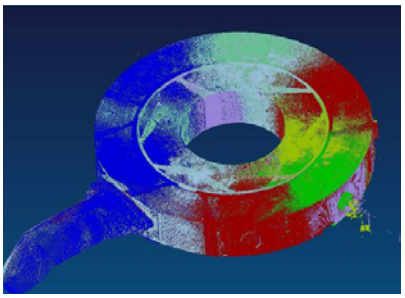
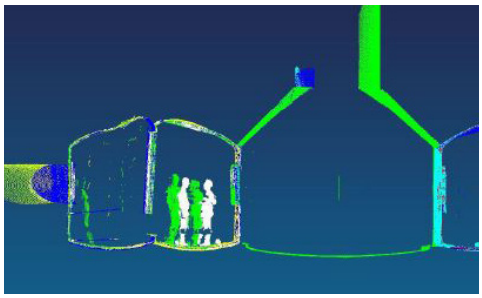
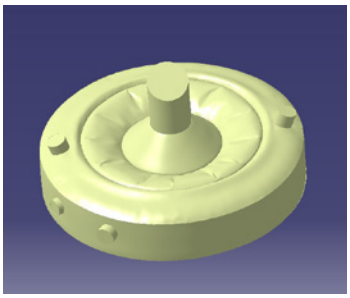
- Norda Stelo being personnel both on site in Madagascar and in the province of Quebec;
- the Original Equipment Manufacturer (OEM) being in British Columbia;
- the specialised laser scan team out ofhaving been called from Mauritius;
- the fabricator for the repair solution in South Africa.

**Project Development Sequence**

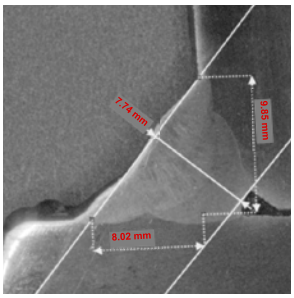
1. **Failed Posts of Roof**

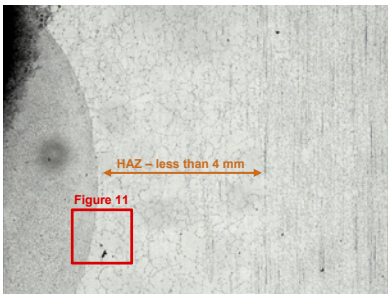
## Project Development Sequence (continued)

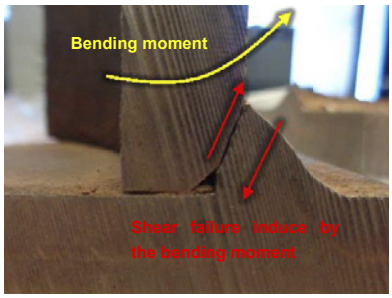
### 2. 3D Scan Renderings

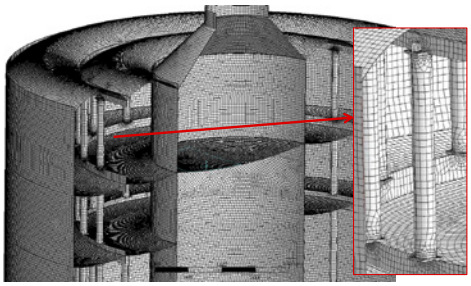
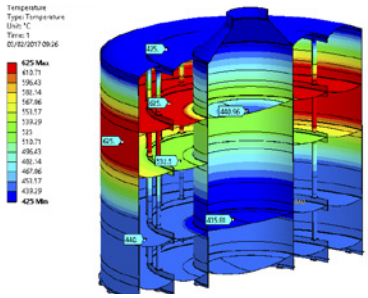
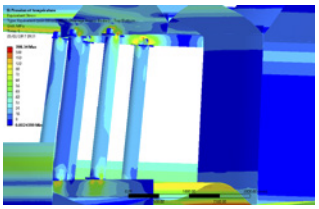
### 3. Metallography and RCFA



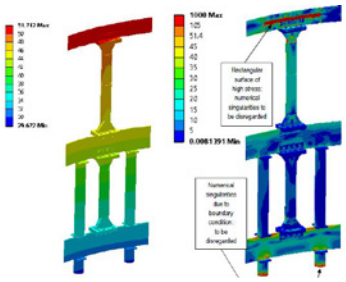
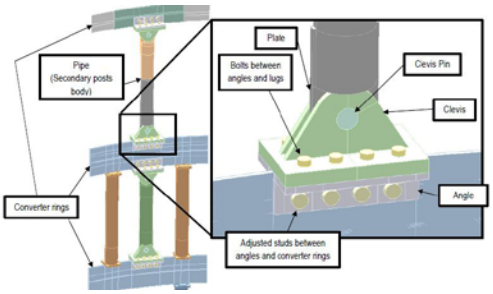





### 4. Model, FEA and Simulation

### 5. Engineering of Solutions

# SOCIAL AND ECONOMIC BENEFITS

THE INTERACTION BETWEEN NORDA STELO AND CLIENT STAFF WAS MUTUALLY ENRICHING IN MANY WAYS. OUR INITIAL INPUT TO IDENTIFY A SHORT-TERM SOLUTION CARRIED OVER TO HELP THE CLIENT ON A STEP-BY-STEP PROCESS TOWARDS AN UNUSUAL PATH–OTHER THAN REPLACING THE CONVERTER ROOF.

This paradigm shift allowed us to integrate the client's priorities, while sharing our approach stemming from our raison d'être: Norda Stelo's vision is focused on asset durability in the service of our partners, the community, and the planet.

Not only was our proposed approach more durable, but it was also less costly than replacing the converter roof.

Indeed, this assistance took place over a long period of time, with the simultaneous presence of the project team in Canada and on site in Madagascar. Thus, the interactions and continuous involvement of Ambatovy's staff allowed for an extraordinary transfer not only of skills and expertise, but also of principles: sharing and implementing the philosophy and methodologies of asset ownership and asset integrity management, with the overall goal of preservation and sustainability.

One economic impact of the project, although indirect, was that it permitted the uninterrupted production of metal at Ambatovy. This was of prime importance to both the local community and to the general economy of Madagascar.

Ambatovy is one of the largest lateritic nickel mines in the world with a production capacity of 60,000 tonnes of nickel and 5,600 tonnes of cobalt per year, making it the highest single source of employment and largest contributor to Madagascar's GDP.

# ENVIRONMENTAL BENEFITS

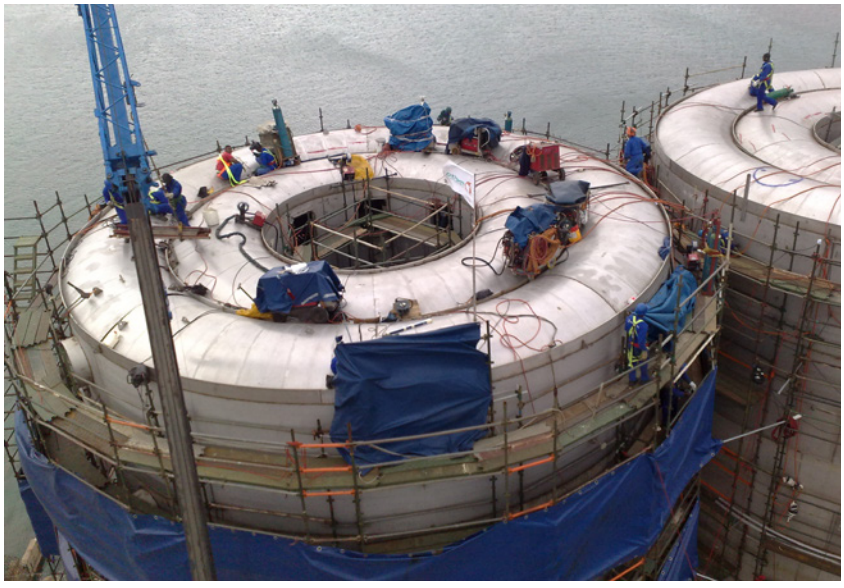
ALTHOUGH IT WAS NOT A PRIMARY OBJECTIVE OF THE PROJECT, AS A LEADER IN ASSET INTEGRITY MANAGEMENT, NORDA STELO UNDERTAKES ALL PROJECTS WITH A CONCERN FOR DURABILITY AND SUSTAINABILITY.

Having successfully investigated and engineered repair solutions allowing the converters to continue to be operated with minimal repairs, Norda Stelo avoided the replacement of a major part of the equipment. While straightforward and safe, the replacement option would have not only been more costly, but also environmentally detrimental.

Consisting of a hemispherical double arched stainless-steel structure, 14 meters in diameter and approximately 2 meters in height, the roof structure weighs around 53 tons. When considering the production of steel, the fabrication in China, the transportation to the plant, the removal of the damaged roof and the installation of the new one, Norda Stelo estimated the carbon footprint of the replacement operation to a Green House Gases (GHG) emission of 290 tons for the two converters. This is significantly higher than the GHG emissions of 90 tons estimated for the repairs engineered by Norda Stelo and implemented by Ambatovy.

By compensating for issues in the equipment's original design, the repair solution has significantly extended the durability of the converters, pushing further away the need for replacement and the associated emission of GHG.

Finally, the implementation of the engineered temporary solution, early in the project permitted to reduce mechanical stresses in the roof, thus avoiding recurrent cracks and correlated dangerous sulphur dioxide leaks into the environment.



Construction of the Original Converters

### Converter Roof Features

**53 tons**
IN WEIGHT

**14 meters**
IN DIAMETER

**2 meters**
IN HEIGHT

# MEETING CLIENT'S NEEDS

EACH OF THE TWO TRAINS OF THE ACID PLANT AT AMBATOVY HAS A NOMINAL PRODUCTION RATE OF 2,750 TONS/DAY OF SULPHURIC ACID, JUST HIGHER THAN REQUIRED TO PROCESS THE NICKEL/COBALT ORE.

Therefore, Ambatovy's main objectives in response to the failure of the two converters' roofs were to limit the outage of the sulphuric acid production, at best, and to avoid the total plant shutdown, at worst. Alternatively, the importation of sulphuric acid would have been a temporary solution, though costly and lengthy to implement.

Although of importance for Ambatovy, cost of remediation was not a significant criterion when compared to the cost of a production stoppage.

As a partner to its client, Norda Stelo was ready to immediately support Ambatovy in developing its own "quick fix" allowing operations to resume shortly after the incident. Following the preliminary RCFA, Norda Stelo determined the requirements for safe nominal operation, and designed temporary repairs in time for implementation at the earliest planned shutdown. This allowed Norda Stelo to develop the permanent solution, taking the opportunity of each planned shutdown of both converters to collect valuable data.

The permanent solution was implemented during another planned shutdown after refining its constructability with Ambatovy, to ensure installation would fit within the limited availability of the converter.

Rigorous engineering by Norda Stelo and close coordination with its client permitted a zero-downtime repair of the converters to the satisfaction of Ambatovy, furthermore at a relatively low cost and with minimal environmental impact.

Norda Stelo Engineers in Ambatovy

# APPENDIX

# NORDA STELO

Founded in Quebec in 1963, Norda Stelo is a privately owned Quebec engineering firm that operates worldwide. We have 16 offices in Canada, the United States and New Caledonia, including operations in Madagascar.

We employ close to 700 talents and carry out projects in some 50 countries. Norda Stelo specializes in the delivery of integrated projects and assists its clients at all mandate stages, from planning to operations; including design, implementation and construction management. To this end, we practice responsible management, develop cutting-edge expertise, and propose teams tailored to the needs and constraints of each client and each project.

Norda Stelo relies on its extensive expertise in port, rail and road transportation infrastructures, buildings or any other type of physical asset, as well as on its in-depth knowledge of the causes of aging components to offer an approach to asset durability that addresses technical, economic, operational, environmental and governance constraints.

Norda Stelo is deeply human and down to earth. Its commitment to quality, integrity, human relations and value creation is the pride of its employees and partners.

**Its mission**: Driving engineering through innovation. Together. Sustainably.

**Its vision**: Mobilizing our collective intelligence towards the sustainability of our partners' assets, our communities and the planet.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