

Pre-Outage and Off-Line Testing — Mitigating Risk in Outages

Nicole Altman¹, Zach Bloede², Katherine Brosky¹, Thomas Ruffner², Neil Tannyan¹

¹Hatch Associates Ltd.
1600 W Carson St. Pittsburgh, PA, USA, 15219
Phone +1 412 497 2000

²Client Confidential

ABSTRACT

This paper will discuss the testing of major pieces of mill equipment before outages utilizing temporary test rigs onsite, and its effects on outage schedule (and downtime), cost management, commissioning strategy, and contractor/operations/maintenance understanding. The paper will focus on the advantages of offline mechanical, electrical, and automation check outs of new mill stand equipment. The following sections detail the case study of long stroke hydraulic automatic gauge control (HAGC) cylinders to be installed in place of existing screw downs in a finishing mill, and the testing procedures, lessons learned, and other added benefits that come from pre-outage trial runs.

Keywords: Pre-Outage, Risk Mitigation, Scheduling, Cost Management, Commissioning Strategy

INTRODUCTION

Maximizing pre-outage activities benefits schedule in “brownfield” outage-based projects, where days of lost production can easily equate to millions of dollars. Outage schedules in operational shutdowns are extremely constrained, and planning and executing work prior to the outage rather than during the outage itself is essential. Beyond factory acceptance & functional testing, there are activities related to equipment such as flushing, electrical connections, pre-commissioning and automation testing, which can be performed pre-outage to eliminate time during the outage and start-up. This approach not only reduces risk in the outage itself, but also reduces the risk of problems after start-up during the ramp up allowing for a short time to achieve full production rates.

Further, these cylinder systems are not only a risk to production time and quality, but safety of the individuals working on and around them. This functional testing onsite allows to check that all the system connections can withstand high pressure requirements, verifies the automation fail safes are working properly, and provides the maintenance and operations teams reassurance on new equipment performance among many other benefits. Confirming these aspects of new equipment prior to outages overall, saves time during outages and mitigates safety risk during and post-outages.

This paper describes the pre-outage testing performed for the installation of three pairs of hydraulic automatic gauge control cylinders (HAGC) for a hot strip mill. The paper outlines test configuration, components and functionality tested or pre-commissioned, procedures, manpower, and the key achievements of the process. Ultimately, this paper will show that pre-outage testing of new major mill equipment mitigates many risks related to safety while improving installation, commissioning and start-up times.

BACKGROUND

In order to de-risk the installation and ensure the cylinders would function properly, a plan was developed to test the Cylinder functionality (stroke, and operation under high pressure), Level 1 and 2 controls and mill production shadowing. In addition, contractors craft personnel who would be involved in outage installation and mill operations and maintenance teams would be able to interact with the new equipment including assisting with installation in a simulated mill stand and functional processes.

TEST SET UP

The following sections describe the HAGC pre-outage test schedule, location, and procedures. At the initiation of the planning process, a schedule was developed (shown in Figure 1) to ensure there was sufficient time for setup preparation and testing procedures. The planning process started at the beginning of the 2022 and detailed the engineering requirements and components required to complete the tests.

The following constraints were considered:

- The outage was planned for October 2022
- Testing was to be completed 1 month prior to the outage to allow time for modifications and training.
- Lead times and construction schedule of certain test rig components also drove the schedule
- All three sets of cylinders, three valve stands, three PLC cabinets were planned to be tested.

The following milestones were achieved:

Milestone 1 – Month 3

- Plan Complete (including schedule, location, and responsibilities matrix)
- Specifications complete (equipment, labor support)

Milestone 2- Month 5

- Equipment Fabricated and Delivered
- Contractors Mobilized
- Begin Assembling test equipment

Milestone 3- Month 6

- Functional tests completed
- Begin shadowing

Milestone 4- Month 9

- Testing Complete

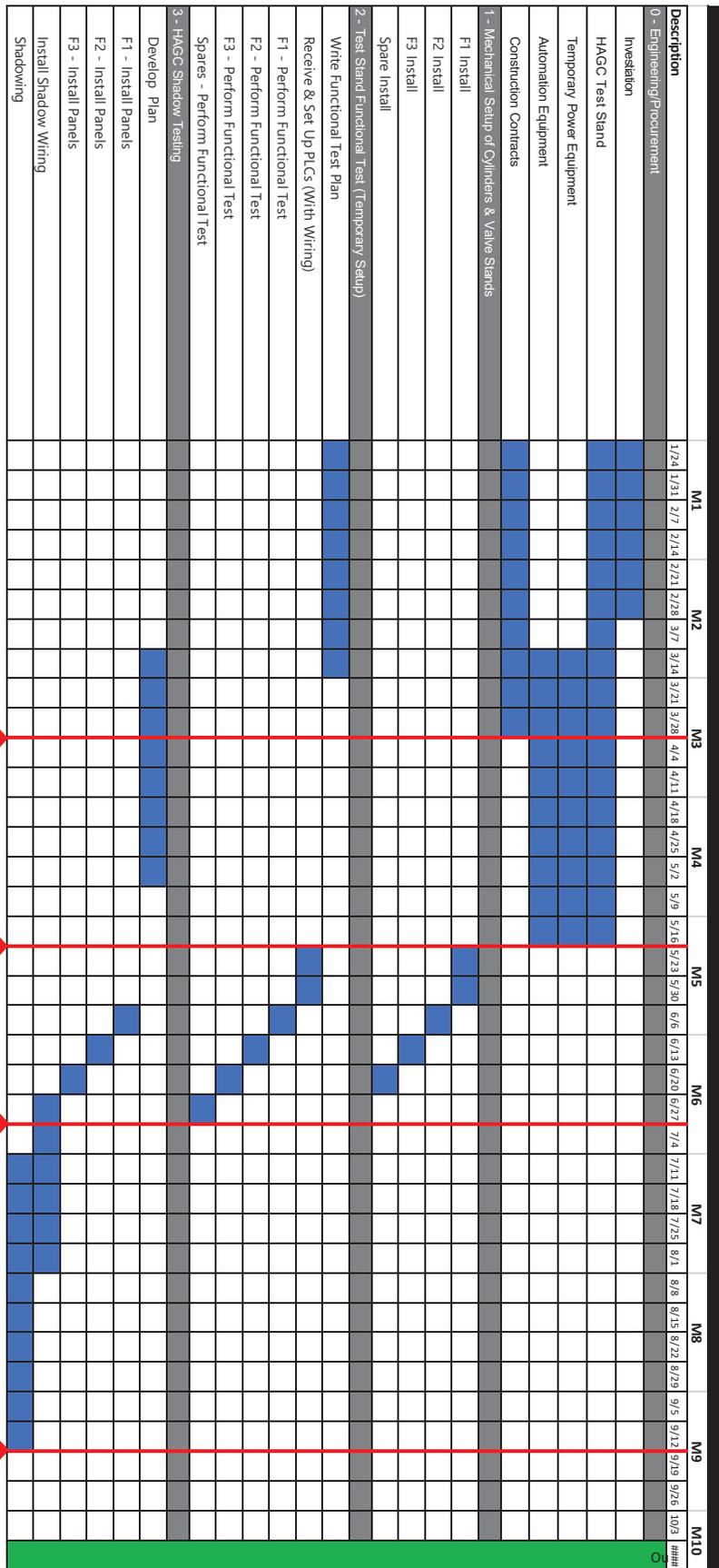


Figure 1. Sample schedule.

TEST LOCATION INVESTIGATION

One of the first challenges when planning this type of testing at an operation facility is finding a suitable location for testing. The cylinders, weighing 12 tons each, required forklifts with turning radii that dictated a 45 ft x 40 ft footprint for installation and tear down. Most areas that can accommodate such a turning radius were occupied and those that were available did not have the cleanliness or infrastructure required (e.g., Cat 6 connections for HMI desktops, fiber boxes for automation, 120V connections, cabinets, and desktops, etc.).

Additionally, safety, network connectivity and climate were considered when choosing test location. The location had to be isolated from major traffic areas to eliminate safety risk from the uncommon operation of heavy equipment. Also, the equipment needed to be ran in a mill environment (i.e., under bay) so that no weathering could occur from natural forces.

To assess these factors, a matrix was created with locations around the plant that were evaluated and ranked. Other factors that were ranked include: impact to operations and buy in from operations/maintenance. An example of the comparison matrix completed is shown in Figure 2.

Location	Constructability	Cleanliness	Impact to Operations	Proximity to Power	Proximity to Network Switch	Buy-In From Plant Operations/Maintenance	Total Score
A	3	2	2	3	1	3	14
B	3	3	2	3	2	2	15
C	3	1	2	3	2	3	14
D	1	2	3	3	3	3	15
E	3	1	1	3	3	1	12
F	3	2	2	3	1	1	12

Figure 2. Test Location Comparison Matrix.

Ultimately, a segregated area of a spare parts storage section of the hot mill roll shop was used as the test location. The next step was to detail the layout of the testing area to ensure safety, restrict access, and to coordinate relocation of other items in the area. A sample sketch schedule of the testing area is shown below in Figure 3.

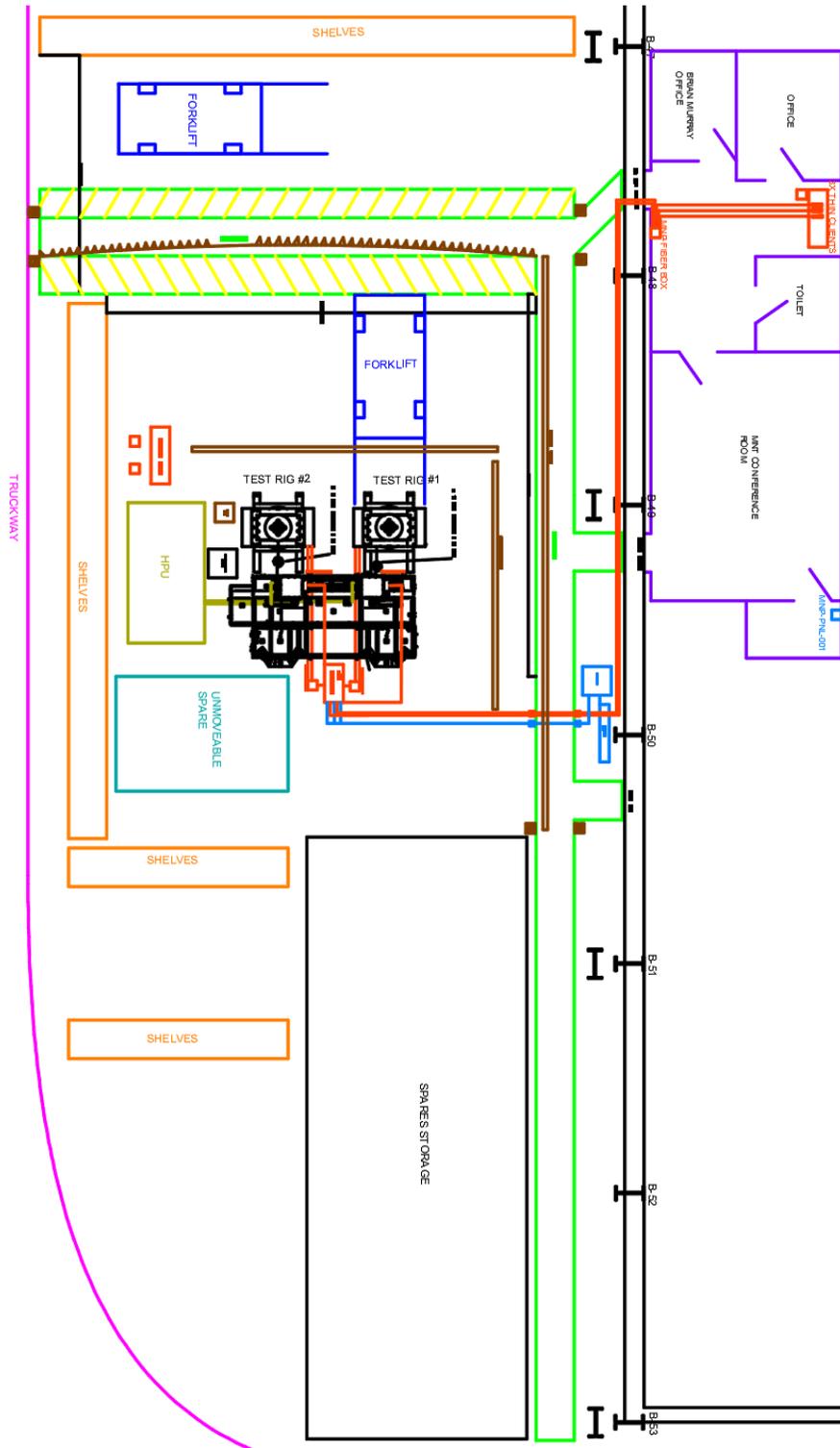


Figure 3. Sketch of Test Stand Plan View.

MECHANICAL SETUP

Planning of the layout and access was essential: as can be seen in Figure 4 the space was very limited. Scaffolding was created around the test area as a barrier to keep anyone not part of the testing from potential harm and built around the testing rigs for construction/installation of the cylinders. Not shown in this view are stations for automation engineers for monitoring test stand and shadowing data in an adjacent office room.



Figure 4. Actual test stand setup.

EQUIPMENT REQUIREMENTS

Due to the offline testing (not in the mill stand), a customized rig to suspend the cylinders mimicking the inside of the housing had to be designed and fabricated. The final rig design is shown in the Figure 5. Two rigs were purchased to test operator and drive side cylinders in pairs.

In addition to the test rigs, the layout had to consider hydraulic equipment including valve stands (which were already supplied by the OEM) and a temporary hydraulic power unit (supplied by the contractor). Valve stands were already preassembled on a mill platform, so the space and access included more than just the valve stands.

Thin clients to connect to the existing network, PLC cabinets and junction boxes to relay data between valve stand and HMI desktops, and mini power zone (MPZ) to rectify 480V to 120V power were utilized for the testing. The thin clients and PLC cabinets were reused.

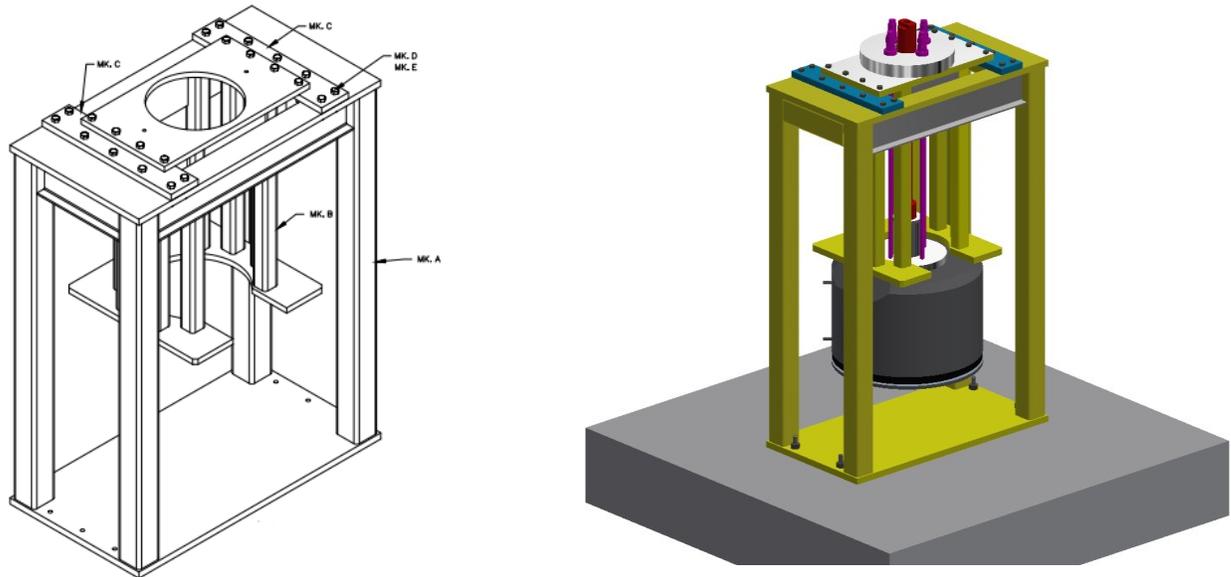


Figure 5. Cylinder Test Rig Engineering Diagrams.

TESTING TEAM

The team engaged in the planning and execution of the tests was comprised of the following personnel:

- Project Manager
- Mechanical, Electrical, and Automation Engineers
- Equipment Manufacturer (OEM)
- Electrical and Mechanical Construction Contractors
- Commissioning Manager
- Project Scheduler
- Project Safety Coordinator
- Plant Operations & Maintenance
- Plant Automation

This separate task force was assembled at the beginning of the effort and then bi-weekly meetings were held to review progress until testing began. During the testing period, daily weekly meetings were used to review any issues or improvements for future tests.

The contractors awarded the installation work for the outage (e.g., pipefitters, electrical contractor, and millwrights) were contracted to assist in pre-outage testing. Testing facilitated the familiarity between contractors and the equipment they are to install including:

- Center of gravity testing
- Polishing and testing of hydraulic oil
- Understanding the fittings
- Wiring of full PLC cabinets pre-outage)
- Taking ownership of materials management

Additionally, because the test was located onsite, plant personnel and stakeholders were able to analyze and interact with the test system. Further, hands on training and manuals were provided to operations, maintenance, engineering, and any plant personnel that would be working with the system daily. The trainings coincided with the testing period to provide a better connection to written manuals. Overall, the test provided a clear visual and physical understanding of what was to be installed on the mill.

FUNCTIONAL TESTING PROCEDURE

The following components were tested: Cylinders, Valve stands, PLC cabinets and L1/L2 systems.

The complete test system consisted of a two test rigs, a set cylinders (one operator side and one drive side), one stand top, and one PLC cabinet. The valve stand was connected to a temporary HPU to provide the pressure and flow of hydraulic oil thru the valves to cylinders and return to HPU in the system. The test system worked such that software would relay L1/L2 functions from HMI desktops to the PLC cabinet which would communicate with the junction boxes for valve actuation on the valve stands and temposonic sensors on the cylinders. In return, data such as pressure of hydraulic oil supplied to the cylinder and cylinder position were tracked within the iBA software.

Operations such as full retraction, stroking to discrete positions, and full extension were tested. These tests provided validation for L1/L2 coding and that the cylinders and valve stand mechanically could withstand these movements. Movements, especially under high pressure (4000 psi) were critical in the understanding of mechanical capabilities of hoses/piping, valves, fittings, cylinders, and overall stand top design.

The following types of functionalities were NOT tested: Cylinder installation in the mill and physical load on the cylinders.

TESTING

The following sections detail the results from the pre-outage testing of the HAGC cylinders. Physical tests completed include:

- System and cylinder flushing
- Servo valve stability under designed system pressure was verified.
- Solenoid valve truth table for vent, block, and operate states were verified
- Hydraulic E-stop and dump push buttons confirmed operational
- Cylinder stroke limit
- Extreme force limit
- Differential force limit
- Differential position limit

All physical tests were completed and verified functional operation of test setup mechanically.

The L1/L2 testing provided most understanding and achievements during pre-outage testing of HAGC cylinders. The following items were verified:

Network Connectivity Confirmation

- PLC controller and its
- I/O modules
- Data collection module.
- Thin clients
- Access for Workstations, HMI server, IBA server

L1 Control Functions

- Valve operation on the manifolds.
- I/O checkout – scaling and operation:
- Pressure transducers feedbacks.
- Temposonic position sensors.
- Confirmed HAGC cylinder control for both drive side and operator side cylinders.
- Closed loop control of the position and force regulators.
- Verified the functionality of operator desk controls from HMI.
- Position feedbacks and force feedbacks and valve commands & feedbacks.
- HAGC mode selection (manual, open, dump, light force, auto).
- Servo valve selection (A only, B only, A leads B, B leads A).
- Position feedback selection
 - Confirmed the fault logic. Verify that the control goes to block state until the loss of metal in stand (simulated by forcing signal in the controller) and then the control goes to vent state
- Verified the Automation Supplier hardware drawings – no markups necessary
- Verified correct scaling of instrumentation and I/O

Shadowing on Existing Network

- All of the control (PLC, HMI, IBA, and workstation) functioning correctly on the production network.
- Verified closed loop cylinder position and pressure regulator functionality from HMI and IBA trending
- Provided personnel with a learning opportunity on the new control system
- Temposonics spread between two (2) cards to provide redundancy

LESSONS LEARNED AND CONCLUSION

The following **sections** detail the findings recorded from pre-outage testing of the HAGC cylinders.

The oil utilized in the HPU was taken from the client plant's internal HPU system; however, on the week of testing, a delivery of oil came in and was staged for testing. Unfortunately, the oil was not to the NAS code required for the test so longer flushing and polishing had to occur to reach the OEM specified oil cleanliness.

The design of the valve stands and cylinders were metric based however the engineering on piping and connections was done in SAE because the client plant is SAE based. Thus, standard sizing strategy to be discussed between the mill operations and engineering.

Temposonic position transducers being tested were reacting opposite than expected on the first test set up compared to second test set up, found and corrected field wiring issues for the following:

- Two (2) Temposonics were swapped (operator side vs. drive side).
- All Four (4) Temposonics data signals polarity reversed.
- Two (2) solenoids signals were incorrectly wired.

The L1/L2 test recordings provided this understanding of HAGC controls:

- Backup servo valve consideration to accommodate fault leading to blockage of mill from extreme offset limit that could further lead to breakage of backup roll clamps.
- Determined and corrected that only need to perform one (1) IOT per high-speed module.
- Corrected I/O software assignments did not match the hardware I/O drawings for the Temposonics.
- Corrected the new load cell healthy I/O signal were not assigned.
- Corrected load cell / pressure transducer selection.
- Corrected scaling of the servo valve spool position feedbacks.
- Found and corrected a multiple write on a signal that prevented the enabling of the null bias circuit.

The major advantage to using the test is related to the schedule. The benefits to the outage schedule from the test stand include:

- Reduced outage duration for pre-wiring of the cabinets and testing (wiring took multiple 8-hour days and each stand testing for one week to eliminate kinks in software and connections)
- Reduced post-outage commissioning time of automation integrations to existing system (calibration of the and testing of each stand took one week to confirm the model was accurate and thorough.)
- Reduced outage duration for assembly of valve stands and testing connections for leaks (assembly took multiple 8 hour working days and each stand tested for one week)
- Reduced outage duration from flushing prior to outage (flushing for this set up could take upward of 18 hours per stand, but was estimated to have been reduced to 8 hours per stand for final installation)
- Reduced outage duration by having the outage contractors assemble and test movements with cylinders and valve stands (unknown reductions in time but familiarity with equipment promoted comfortability and understanding of the system)

Other major advantages to using the test are related to safety and mitigated risk. The benefits to the operational / maintenance safety from the test stand include:

- Reduction in everyday incidents as all crews will be more than familiar with the equipment before final installation
- Reduction in incidents related to lifts and rigging as the test stand allows the contractors/mill personnel to test centers of gravity prior to movement of equipment to final install location
- Reduction in operational error as there is operator training on new software during the testing
- Reduction in maintenance error as the maintenance personnel receive training and familiarity with equipment and specific critical areas

In summary, pre-outage testing allows for offline testing of equipment prior to installation, reducing the risk of extended outages and major delays during start-up which can have a significant financial impact on a major production unit. Further, offline testing reduces safety concerns with unfamiliar and new equipment. Such offline testing requires detailed planning considering the constraints of an operating facility.