

## Vertical Direct Chilled Casting Facilities (VDC) Reliability Improvement at EGA

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### Abstract

EGA's Casthouse in Al Taweelah is equipped with multiple large size hydraulic cylinders that are installed in Vertical Direct Chilled (VDC) casting facilities. These facilities are used for batch casting of billets and sheet ingots. The cylinder size varies between 10 to 12 meters of stroke length with a rod diameter of 800 mm. The function of these cylinders is to control the casting speed and provides support for the casting equipment weight. The casting batch weight varies between 80 to 120 tonnes.

The casting machine was taken up for major maintenance that involved pit repair and coating, cylinder inspection and overhaul work along with other associated tasks. This was the first intervention since the initial installation.

The following observations were made from the cylinder casing and the protection enclosure (caisson). The cylinder protective enclosure (caisson) was corroded and punctured, which exposed the cylinder casing to saline groundwater. The cylinder coating was also damaged with surface pitting and wall thinning due to corrosion.

The Casthouse operation and maintenance team implemented the best alternative solution for life extension of VDC hydraulic cylinder by providing innovative solutions. A double layer corrosion protection technique was applied in combination with an Impressed Current Cathodic Protection (ICCP) and a Sacrificial Anode Cathodic Protection (SACP). The combined approach contributes to eliminate unwanted production downtime and frequent hydraulic oil replacements.

In addition, this work also contributed to improving the following:

- EHS: Unwanted hydraulic oil replacements for a sustainable operation.
- Productivity: A reduction from 45 to 12 days of unplanned downtime to planned shutdown on all VDC facilities.
- Quality: Improved service life of the hydraulic cylinder and associated structures according to design values by providing an innovative corrosion protection system.
- Customer Satisfaction: Recognised by Al Taweelah casthouse operation teams due to machine uptime and improved hydraulic cylinder reliability.

In conclusion, this innovative approach provides improvements that have resulted in an audited annual savings of 2.2 MUSD.

**Keywords:** Vertical Direct Chill (VDC) casting, Corrosion protection, Productivity improvement, Sustainability, Environmental improvement, Reliability improvement.

### 1. Introduction

The objective of this study was to establish the failure mechanism and progression, identify contributory factors, development of a protection and monitoring system with a desired engineering life. As the buried structure is completely inaccessible for inspection and maintenance, a system with multiple layers of protection was envisaged and applied.

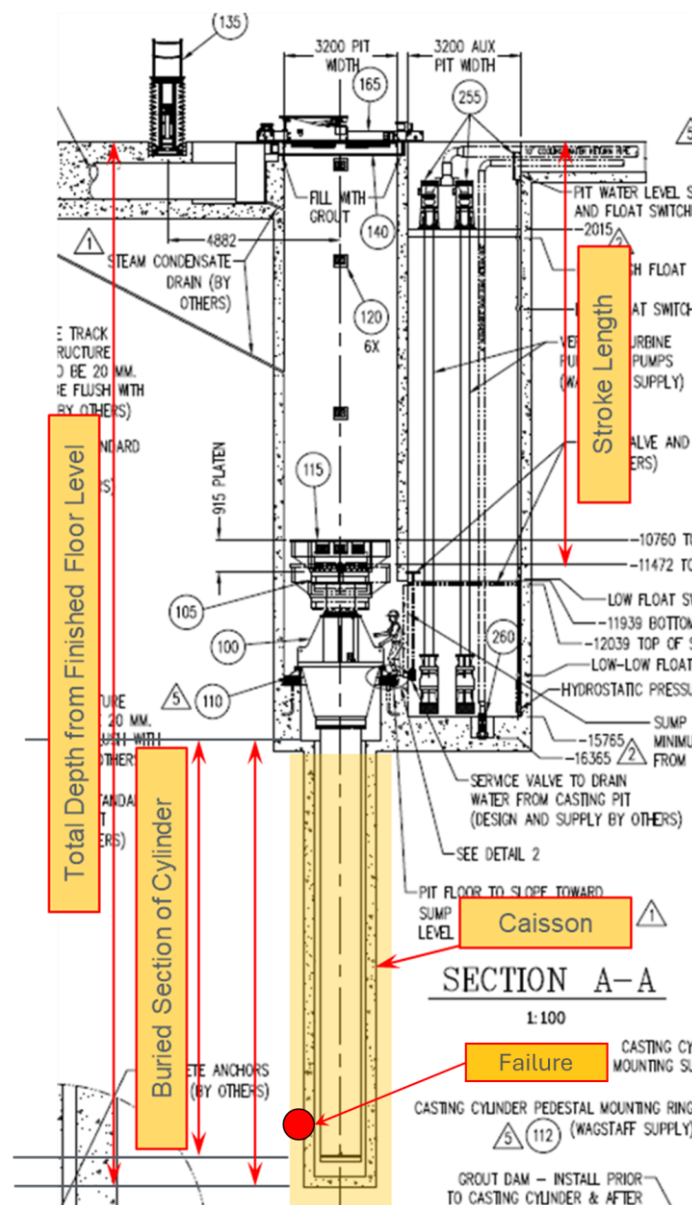


Figure 1. General arrangement of Vertical Direct Chilled Casting (VDC) facilities.

EGA's Al Taweelah Casthouse is equipped with multiple large size hydraulic cylinders that are installed in Vertical Direct Chilled Casting Facilities (VDC). These Facilities are used for batch casting of billets and sheet ingots.

- The cylinder size varies between 10 m to 12 m of stroke length with rod diameter of 800 mm.
- The function of these cylinders is to control the casting speed and to provide support for the casting and the equipment weight.
- Casting batch weight varies between 80 t and 120 t.
- The total depth of the cylinder is approximately 28 m from the finished floor level, out of which approx. 12 m is the cylinder casing that is buried under the ground, without any access for inspection.
- This buried section (or the cylinder body) is protected by a fully enclosed cylindrical metallic structure (caisson). The shell thickness of the caisson is 30 mm. The corrosion protection of caisson was by 400  $\mu\text{m}$  coal tar epoxy paint at external and internal surfaces. No cathodic protection (CP) system was considered during design phase.

### 1.1 The Failure

The buried section along with its protective enclosure (caisson) are installed in a deep ground pit (without any access for inspection). This exposed the structure to a severe corrosive environment as it is in continuous contact with saline groundwater (with varying level from one season to another, between high tides and low tides of the nearby sea). This in combination with hot and humid environment of the facility accelerated the corrosion failure of the caisson (puncturing).

The oil analysis also showed sharp increase in moisture and acidity values, indicating water ingress in hydraulic system.

### 1.2 Further Observations

Figures 2 and 3 indicate the surface condition of the cylinder, which was heavily pitted and extending throughout the periphery of the cylinder. Significant localized material loss (thinning) of the parent material was also observed. In the absence of adequate protection or access for inspection, this could have led to a catastrophic failure of the pressurized cylinder.



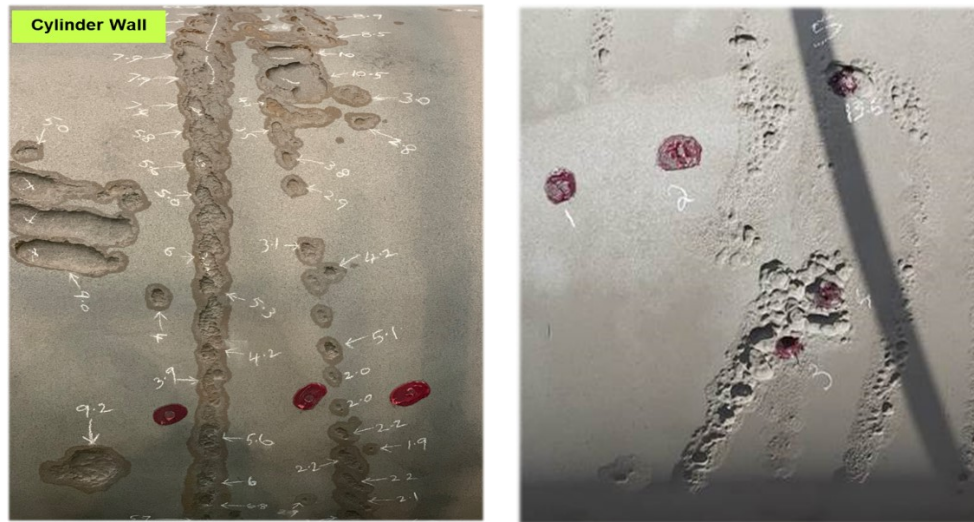
**Figure 2. Cylinder after removal.**



**Figure 3. Cylinder casing localized pitting.**

Ultrasonic thickness mapping was carried out for the cylinder assembly, which revealed thickness reductions of 13.28 mm against a nominal wall thickness of 32 mm. This is approximately 42 % reduction in the wall thickness, which called for an immediate action to control and monitor the corrosion.

A pit gauge was used to assess the condition of the cylinder shell. The damage due to the corrosion was localized, primarily distributed around the bottom of the cylinder. The cylinder was taken up for overhauling and dismantled for internal and external inspection after surface cleaning. The wall loss was measured by using an ultrasonic thickness tool (UT) from the internal and pit gauge from the external surfaces.



**Figures 4 and 5. Cylinder casing localized wall loss.**

It was observed that caisson was corroded and punctured, which allowed saline groundwater ingress and exposed the cylinder casing. The damaged portion was subsequently repaired by metal patch and welding.



**Figure 6. Corrosion failure of caisson wall.**

## **2. Corrective Work: Cylinder Body Protective Coating**

Detailed evaluation of existing condition of the pit, caisson and the cylinder were carried out.

- The caisson was repaired by metal patch and welding to seal the cavity from water ingress.
- The cylinder body was repaired by metal build up and machining followed by painting.
- Abrasive sand blasting and application of corrosion resistance coating (glass flake epoxy coating system with a Dxx Fyy Tzz (DFT) of 600  $\mu\text{m}$  was applied as per NACE standards [1] and Marine environment). This will be the primary protection of the cylinder surface.

In highly corrosive environments like VDC pits, the surface protective coatings alone cannot be an adequate solution. Additional protection systems are required to protect the cylinder casing metal surface from further corrosion, damages. It was decided to explore the possibility of design and installation of a cathodic protection system as per NACE standards (SP0169) [1] to protect the cylinder and caisson from further corrosion.

Furthermore, a detection system was also needed to continuously evaluate the condition of the structure as the buried portion of the cylinder is completely inaccessible.



**Figure 7. Cylinder casing (after coating repair).**

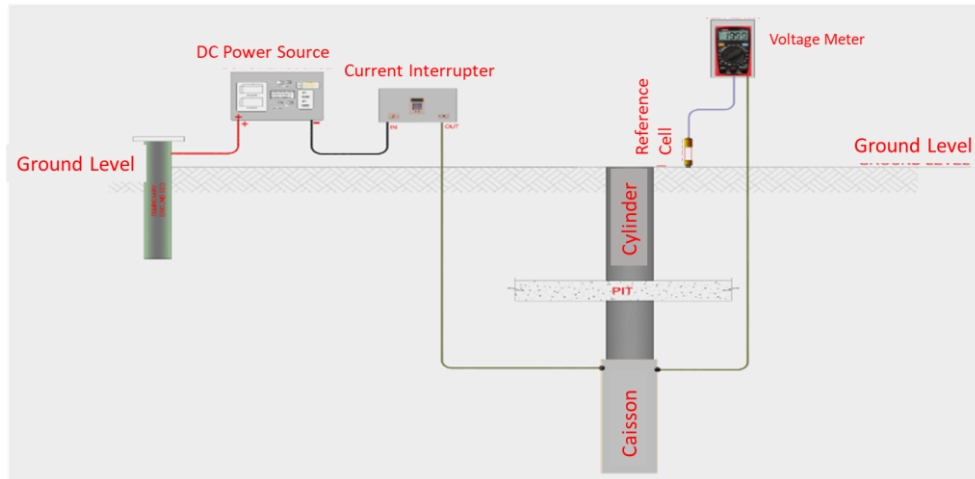
### **3. The Validity Test for the Cathodic Protection System**

A current drain test was performed (during plant shutdown) by energizing the targeted structure (caisson) using temporary anodes installed near the caisson. This is to observe the magnitude of current required to shift structure (caisson only) potential to desired protection level. The potential was measured using portable copper- copper sulphate reference electrode placed at nearest accessible place to caisson.

The cylinder was out for repair and caisson was electrically isolated with a variety of other structures in the vicinity. A portable DC power source was used to power the system. Proper care was taken in selecting the temporary anode bed location to avoid shielding by other incidental structures in between the targeted structure and anode bed.

The following parameters were measured and recorded as part of the test.

- Natural structure potential
- ‘On’/‘Off’ Potentials at each current output settings.
- DC output voltage and current at each setting



**Figure 8. Current drain test setup.**

The test results revealed a satisfactory condition for protection of the structure with the help of a suitably designed cathodic protection system. However, there was a need for a second layer of protection and monitoring mechanism

#### **4. Development of Protection and Monitoring System**

An Impressed Current Cathodic Protection (ICCP) system was implemented to protect external surface of the caisson. In addition, Sacrificial Anode Cathodic Protection (SACP) ribbon anode was installed between caisson and cylinder as a second layer of protection to the cylinder body in case of any electrolyte ingress in future. At present, this second layer of protection is in a dormant state.

##### **4.1 Protection Layer 1 (ICCP System for Caisson)**

Caisson life enhancement and reliability improvement was done by introducing an ICCP system due to its continuous exposure to corrosive environment (soil/sea water).



**Figure 9. ICCP system.**

##### **4.2 Protection Layer 2 (SACP System for Cylinder Casing)**

In conjunction with the glass flake epoxy coating, cathodic protection system as per NACE standards SP0169 was installed using sacrificial Zinc Ribbon Anode (SACP) for the complete

cylinder assembly. This will be acting as a secondary protection (if electrolyte is present in-between caisson and cylinder) in addition to the epoxy coating.



Figures 10 and 11. SACP system.

#### 4.3 Design of Cathodic Protection

The buried section of the caisson external is protected using an impressed current cathodic protection system for the design life of 25 years. A monitoring system is designed by installing test post with permanent reference electrode adjacent to the caisson.

A sacrificial anode cathodic protection system was installed at the cylinder external section using zinc ribbon anodes. This zinc anode will protect the cylinder external (if electrolyte is present). Design life of sacrificial anode is 10 years in such conditions.

Table 1. Design consideration.

| Locations | Serial number | Description      | Diameter (m) | Length (m) | Surface area (m <sup>2</sup> ) |
|-----------|---------------|------------------|--------------|------------|--------------------------------|
| SVDC 2    | <b>ICCP</b>   |                  |              |            |                                |
|           | 1             | Caisson          | 2.3          | 13.24      | 95.67                          |
|           | <b>CACP</b>   |                  |              |            |                                |
|           | 2             | Casting cylinder | 2            | 13.24      | 83.19                          |

#### 4.4 Description of the Installed CP System

A transformer rectifier, suitable for outdoor safe area is installed. Mixed Meal Oxide (MMO) anode is installed as part of deep well anode installation. A proper monitoring system including permanent reference electrode is in place. The zinc ribbon anode is placed between casing and cylinder along with reference electrode.

### 5. Conclusions

Installation of a suitably designed cathodic protection with two-layer protection (ICCP as active and SACP as dormant) brings the following benefits:

- Avoidance of unplanned downtime (production loss)
- Reliability enhanced: Addition of multiple levels of protection
- The structure life is extended by reducing the corrosion rate (CP design life of 30 years)
- Level of detection is enhanced.
- Horizontal deployment: The same improvement action was applied in other similar structures.
- Hydraulic oil life enhanced.

## 6. Reference

1. NACE SP0169-2007, Standard Practice, Control of external corrosion on underground or submerged metallic piping systems, <http://zinoglobal.com/wp-content/uploads/2019/12/NACE-SP0169-2007.pdf> .