Increasing needs at the Mexico City International Airport (MCIA) led to the construction of a new terminal and the modernization and expansion of the original one. A new jet fuel pipeline and hydrants now provide a supply of over 3.5 million L/day. The airport is located in the former Lake of Texcoco. The high saline content of the clays is directly related to the very low resistivity (300 to 600 Ω·cm) and high corrosiveness of the soil.

This article describes the design and installation of the cathodic protection (CP) system for the new jet fuel pipeline. Several particularities made this CP project interesting and challenging. Two generations of materials, pipeline steels, coating types, and conditions, as well as construction techniques, were involved in the final jet fuel configuration and had to be addressed in the CP design. Also, security issues established a fixed framework for the CP design work. No power devices were to be installed inside the terminal areas; rectifiers could be installed only in the tank farm.

In the terminal fields, all connections had to be housed in flame-proof boxes and only underground test stations were allowed. There were many casings on the pipeline, which, in the long term, may not remain isolated. We originally targeted this CP system for the −100 mV criterion, but test results showed the system worked well using the polarized potential of 0.850 V to copper/copper sulfate (Cu/CuSO₄) electrode (CSE).

**Site and Conditions**

**Piping, Cathodic Protection, and Soil Factors**

The jet fuel pipeline consists of two networks. One was constructed ~25 years ago using API B2 type steel and coal tar coating to fuel ~40 hydrants existing before the expansion project. An API
X65 steel and fusion-bonded epoxy (FBE)-coated new pipeline was constructed to fuel the new Terminal 2, and a portion of the old pipeline went into Terminal 1. Figure 1 shows the runways (marked with red arrows), the services area, the older terminal, and the new one (marked as A, B, and C, respectively).

The jet fuel pipeline network consists of three pipeline segments. Segment A is 25 years old, 18 in (0.46 m) in diameter, coal tar-coated B2 type of steel (green), to be decommissioned, but still electrically connected to Segment B. Segment B consists of a similar 25-year-old coal tar-coated B2 type of steel (blue), which feeds the set of hydrants of Terminal 1 (isolation joints are used and shown as orange circles). The largest is the new pipeline segment (magenta), which is 14 in (0.36 m) in diameter, is coated with a three-layered system of FBE, polyolefin adhesive, and polyvinyl chloride (PVC). This segment connects to Segment B through an isolating joint and has another isolating joint at the entrance to the tank farm. Segments A and B also have isolation joints at the tank farm.

The current demand for the older pipeline (including the decommissioned one) was measured at 60 A by field tests; theoretical current demand calculations (described in Table 1) show that the current requirement to achieve acceptable CP potentials would be ~46 A. The difference between the 60 and 47 A can be explained as a consumption of CP system current due to pipeline electrical contact with fittings and foreign undetected structures.

Three deep anode beds were designed and are identified by red circles in Area A (Figure 1). Each anode bed can produce 50 A; two of them are for the old pipelines and the third one is for the new pipeline.

The terrain of the old lake bed is of very low shear strength, particularly in the zone of the last section of the jet fuel pipeline, marked with the yellow rectangle on Figure 1. The soil is typically clay saturated with water, and it produces the imminent risk of sinking. It was necessary, therefore, to design complex and hybrid solutions to reduce the sinking risks and to apply CP to the jet fuel pipelines.

**Anti-Sinking Platform**

The strategy to maximize the space utilization in the current location led Aeropuertos y Servicios Auxiliares (ASA), the Mexican airport authority, to select a design for the new terminal taxi ways using a tailored construction methodology based on concrete decks above the wet clay soil. Structures are prone to sink with time in this type of soil; therefore, the decks were made of a low enough density to remain above the wet clay soil, but with high enough rigidity to support the aircraft traffic of Terminal 2.

The construction selected was a sandwich with three layers—two steel-reinforced concrete slabs with the in-between
TABLE 1
Current demand values and parameters to consider

<table>
<thead>
<tr>
<th>Description</th>
<th>Diameter (in)</th>
<th>Length (m)</th>
<th>Area (m²)</th>
<th>Coating Efficiency (%)</th>
<th>Current Demand (A/m²)</th>
<th>Actual Current Demand (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New pipeline natural ground</td>
<td>18</td>
<td>7,230</td>
<td>10,384.4</td>
<td>95</td>
<td>0.02</td>
<td>10.4</td>
</tr>
<tr>
<td>New pipeline sandwich area</td>
<td>18</td>
<td>3,724</td>
<td>5,348.8</td>
<td>95</td>
<td>0.02</td>
<td>5.3</td>
</tr>
<tr>
<td>Hydrant pipeline branches (Terminal 2)</td>
<td>6</td>
<td>797</td>
<td>381.6</td>
<td>95</td>
<td>0.02</td>
<td>0.4</td>
</tr>
<tr>
<td>Old pipeline (Terminal 1)</td>
<td>18</td>
<td>6,635</td>
<td>9,529.8</td>
<td>80</td>
<td>0.02</td>
<td>38.1</td>
</tr>
<tr>
<td>Old decommissioned pipeline (Terminal 1)</td>
<td>18</td>
<td>1,232</td>
<td>1,769.5</td>
<td>80</td>
<td>0.02</td>
<td>7.1</td>
</tr>
<tr>
<td>Old pipeline hydrant branches (Terminal 1)</td>
<td>6</td>
<td>488</td>
<td>233.6</td>
<td>80</td>
<td>0.02</td>
<td>0.9</td>
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<tr>
<td>Copper-coated groundrods</td>
<td>0.75</td>
<td>300</td>
<td>18.0</td>
<td>0</td>
<td>1.1</td>
<td>3.9</td>
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<tr>
<td>Total current demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>62.2</td>
</tr>
</tbody>
</table>

FIGURE 2

Anti-sinking platform for Terminal 2. (a) longitudinal, (b) transverse view, and (c) photograph of the building process.

The first stage was the collocation of the steel-reinforced concrete, the Tezontle fill, and the sand bed for the pipeline. The final slab of reinforced concrete with an asphalt surface lies above the tezontle. Figure 2(c) also shows the space between the concrete layers and the pipeline (to be filled with tezontle and sand), which provides mechanical protection for the pipe supports.

Cathodic Protection Current Demand

About 25% of the new jet fuel pipeline and hydrants are built inside the sandwich structure, which may act as an isolating cavity to the electrical field of an impressed current CP (ICCP) system. The rest of the pipeline and the hydrants of Terminal 2 are buried in natural soil where a remote bed ICCP system is indicated. The corrosion control system design considered these two different conditions. Consequently, remote and distributed anode beds, and sacrificial and IC anode beds were designed.

Table 1 shows the current demand calculations. It is necessary to protect ~15,558 m of pipelines in natural ground. The segments that are inside the anti-sinking platform are 3,724 m of jet fuel pipeline and 797 m of associated connections and hydrants. We estimated the old
pipelines in the natural ground would have a coating efficiency of 80%, while the new pipelines in natural ground and inside the deck would show a value of 95% plus the hydrant connection branches. In this way, the exposed metal, having a unit demand of 0.020 A/m², would have a given theoretical current demand. The total calculated current demand is 62 A (Table 1). The installed capacity for the CP system including IC and galvanic systems would be ~150 A.

The proposed solution involved a hybrid system, utilizing ICCP with remote ground beds for the pipelines in natural ground, and galvanic anode CP for the pipeline that is inside the anti-sinking platform. The galvanic CP was designed to cathodically protect the pipeline when seasonal resistivity changes take place and also to have backup protection if a probable current blockage (shielding) from the IC system occurred in the space between the two connected decks.

**Impressed Current Cathodic Protection System**

A set of three deep anode groundbeds were located in the tank farm area (Figure 3). That location made it possible to excavate and also to control, maintain, and operate the CP with no major logistical complications. The deep anode beds were located in soil of low resistivity and high humidity. The three deep anode beds are located 20 m apart, drilled to a depth of 100 m with an active zone of 35 m. The selected anodes were mixed metal oxide over titanium tubes, while the active column is embedded in low-resistivity carbon coke. The IC part of the CP system was targeted to provide corrosion protection to the jet fuel pipeline segments buried in soil.

**Galvanic Anode Cathodic Protection System**

A galvanic anode was required in the sandwich area. About 25% of the new jet fuel pipeline is located within the sandwiched, water structured deck. The water level in the former Lake of Texcoco reaches ground level most of the year, especially in the rainy season that lasts about seven months. Water leakage into the sandwiched deck structure was considered unavoidable. The proposed
solution for the protection of the jet fuel pipelines and hydrants inside the anti-sinking platform was the use of a magnesium continuous ribbon anode following the same trajectory as the pipe at a distance short enough to present the effects of a distributed galvanic anode system. The ribbon anode is connected to the pipeline at 20 points to minimize IR drop from CP current in the core wire of the ribbon. This also permits appropriate behavior of the magnesium ribbon under the high gradients of humidity that occur in the sand.

Figure 4 shows the placement of the anode and the sand backfill. The weight required for the magnesium anode was calculated for the worst-case scenario, where 5.3 A are required to protect the jet fuel pipeline. Considering a consumption rate of 18 kg/A-y, it was derived that the minimal weight requirement of Mg is 1,344 kg. The anode ribbon size is 0.0912-m wide and 0.36-kg/m linear density, and because the jet fuel pipeline length is 4 km (sacrificial anode is parallel and will have similar length), the total amount of mass is >1,440 kg, covering the established requirements.

### Results

The effects of this designed CP hybrid system were evaluated with current interrupters to determine the on-off soil/pipeline potentials. The sites for the analyses were selected considering eight points over the old pipeline and eight more for the new one (Table 2). The criterion used is –0.850 V polarized to CSE. Field measurements showed that during the rainy season, the ICCP system would have influence over the whole pipeline, including the anti-sinking platform, as it can be observed from the sandwich area measurements (positions 22 to 26).

### Conclusions

The CP system was a hybrid design so that the pipeline transporting jet fuel into the hydrant pits of Terminal 2, within the sandwiched deck structure, could have a galvanic anode configuration, and the rest of the jet fuel pipeline network would be protected by a remote deep three-anode CP array. This hybrid system can be used in future cases where similar conditions are found. Most of the test stations read a polarization potential complying with the standard –850 mV criterion. Natural potentials ranged between –500 and 625 mV; from Table 2, one can conclude that the hybrid system is applied successfully.

### References


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