Cathodic Protection Design Algorithms for Refineries Aboveground Storage Tanks

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ABSTRACT

Storage tanks condition and integrity is maintained by joint application of coating and cathodic protection. Iraq southern region rich in oil and petroleum product refineries need and use plenty of aboveground storage tanks. Iraq went through conflicts over the past thirty five years resulting in holding the oil industry infrastructure behind regarding maintenance and modernization. The primary concern in this work is the design and implementation of cathodic protection systems for the aboveground storage tanks farm in the oil industry.

Storage tank external base area and tank internal surface area are to be protected against corrosion using impressed current and sacrificial anode cathodic protection systems. Interactive versatile computer programs are developed to provide the necessary system parameters data including the anode requirements, composition, rating, configuration, etc. Microsoft-Excel datasheet and Visual Basic.Net developed software were used throughout the study in the design of both cathodic protection systems.

The case study considered in this work is the eleven aboveground storage tanks farm situated in al-Shauiba refinery in southern IRAQ. The designed cathodic protection systems are to be installed and monitored realistically in the near future. Both systems were designed for a life span of (15-30) years, and all their parameters were within the internationally accepted standards.

Keywords: Aboveground storage tanks; Corrosion control; Impressed current cathodic protection; Sacrificial anode cathodic protection.

خوارزميات تصميم الحماية الكاثودية لخزانات المصافي

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الخلاصة

من المعروف ان جنوب العراق غني بالموارد النفطية، ولاستثمار هذه الموارد بنيت العديد من المنشآت وخزانات النفط. ولكن خلال الخمس وثلاثين سنة الماضية تعرضت البنى التحتية للصناعة النفطية الى كثير من الاهمال في جانبي الصيانة والتطوير، ومنها على سبيل المثال تعرض خزانات النفط الى التآكل بسبب عدم فاعلية منظومات الحماية الكاثودية.

الدراسة الحالية تهدف الى تصميم وتنفيذ منظومات حماية كاثودية لهذه الخزانات ، حيث أعتمد في هذه الدراسة طريقتين لتنفيذ هذه المنظومات ، القطب المضحي وطريقة حقن التيار الكهربائي . لتنفيذ هذه الدراسة ، طورت برمجيات لوضع تصاميم لمنظومات الحماية الكاثودية وتنفيذها لأحد عشر خزانا للنفط في مصفى الشعيبة ، بأستخدام الطريقتين والاشتغال لفترة زمنية 15-30 سنة . النتائج المستحصلة كانت ضمن الحدود القياسية الدولية ومن المؤمل أستخدامها من قبل وزارة النفط في المستقبل القريب.

الكلمات الرئيسة: خزانات فوق الارض، التآكل، حماية كاثودية بالتيار القسري، حماية كاثودية بأقطاب مضحية.

1. INTRODUCTION

Aboveground storage tanks are vital components in many industries dealing with fluids and in particular those huge tanks used in the petroleum industry. Storage tanks situated on soil ramps are exposed to various causes of corrosion processes. Corrosion is an electrochemical process interaction between the structure metal (tank base and wall) and its environment (water, soil, etc.) resulting in a change of the metal properties and ultimately structure failure. Broadly speaking, corrosion is characterized by, presence of an electrolyte (fluids, soil, etc.), presence of corrosion cells i.e. two patches of the metal surface become electrically connected through the electrolyte. Factors affecting corrosion are, metal fabrication process, stresses, presence of acids, oxygen and other gases sulphide, bacterial activities, etc. **Fig. 1** shows a symbolic corrosion cell containing the four main corrosion components, namely, the anode, the cathode, the metallic structure, and the electrolyte, **API, 2007**.

In order to prevent the structure metal deterioration due to corrosion, Cathodic Protection (CP) is applied to halt or delay the corrosion process. Cathodic protection is an electrical based method used to turn the metal structure into a cathode by means of DC current injection or by the attachment of galvanic/or sacrificial anodes. Each CP method has its merits and flaws, therefore, the decision on which to use is very dependent on the structure, the environment, the economy, etc. For corrosion mitigation in aboveground storage tanks, both CP methods are in wide use, **USA ARMY** and **Durham, 2005**.

Fig. 2 shows sample sections of aboveground storage tank protected by the two abovementioned CP methods. Practically, storage tank base external surface is protected using the DC current injection method, widely known as, Impressed Current Cathodic Protection (ICCP), while the tank base inner surface and wall are protected by sacrificial anodes attachment.

In this work computer software are developed, one in Microsoft-Excel sheet and the second in Visual Basic.Net interactive platform, both for the design of CP systems for use in aboveground storage tanks. The aboveground storage tank farm of al-Shauiba refinery, situated in al-Basrah governorate in southern IRAQ is considered in this work for case study. The work was done in response to the request by the State Company for Oil Projects (SCOP) of properly designed CP systems for use in the abovementioned site. The design results obtained are well within the international standard requirements for such CP applications.

2. CATHODIC PROTECTION IN ABOVEGROUND STORAGE TANKS

The primary concerns in hydrocarbon fluid tank installations are loss of product, hazardous material leak, and pollution where metal corrosion can be the main cause. Soil resistivity provides a measure of the soil corrosivity, therefore the tank farm site resistivity survey is an important design prerequisite. A general resistivity classification is given in **Table 1, API, 2007.** Coating is used in aboveground storage tanks as another counter corrosion measure. Most coatings are either wrapped or painted on the metal structure surface. A sample coating types and their use in tank structures is given in **Table 2**, **Schweitzer, 2007.**

In galvanic/or sacrificial anode CP systems the anode corrodes with time keeping the protected structure potential below the corrosion level. **Table 3** shows a sample of different sacrificial anode specifications commonly used in CP systems.

In ICCP systems, an external source of D.C. voltage is employed to drive the current between the buried anode and the protected metallic structure. The positively connected anode mostly used is of high silicon iron material, but others, as the sample given in **Table 4** are also in use. Negatively connected protected metallic structures should be always kept at potentials below those given in **Table 5, USA ARMY, 2005.** Anodes usually buried in coke breeze backfill for anode life extension and the reduction of the anode-soil contact resistance, **API, 2007**.

A variety of ways and methods are practiced in anode installations for aboveground storage tank CP systems. **Fig. 3** shows such practically adopted installations, **API, 2005, Hawkins**, **Kroon** and **Urbas**, **2009**. **Fig. 3 a-b** are used in sacrificial anode CP systems for tank internal base and wall surface protection. **Fig. 3 c-g** shows the different installation methods of ICCP systems for tank base external surface protection. The choice of the method for a particular structure is very much dependent on, soil chemical and electrical properties, tank size and number, the stored fluid, boundary conditions, etc.

In IRAQ, most of the aboveground storage tanks are cathodically protected adopting the shallow anode bed type with anode beds distributed amongst tank groups.

3. DESIGN ASPECTS OF TANK CATHODIC PROTECTION

The CP for aboveground storage tanks (oil products and/or water), covers the internal and external surfaces of the tank metal. Pure hydrocarbon fluids are usually not corrosive and do not require corrosion control for internal surfaces. However, based upon experience, internal corrosion may occur in aboveground storage tanks that have internal surfaces exposed to water, sediments, or other contaminants. Irrespective of the CP system type, whether sacrificial anode or ICCP, a soil resistivity test of the installation site is required. Moreover, a D.C. current requirement test if possible need to be done, if not, an estimated (from experience of previous application) current density value is adopted for the CP system design, and the CP system current requirement is then calculated.

3.1 Protective Current Requirements

D.C. protective current required (I_s) for any CP system depends upon, physical dimension of structure to be protected, estimated current density, holiday's percentage (coating deficiency or coating breakdown), ambient temperature and site measured soil resistivity. The required current can be simply calculated using, **Bushman, 2010**:

$$I_s = J_s * A * (1-CE) \quad (1)$$

Where the tank area to be protected $(A) = \pi * D_t * [(D_t / 4) + H]$ (2)

3.2 Elements of the CP Circuit Resistance

It's a rule of thumb to consider a maximum anode bed resistance of 1Ω and a CP circuit maximum total resistance of 2Ω as acceptable values in the CP system design procedure, **USA ARMY, 2005, Baekmann, et al., 1997, Kutz, 2005**. The cathodic protection circuit resistance includes the anode bed to soil resistance, the connections (wire/cable) resistance, and the structure to soil resistance. In CP design studies, calculating the anode bed resistance, H.B Dwight equations are the standard relations used, **Baekmann, et al., 1997, Peaboody, 2001**. The anode bed resistance has the major role in determining the amount of the anode material to be used. Multiple anodes are used in cases where the current capacity of one anode is not sufficient for the CP system or when the anode bed resistance is higher than 1.0 Ω. Therefore, the number of anodes is very much dependent on the structure size and soil characteristics. The anode bed resistance (R_n) to earth is calculated using, **API, 2007, Kutz, 2005** :

$$R_n = \frac{0.00521\rho}{N\,L_a}\left(ln\frac{8\,L_a}{D_a} - 1 + \frac{2\,L_a}{S_a}\;(\,ln\,0.656\,N\,)\right) \qquad (3)$$

The anode bed components and the tank structure are electrically interconnected by insulated stranded copper cables. The copper cables have an inherent resistance (R_c), and at 55 ºC can be calculated using the following equation:

$$R_c = \frac{L_c}{56 * S_c} \qquad (4)$$

The tank to soil resistance ($R_{s\text{-}soil}$) is a very marginal quantity in the CP system total resistance and therefore often neglected. In this work, a simple Wenner method based equation is used to calculate the tank to soil resistance and is given by, **API, 2007, Kutz, 2005, Peaboody, 2001**;

$$R_{s-soil} = \frac{\rho}{191.5\,h_d} \qquad (5)$$

Finally, the total cathodic protection circuit resistance (R_T) is a simple series sum and given as:

$$R_T = R_n + R_c + R_{s-soil} \qquad (6)$$

3.3 Anodes Number and Life

In section 3.2, a starting anode number is reached based on the protected structure size and the supposed current density requirements. As anode materials disintegrate with time, which leads to improper functioning of the CP system, the anodes life expectancy calculation is an important factor to consider. Obviously, the CP system shall be designed to perform its task protecting the structure throughout its operating life. Therefore a check on the anodes estimated life need to be done in order to determine whether the CP system design will provide the necessary protection. **Bushman, 2010** proposed Eq. (7) for calculating the estimated life (AL) in years of an anode, and is given as:

$$AL = (\,CR\,/\,8760\,)(\,W_a * \,EF_a * \,UF_a\,/\,I_a\,) \qquad (7)$$

In Eq. (7), W_a is replaced by ($N\times W_a$) for N anodes and I_a is replaced by I_s, both for a multi anode chain CP system. A settlement on the number of anodes can be reached for the desired life expectancy (in IRAQ, usually 30 years for ICCP and 15 years for sacrificial anode systems are assumed).

3.4 Selecting the DC Power Supply

Many factors are needed to be considered in the process of determining a particular D.C. power supply for an ICCP system. Among these factors are, the D.C. current, the D.C. voltage, the power requirement, the controls, the monitoring and metering, etc. It is a known fact that over the years of use, the protected structure coating deteriorates leading to increased ICCP system current requirement. Moreover, seasonal meteorological environmental changes do impact the ICCP system parameters, due to changes in the surrounding medium. With the above mentioned in mind, and having calculated the I_s and R_T of the particular CP system, the required driving source voltage (Vs) can be determined. That is simply done using Eq. (8) (Ohm's law). The voltage Vs is scaled up by 150% to cater for variations in the CP system demand.

$$Vs = 1.5 \times I_s \times R_T \quad (8)$$

4. AL-SHAUIBA TANK FARM: CASE STUDY AND RESULTS

The revamping, of al-Shauiba refinery, located in al-Basra governorate south of IRAQ is a part of national Iraqi agenda to upgrade the country refining capabilities. This site was also called "Ash Shaaibiya refinery" was built in 1970, started operation 1974. The refinery is around 50 km from the Arabian Gulf and was built to supply part of IRAQ hydrocarbon products, **Basra_Refinery**. The relevant part of this project to the work in hand is the CP system design for several aboveground storage tanks.
The tank farm consists of eleven tanks for storage of benzene, gasoil, crude oil and water for firefighting. **Fig. 4** shows sample photos of the tank farm area. The project site top view mapping is shown in **Fig. 5** and the tanks dimensions are given in **Table 6**.

4.1 Al-Shauiba Depot: Site Survey

Al-Shauiba tank farm project site was visited and surveyed during Feb. 2015. The visit was mainly to inspect the site soil and collect data regarding site soil resistivity. The Winner-four pin method for soil resistivity measurements was used in the data collection. It is worth mentioning here that, due to the military activities during the past few decades, huge amount of hydrocarbons was leaked to the surrounding soil. **Figure 6** shows site photos showing the affected soil layers.
Extensive series of soil resistivity measurements were conducted in site. The measurements were done on three depths in order to collect non-polluted earth soil resistivity readings. **Table 7** shows a summarized site soil resistivity results. A note need to be brought here is, the area water table is in the range of 8-12 meters.

4.2 Al-Shauiba Tank Farm CP Systems

Four CP systems were designed for the eleven tanks external surfaces cathodic protection. A CP system for the four benzene and gasoil tanks, two CP systems for each pair of the crude oil tanks and a single CP system for the firefighting water tanks. Deep well anode type installation is used for all CP systems due to site restrictions. The anode beds position are marked on **Fig. 5**.
Fig. 7 – 9, show sample ICCP system design parameter screen results for the water tanks, crude oil tanks, and the benzene and gasoil tanks respectively. In the mentioned figures, the current, the anode, the ground bed, and the transformer/.rectifier (T/R) parameters are presented.
The sacrificial anode CP system parameters, designed for the three tanks sizes mentioned earlier are presented in **Fig. 10.**

5. CONCLUSIONS

This work highlights the design and application of both sacrificial anode and the impressed current cathodic protection systems. Fast, versatile and interactive computer algorithms were developed for use in the CP systems design. The work was done in response to SCOP/IRAQ request for development of such algorithms. Two programs were built, one based on Microsoft-Excel sheet and the second on Visual Basic.Net programming. Both algorithms were used to design the cathodic protection systems necessary for the al-Shuaiba refinery tank farm. The calculated CP system parameters for the three tank sizes are all within the practically accepted standards in the oil industries. Finally, the versatile nature of the written programs makes it possible to use them in designing the required CP systems in any environment and for any metal structure.

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NOMENCLATURE

A = the protected structure surface area in (m^2)
AL = anode estimated life in (years)
CE = the coating efficiency in %
CR = the anode consumption rate (A.hr/kg)
D_a = the anode diameter including backfill in (m)
D_t = the tank base diameter in (m)
EF_a = the anode efficiency
H = the water or sludge height in water and hydrocarbon product tanks respectively in (m)
= zero in case of protecting tank base outer surface only
h_d = the horizontal distance between the anode-bed and the tank base center (m)

Ia = the anode current (A)
I_s = the required current in (A)
J_s = the supposed current density measured or acquired for a particular soil and structure material measured in (mA/m^2)
L_a = the anode length including the backfill in (m)
L_c = the cable length in (m)
N = the number of anodes
R_n = anode bed resistance (Ω)
R_c = cable resistance (Ω)
$R_{s\text{-}soil}$ = tank to soil resistance (Ω)
R_T = the total cathodic protection system circuit resistance (Ω)
S_a = the anode spacing in (m)
S_c = the cable cross sectional area in (mm^2)
UF_a = the anode utilization factor (usually assumed 0.85)
Vs = the supply voltage (V)
W_a = the anode weight (kg)
ρ = the soil resistivity in (Ω-m)

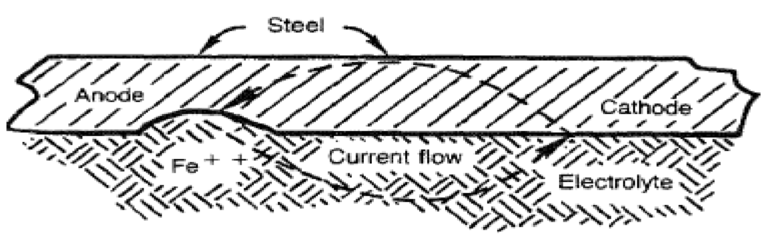
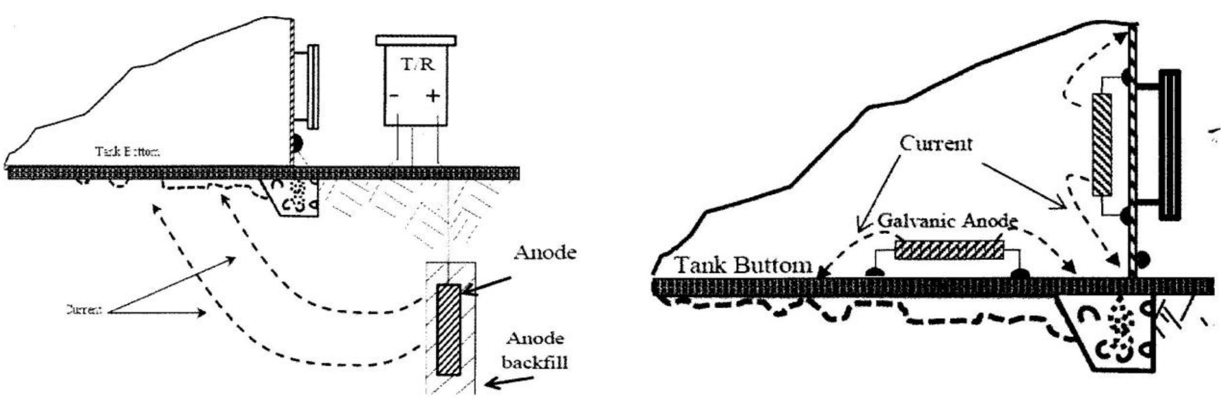


Figure 1. Corrosion in a metal structure (Sample), **API, 2007.**



(a) Impressed current cathodic protection **(b)** Sacrificial anode cathodic protection

Figure 2. Aboveground storage tank CP systems, **API, 2007**.

Table 1. General classification of resistivity.

Resistivity Range (Ohm-m)	Potential Corrosion Activity
< 5	Very corrosive
5 - 10	Corrosive
10 - 20	Moderately corrosive
20 - 100	Mildly corrosive
> 100	Progressively less corrosive

Table 2. Sample coating type and use**.**

Coating Type	Tank Surface	
	Internal	External
Coal tar / tape	A	A
Epoxy	A	N/A
Vinyl's	N/A	N/A
Resins	A	N/A
Alkyds	N/A	N/A
A= Applicable; N/A= Not Applicable		

Table 3. Properties of Sample Sacrificial Anodes, **USA ARMY, 2005**.

Anode Material	Amp-hrs. per kg.	Potential (V) Cu/CuSo4	Density g/cm^3	Current Density A/m^2
Zn	780	-1.1	7.1	0.5 - 2.0
Al	2700	-1.15	2.7	0.6 - 2.5
Mg	1230	-1.55	1.7	1.5 – 5.6

Table 4. Sample impressed current anodes.

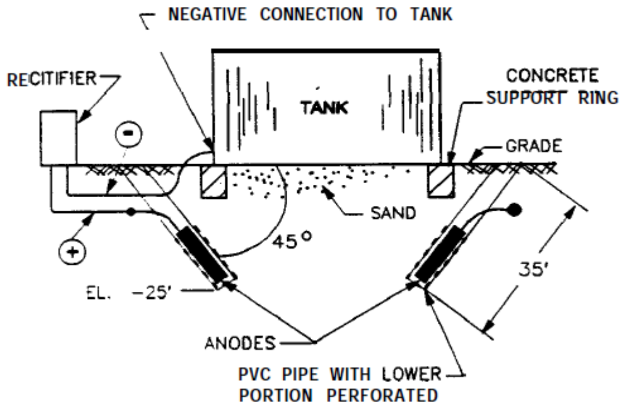
Anode Material	Maximum Voltage (Volt)	Current Density A/m^2
Platinum/Niobium	100	250 -1500
Lead/Silver/ Antimony	100	250 – 1000
High Silicon Iron	100	10 – 100
Graphite	25	200

Table 5. Metals Potential.

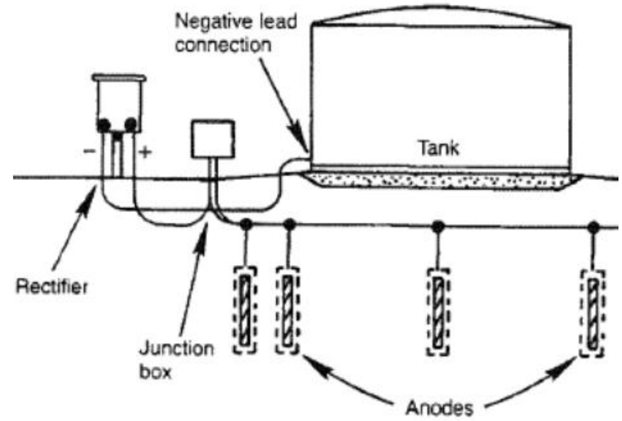
Metal	Potential (mV), Cu/CuSo4
Steel	-850
Steel (Sulphate reducing bacteria)	-950
Copper alloys	-500 to -600
Lead	-600

(a) Sacrificial surface bolted anode **(b)** Sacrificial string anodes

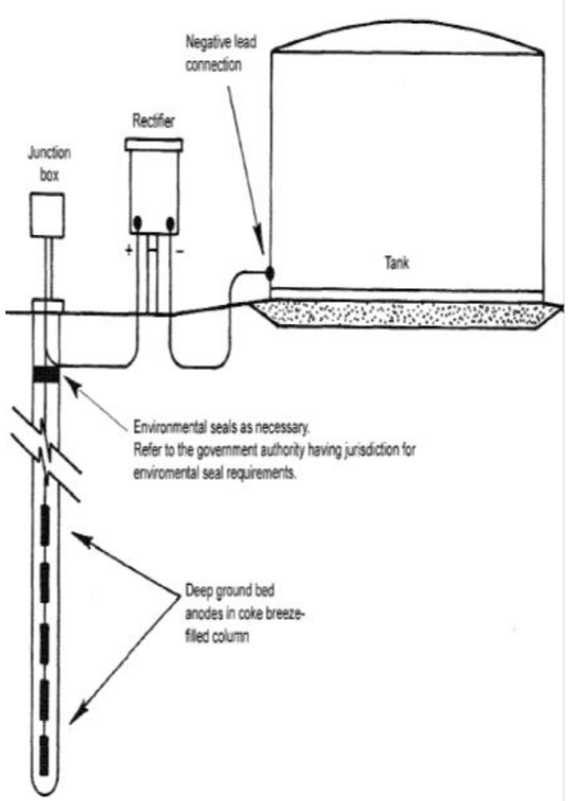
Figure 3. Sacrificial anode and ICCP systems in aboveground storage tank application.



(c) ICCP angle drilled anode system
API, 2007



(d) ICCP shallow anode bed installation
API, 2007



(e) ICCP deep anode bed installation
API, 2007

(f) ICCP grid anode system

(g) ICCP loop anode system

Figure 3. Continued.

Figure 4. Sample photos of al-Shauiba tank area.

Table 6. Al-Shauiba tank farm specifications.

Tank Designation	Storage Liquid	Tank Diameter	Tank Height
Tk01, Tk02	Benzene	45m	12m
Tk03, Tk04	Gasoil	45m	12m
Tk05,Tk06, Tk07, Tk08	Crude	72m	12m
FF-01, FF-02, FF-03	Water	20m	12m

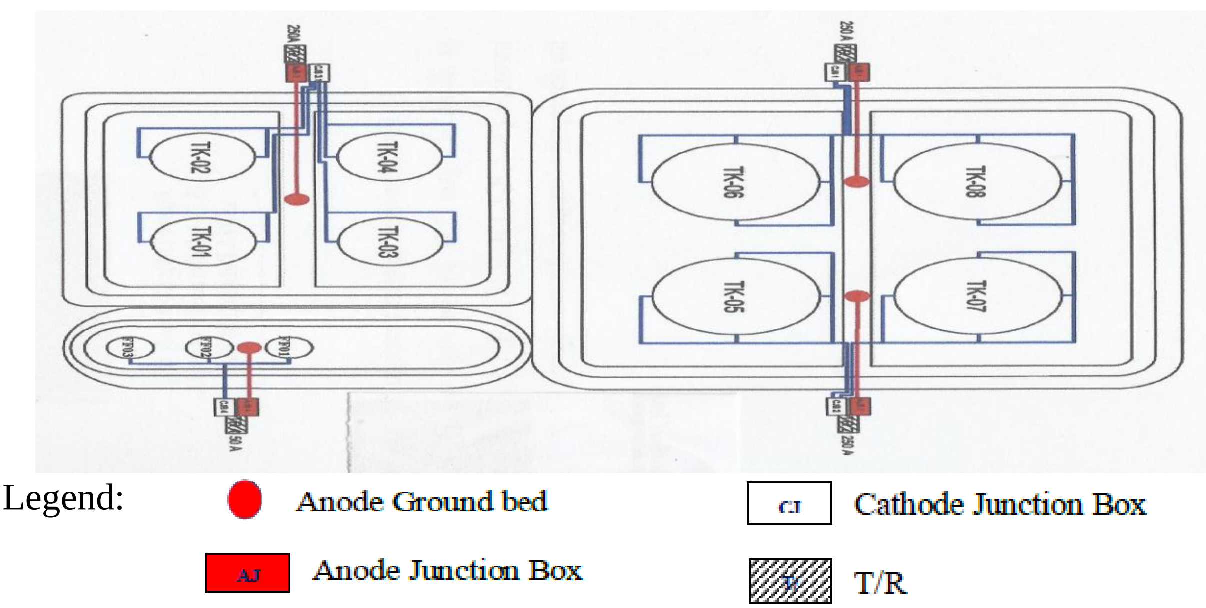


Figure 5. Top view of al-Shauiba tank farm.

Figure 6. Soil layers at al-Shauiba depot**.**

Table 7. Al-Shauiba depot: soil resistivity readings.

Tank Area	Measurement Depth (m)	Measured Soil Resistivity (Ω.m)
TK-01, TK-02, TK-03, TK-04	0.85 2.5 6	95 25 5
TK-05, TK-06, TK-07, TK-08	0.85 3 6	112 25 5
FF-01, FF-02, FF-03	0.85 3 6	169 25 5

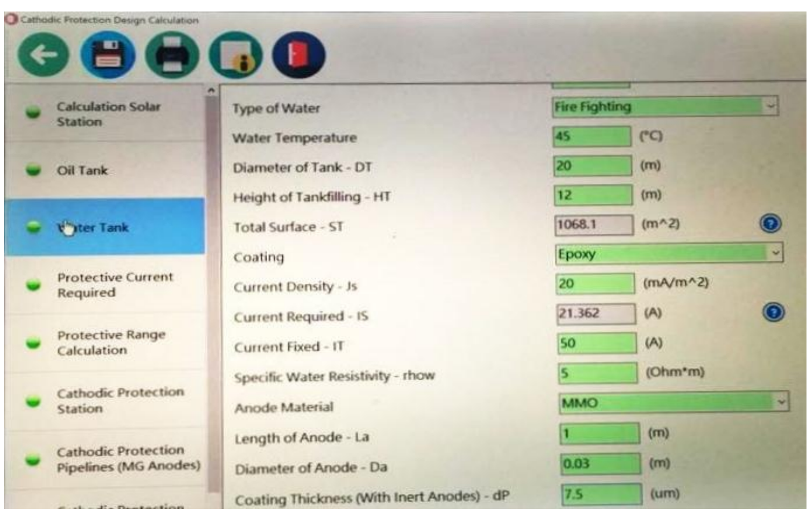


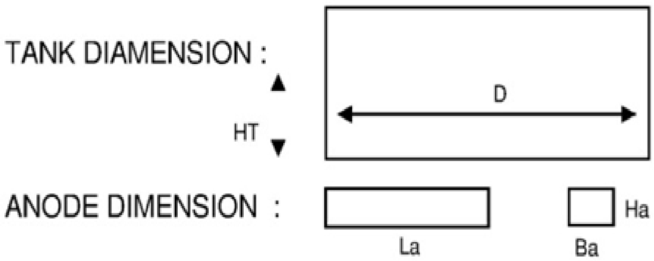
Figure 7. VB.Net sample window: ICCP for water tanks.

CP-STATION No.: CRUDE OIL	TANKS TK05 - TK06		
CURRENT REQUIRED (2 TANKS)	IS	(A)	162.8
CURRENT FIXED	IT	(A)	250
SOIL RESISTIVITY	rho	(Ohm*m)	5
ANODENMATERIAL			MMO
LENGTH OF ONE ANODE	La	(m)	1
DIAMETER OF ANODE	Da	(m)	0.025
ARRANGEMENT OF ANODES			CHAIN
MEDIUM			SALTY WATER
OPERATING CURRENT PER 1 ANODE		(A)	9.04
NUMBER OF ANODES (TOTAL)	n		18
DISTANCE BETWEEN TWO ANODES	s	(m)	2
DEPTH OF GROUNDBED (WATER LEVEL)	tb	(m)	40
LENGTH OF GROUNDBED	Lb		60
TOTAL DEPTH OF BOREHOLE [23]	T	(m)	100
DIAMETER OF GROUNDBED	Db		0.3
GROUNDBED RESISTANCE [22]	Rb	(Ohm)	0.082
LENGTH OF CATHODE CABLE (AVERAGE)	Lc	(m)	200
SIZE OF CATHODE CABLE (8 CABLES 95 mm^2)	Sc	(mm^2)	760
RESISTANCE OF CATHODE CABLE [10]	Rcc	(Ohm)	0.005
LENGTH OF ANODE CABLE (AVERAGE)	Lca	(m)	200
SIZE OF ANODE CABLE (3 CABLES 16 mm^2)	Sca	(mm^2)	48
RESISTANCE OF ANODE CABLE [10]	Rca	(Ohm)	0.074
TOTAL RESISTANCE OF CABLE [21]	Rc	(Ohm)	0.079
TOTAL EARTHING RESISTANCE [13]	RT	(Ohm)	0.161
LIFETIME OF GROUNDBED	LF	(years)	20
TRANSFORMER RECTIFIER OUTPUT			
TOTAL EARTHING RESISTANCE [13]	RT	(Ohm)	0.161
TOTAL CURRENT FIXED	IT	(A)	250
VOLTAGE [14]	V	(V)	40.4
VOLTAGE FIXED	VT	(V)	70
OUTPUT POWER [15]	P	(W)	17500

Figure 8. Excel sheet sample: ICCP for crude oil tank**.**

CP-STATION No.: 2 - BENZIN AND GASOLNE	TANKS TK01 - TK02 - TK03 - TK04		
CURRENT REQUIRED (4 TANKS)	IS	(A)	127.2
CURRENT FIXED	IT	(A)	250
SOIL RESISTIVITY	rho	(Ohm*m)	5
ANODENMATERIAL			MMO
LENGTH OF ONE ANODE	La	(m)	1
DIAMETER OF ANODE	Da	(m)	0.025
ARRANGEMENT OF ANODES			CHAIN
MEDIUM			SALTY WATER
OPERATING CURRENT PER 1 ANODE		(A)	7.07
NUMBER OF ANODES (TOTAL)	n		18
DISTANCE BETWEEN TWO ANODES	s	(m)	2
DEPTH OF GROUNDBED (WATER LEVEL)	tb	(m)	40
LENGTH OF GROUNDBED	Lb		60
TOTAL DEPTH OF BOREHOLE [23]	T	(m)	100
DIAMETER OF GROUNDBED	Db		0.3
GROUNDBED RESISTANCE [22]	Rb	(Ohm)	0.082
LENGTH OF CATHODE CABLE (AVERAGE)	Lcc	(m)	125
SIZE OF CATHODE CABLE (8 CABLES 95 mm^2)	Sc	(mm^2)	760
RESISTANCE OF CATHODE CABLE [10]	Rc	(Ohm)	0.003
LENGTH OF ANODE CABLE (AVERAGE)	Lca	(m)	200
SIZE OF ANODE CABLE (3 CABLES 16 mm^2)	Sc	(mm^2)	48
RESISTANCE OF ANODE CABLE [10]	Rca	(Ohm)	0.074
TOTAL RESISTANCE OF CABLE [21]	Rc	(Ohm)	0.077
TOTAL EARTHING RESISTANCE [13]	RT	(Ohm)	0.160
LIFETIME OF GROUNDBED	LF	(years)	20
TRANSFORMER RECTIFIER OUTPUT			
TOTAL EARTHING RESISTANCE [13]	RT	(Ohm)	0.160
TOTAL CURRENT FIXED	IT	(A)	250
VOLTAGE [14]	V	(V)	39.9
VOLTAGE FIXED	VT	(V)	70
OUTPUT POWER [15]	P	(W)	17500

Figure 9. Excel sheet sample: ICCP for benzene and gasoline tank.



		CRUDE	B & G	WATER
DIAMETER OF TANK - DT	(m)	72	45	20
HEIGHT OF SHELL COATING - HT	(m)	1.5	1	12
PROTECTED SURFACE - BOTTOM [31]	(m^2)	4071.50	1590.43	314.16
PROTECTED SURFACE - SHELL [32]	(m^2)	339.29	141.37	753.98
TOTAL PROTECTED SURFACE [51]	(m^2)	4410.80	1731.80	1068.14
CURRENT DENSITY - Js	(mA/m^2)	1.5	1.5	1.5
TOTAL CURRENT REQUIRED - IS [3]	(A)	6.616	2.598	1.602
REQUIRED LIFETIME OF ANODES - LF	(years)	15	15	15
RESISTIVITY oF ELECTROLYTE- rho	(Ohm*m)	3	3	3
CHOSEN TYPE OF ANODE MATERIAL		ZINC		
CAPACITY OF ANODE - Ca	(Ah/kg)	780	780	780
DRIVING VOLTAGE OF ANODE - Ua	(V)	0.2	0.2	0.2
UTILIZATION FACTOR OF ANODE - uf		0.9	0.9	0.9
NECESSARY TOTAL MASS OF ANODES - mT [27	(kg)	1239.3	486.6	300.1

B & G : Benzene and Gasoline

TYPE OF ANODE	LENGTH La (m)	WEIGHT ma (kg)	WIDTH Ba (m)	HEIGHT Ha (m)
	1	22	0.068	0.056

MAX. CURRENT OUTPUT OF ONE ANODE - Ia [26	(A)	0.120	0.120	0.120
NUMBER OF ANODES (+20% SPARE) - n [28/29]		68	27	17
APPR. CURRENT OUTPUT OF ONE ANODE - I [30	(A)	0.097	0.096	0.094
CALCULATED LIFETIME OF ANODE - LF [12]	(years)	18	18	19

Figrue 10. Sacrifical anode CP system parameters.