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Floating Homeowners Association
C/o Mr. Stan Barbarich
15 Liberty Dock
Sausalito, CA 94965

Subject: **Cathodic Protection Evaluation and Preliminary Design Survey**
Selected Floating Homes with Reinforced Concrete Hulls at
Commodore, Kappas Marina, Yellow Ferry Harbor,
Waldo Point Harbor and Varda Landing Marinas
Sausalito, CA

Gentlemen:

During July and August, 2008 Corrpro Companies, Inc. engineering personnel conducted a cathodic protection survey and evaluation of selected representative floating homes at the subject site. These floating homes are constructed with reinforced concrete hulls (barges), some of which are equipped with cathodic protection for corrosion control of the hull reinforcement steel.

This work was performed under contract with Marin Floating Homeowner's Association (HOA) as described in the Corrpro proposal dated February 13, 2008. The proposed work scope included collection of the largest sampling of survey data as could be accomplished during three (3) days allotted for the field survey, but including at minimum, two (2) vessels moored at each dock of the subject marinas.

This investigation was initiated by a concern for unsatisfactory anode life (less than two years) on those vessels equipped with cathodic protection, and the progression of corrosion as evidenced by rust staining and spalling of the concrete cover visible at low tide in the case of certain vessels not equipped with cathodic protection. The objective of these surveys was to evaluate the existing cathodic protection systems with regard for adequacy of cathodic protection in accordance with applicable NACE International criteria, and anode life calculations based upon the measured operating parameters.

Two (2) vessels each at Liberty Dock, South 40 Dock, 'A' Dock, Kappas West Dock, Issaquah Dock, 6-1/2 Dock, and Commodore Dock were surveyed. A single vessel only was surveyed at the Main Dock, Kappas East Dock, and Yellow Ferry Dock, as no additional vessels at these docks were equipped with anode attachment (structure) leads or other means of electrical contact to the reinforcement steel. Additionally, the surveys were repeated on the vessel at 15 Liberty Dock, in conjunction with the aluminum replacement anodes installed.

Structures

The structures intended for cathodic protection are several of the approximately 390 floating home barges at the above referenced marinas in Sausalito, CA. The majority of the barges are constructed of reinforced concrete, ranging in size from 16' x 32' x 6' to 20' x 46' x 6' as built by Aquamaison of Sausalito, CA. Based on information provided by the manufacturer, standard barge construction comprises #4 bars at 12" centers both ways in the walls and floor slab; #5 bars at 6" centers in the top of the floor slab and #6 bars at the top and bottom of the walls, with additional #5 bars at the corners.

All of the moored barges are floating at high tide, corresponding to the maximum submerged surface area (bottom surface plus sides up to the flotation line). The barges come to rest on the bottom at different points of the tidal cycle, varying by slip location and the individual homes. Minimum low tide depth observed in any slip during this survey was approximately 18".

Some of these concrete barges were retrofitted with galvanic anode cathodic protection (GACP) systems, at the option of the individual owners. These GACP systems consist of bare zinc anodes, and large gauge (500kCM) bare copper cables attached at opposite corners to the reinforcement steel used for terminating the anodes. The concrete cover was removed and patched (above the flotation line) for access to the reinforcement steel at each location. Forty-six pound (46#) zinc hull anodes were bolted to the side of the barge below the low water line and terminated (wire wrapped and soldered) one (1) each at opposite corners of each typical (16'x36') barge. The bigger barge at Commodore Dock, No. 10 was equipped with four anodes, one on each corner of the barge.

Test Procedures

The following tasks were conducted:

- A rebar potential survey was conducted by measuring the potential versus a portable silver-silver/chloride (AG/AgCl2) reference electrode submerged to approximately half water depth at each corner of the barges included in the survey. Potentials were measured with available protective current from all operational anodes applied. Anode output current was measured using a clamp-on ammeter (current clamp) at each accessible anode.

- Marine side access to each barge included in this survey was generally accomplished working from a small dingy, with the assistance of others. Further access in some cases was gained working off the vessel decks, catwalks, and access ramps.

- A general visual inspection of the accessible concrete barge and existing anodes were conducted.

- Verified electrical continuity of the rebar between anode locations on the barges inspected.

- Additional surveys were conducted on the barge at 15 Liberty Dock after installation of new aluminum anodes, and included measurement of polarized and depolarized potentials. Surveys were performed with the original anodes (Zinc) and the replacement anodes (18.5# Aluminum) installed. Structure potentials were measured at 6-second intervals over 2-tide cycles (50 hours continuous operation) using a data recorder to identify any stray current from intermittent or occasional sources.

Analysis and Conclusions

The underside of each barge represents the majority of the wetted structure surface area and is continuously submerged or in physical contact with the mud bottom. Cathodic protection is generally applicable to any buried or submerged metallic structure, and should be considered necessary for corrosion control of the reinforced concrete hull vessels exposed to salt water and/or bay mud at these Marinas, based on industry practice and on the observations and testing conducted. Adequate cathodic protection of these structures can be achieved with galvanic anode cathodic protection (GACP) systems, designed according to hull size and desired anode life and based upon either zinc or aluminum anodes. However, in saltwater environments aluminum anodes are usually the most economical choice for corrosion protection. These anodes offer higher current efficiency and lower anode consumption compared to zinc in aqueous saline areas, making aluminum ideal for the protection of the barge hulls.

Tabulated survey data including structure potential, individual anode output, and results of electrical continuity testing at each floating barge included in this investigation are provided in Appendix 1.

The present design (anodes bolted to the hull) precludes measurement of ‘depolarized’ or ‘instant-off’ potentials necessary for a definitive analysis for adequacy of cathodic protection based on NACE International criteria. Measurement data was collected ‘as found’ in each case (anodes missing, anodes submerged, etc.), except the vessel at 15 Liberty Dock. This vessel presented a special case wherein ‘depolarized’ and ‘instant-off’ potentials could be measured by simply pulling the anodes out of the water, due to the unintended detachments of both anode mounting brackets. The replacement (aluminum) anodes were installed by suspending each anode by the current return cable, not using an attachment bracket, allowing the same method for On/Off potential measurement. Adequate cathodic protection of the reinforcement steel in accordance with NACE International criteria was confirmed in the case of the vessel at 15 Liberty Dock, and was likely achieved for the other vessels surveyed with at least two functional anodes installed.

Combined anode output at each standard sized barge surveyed and with two (2) functional zinc anodes ranged from 530mA to 1520mA, while the larger barge moored at main Dock, Slip No. 27 exhibited a 2-anode combined output of 1850mA. The barge moored at Liberty Dock, Slip No. 15 exhibited a combined output of 1620mA from the two replacement aluminum anodes installed.

From the data collected, and based upon the published consumption rates for zinc anodes, theoretical anode service life for the barges equipped with 2-46 pound zinc anodes range from 2.5 years to 7.0 years. While the data collected is useful to predict relative anode life at various locations, and approximate replacement intervals, actual anode service may vary. Reported anode yields are generally consistent with ‘worst case’ consumption rates predicted by the measurement data.

Theoretical anode service life for the barge presently equipped with 2-18.5 pound aluminum anodes is approximately 2.6 years. Larger anodes would yield proportionately greater life, up to 6.5 years based on 92- pounds total aluminum anode weight.

Corrpro can supply aluminum hull anodes made to either of two alloying standards. Alloy I produces an open circuit potential of 1.05 volts (with respect to an Ag/AgCl reference cell), and realizes a 95% current efficiency. Alloy II generates a voltage potential of 1.10, and has a lower current efficiency rating of 87% in free-flowing water. Consumption rate for either aluminum anode is approximately 7.6 pounds per amp-year.

Corrpro also manufactures zinc hull anodes for use on structures in brackish and saltwater environments. The anodes are cast using 99.99%-pure high-grade zinc, and alloyed to meet military specification MIL-A-19001 and the ASTM-B-418, Type I chemical composition standard. Consumption rate for this zinc anode is approximately 24.7 pounds per amp-year.

No evidence of stray current induced corrosion was indicated based on any of the testing conducted including the 50-hour data logger survey performed on the vessel at 15 Liberty Dock.

Recommendations

- Develop a standardized Galvanic Anode CP system design for the typical sized barges, based on the survey data collected. The same design could be used for multiple barges of similar size and construction type, and include up-rating factors for application to larger barges. The cathodic protection design package would include detailed service life calculations for each anode alloy and configuration considered, and factors for anode efficiency and utilization.

Cost Estimates

Engineering services for CP design, including drawings and installation details, can be provided for a fee of $3,000. A materials cost estimate can be provided after a final design is completed.

Corrpro appreciates this opportunity to be of service. Please do not hesitate to contact the undersigned at our San Leandro office, Ext. 228 for further assistance. Our invoice for these services is included.

Very truly yours,

Greg D. Markus

Greg D. Markus
Engineering Division
Corrpro Companies, Inc.

GM Server G: Regional/572-5175/5175.xls
Encls: Data, Invoice

APPENDIX 1

FLOATING HOMES OF KAPPAS AND WALDO POINT HARBOR
LIBERTY DOCK
CATHODIC PROTECTION SURVEY DATA

	Rebar Potential vs $AgAgCl_2$ (-mV)				
Slip No. (Notes) Barge Corner	**Anodes Submerged (On)**	**Anodes Momentarily Out-Of-Water (I-Off)**	**Anodes Out-Of-Water Extended Period (time), or No Anodes Installed (Depol.)**	**Voltage Drop Between Opposite Anode Cables (Cont.)**	**Anode Current Output (mA)**
15 (With Existing Zinc anodes, 75% Consumed)					
1	804	753	642 (7hrs.)		
2	827	751	639 (7hrs.)	.000v	450
3	770	705	631(7hrs.)		
4	689	577	635 (7hrs.)	.000v	350
15					
1	804	753	578 (24hrs.)		
2	827	751	576 (24hrs.)		
3	770	705	-		
4	689	577	779 (24hrs.)		
	Pulled Anodes out to read 'Depol' and 'I-Off ' (Slip 15 Barge Only)				
15 (With 2 - 18.5# Aluminum Anodes)					
1					
2	790				780
3					
4					840
68					
1	872			.000v	430
2	854				
3	853			.003v	420
4	850				

APPENDIX 1

FLOATING HOMES OF KAPPAS AND WALDO POINT HARBOR
SOUTH 40
CATHODIC PROTECTION SURVEY DATA

	Rebar Potential vs $AgAgCl_2$ (-mV)				
Slip No. (Notes) Barge Corner	**Anodes Submerged (On)**	**Anodes Momentarily Out-Of-Water (I-Off)**	**Anodes Out-Of-Water Extended Period (time), or No Anodes Installed (Depol.)**	**Voltage Drop Between Opposite Anode Cables (Cont.)**	**Anode Current Output (mA)**
22 (Low Tide)					
1	749				
2	782			.000V	650
3	733				
4	812			.001V	730
22 (High Tide)					
1	755				
2	769			.000v	740
3	763				
4	781			.000v	780
23 (Anodes Lost)					
1			487		
2			489	.000v	0
3			493		
4			490	.000v	0

APPENDIX 1

FLOATING HOMES OF KAPPAS AND WALDO POINT HARBOR
'A' DOCK
CATHODIC PROTECTION SURVEY DATA

	Rebar Potential vs $AgAgCl_2$ (-mV)				
Slip No. (Notes) Barge Corner	**Anodes Submerged (On)**	**Anodes Momentarily Out-Of-Water (I-Off)**	**Anodes Out-Of-Water Extended Period (time), or No Anodes Installed (Depol.)**	**Voltage Drop Between Opposite Anode Cables (Cont.)**	**Anode Current Output (mA)**
_______(TJ Nelson)					
1	866			.000v	870
2	736				
3	781			.000v	370
4	724				
_______(Pictures show spalling and corroded rebar.)					
1	824			.000v	350
2	795			-	
3	835			.000v	460
4	789			-	
Manufactured 2/83					

APPENDIX 1

FLOATING HOMES OF KAPPAS AND WALDO POINT HARBOR
MAIN DOCK
CATHODIC PROTECTION SURVEY DATA

Slip No. (Notes) Barge Corner	Rebar Potential vs $AgAgCl_2$ (-mV) Anodes Submerged (On)	Anodes Momentarily Out-Of-Water (I-Off)	Anodes Out-Of-Water Extended Period (time), or No Anodes Installed (Depol.)	Voltage Drop Between Opposite Anode Cables (Cont.)	Anode Current Output (mA)
27 (Oversized Barge)					
1	619			.000v	830
2	746				
3	613				
4	684			.000v	1020

Reportedly Epoxy-Coated Rebar (not confirmed by survey data)

APPENDIX 1

FLOATING HOMES OF KAPPAS AND WALDO POINT HARBOR
KAPPAS WEST PIER
CATHODIC PROTECTION SURVEY DATA

	Rebar Potential vs $AgAgCl_2$ (-mV)				
Slip No. (Notes) Barge Corner	**Anodes Submerged (On)**	**Anodes Momentarily Out-Of-Water (I-Off)**	**Anodes Out-Of-Water Extended Period (time), or No Anodes Installed (Depol.)**	**Voltage Drop Between Opposite Anode Cables (Cont.)**	**Anode Current Output (mA)**
23					
1	690			.000v	430
2	647				-
3	929			.000v	450
4	866				
35					
1	798			.000v	450
2	745				-
3	842			.000v	460
4	751				