Corrosion Prediction and Corrosion Modeling Software

EVS-Compass®: Extreme Value Statistics for Corrosion Modeling and Corrosion Life Prediction

Version 9.20

☆ **Performance** ☆ **Functionality** ☆ **Usability**

Anytime Anywhere Any Device Any OS

No USB dongles No installation No Browser Plug-ins

Overview and Application Examples of EVS-Compass - Extreme Value Statistics for Corrosion Modeling and Corrosion Life Prediction

Extreme value statistics (EVS) has been used since the 1950s for extrapolating corrosion damages (maximum pit depth, crevice depth, crack depth etc.) from small lab samples, field coupons, or partial coverage inspection blocks to larger area of structures and assets at present or future times. WebCorr's EVS-Compass is the only device and OS independent EVS software on the market for corrosion modeling and life prediction of corrodible structures. Designers, OEM engineers, consultants, operation personnel, maintenance and inspection engineers, and government regulators can quickly and accurately determine:

1. the time to first leak or perforation;
2. the number of leaks or perforation at any given time;
3. the time to ***N***th leak or perforation for any given number of ***N***;
4. the area of perforation holes;
5. the depth of the largest pit at any given time;
6. the depth of the ***N***th largest pit at any given time;
7. the number of pits exceeding a given depth ***D*** at any given time;
8. the time required for ***N*** pits to exceed the depth of ***D***;
9. the probability of failure (POF) at a given time and a given wall thickness;
10. the service life for a given wall thickness at a given POF threshold;

11. the maximum surface area for EVS extrapolation in partial coverage inspection;
12. the recommended area for lab coupons or inspection blocks for EVS extrapolation in space and in time;
13. the recommended number of lab coupons or inspection blocks for EVS extrapolation in space and in time;
14. the charts showing (a) pit depth vs service life; (b) pit depth vs area; (c) probability of failure vs service life; (d) probability of failure vs area; (e) probability of failure vs wall thickness.

The probability of failure (POF) is an important factor in API 580 Risk-Based Inspection and API 581 Risk-Based Inspection Methodology. EVS-Compass is a powerful EVS software tool that goes beyond the prediction of the probability of failure (POF) in time (POF vs service life) and in space (POF vs area, POF vs wall-thickness), it predicts **the time to FIRST leak or perforation**, **the number of leaks at any given time**, **the depth of corrosion and the number of pits exceeding the specified depth at any future time**. For partial coverage inspection, EVS-Compass determines both the size and number of inspection blocks to minimize uncertainties. The unique capabilities of EVS-Compass help assets owners, operators, and government regulators make quantitative risk-based decisions pertaining to the future conditions and operations of structures and assets.

EVS-Compass is a cloud-based software that works on any device running any OS without the need for users to install or download anything. Figure 1 below shows an overview of the user interface of EVS-Compass.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Stainless Steels		Note on Data Entry				
Service environment	Chemicals		1. Enter the actual remaining wall thickness in mm.				
Remaining wall thickness, d	mm	12.700	2. Enter the surface area of the coupon or inspection block in m2.				
Area of coupons or inspection blocks, A_C	m^2	0.00258	3. Enter the exposure time in **ascending order** from dataset 1.				
Total surface area of the structure, A_T	m^2	0.0929	4. Enter the maximum pit depth in mm in **ascending order**.				
			5. Each dataset consists of a number of coupons or inspection blocks.				
			Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Days		2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction		3	0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days	4015.000	0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	882		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	No./m^2	675		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	8871		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	9.955%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	24.532					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.999					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	2318					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	5					1.768
Probability of Failure (POF)							1.776
Probability of failure at time t and wall thickness d, $POF_{t,d}$		100.000%					
Service life for wall thickness d, t_d	Days	170					
at the user defined POF threshold of		5.000%					
EVS for Optimization of Partial Coverage Inspection (PCI)							
Max area (m^2) of EVS extrapolation under the current settings		2.010					

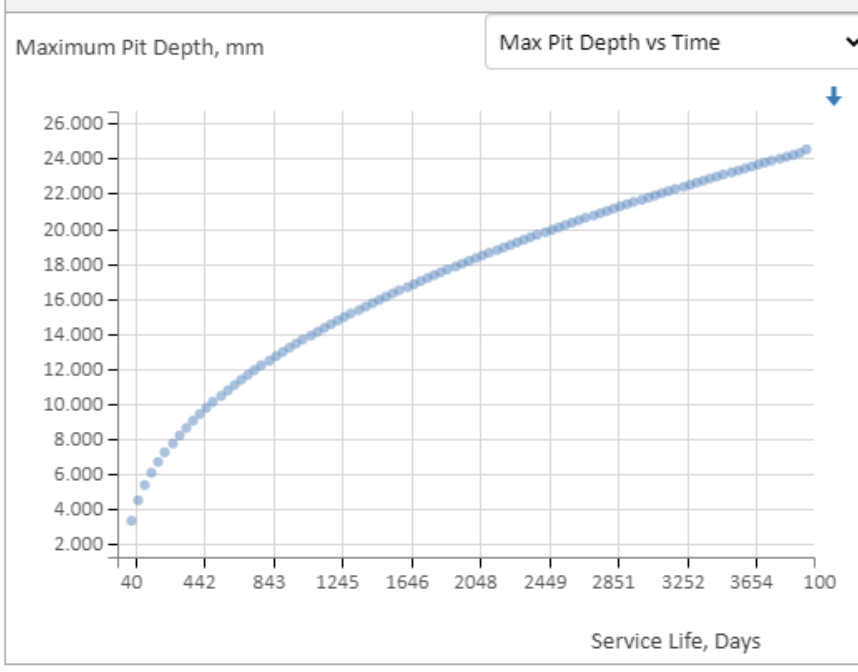

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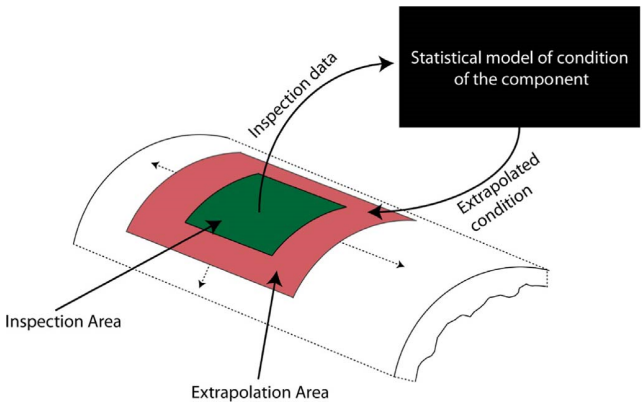
Figure 1 EVS-Compass: Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets.

EVS-Compass Application Example No.1

Prediction of Pitting Corrosion in Type 316L Stainless Steel: EVS Extrapolation in Space and in Time

In Figure 1 above, type 316L stainless steel coupons of 2" by 2" (4 in^2= 0.00258 m^2) with a thickness of 0.5" (12.7 mm) were immersed in chloride solution at 50^oC for durations ranging from 49.50 hours to 528 hours (2.063 to 22 days) in the laboratory. For each exposure duration, a number of identical coupons (from 3 to 15) were used. The maximum pit depth on each coupon was measured and entered in EVS-Compass. The 5 exposure durations produced 5 datasets. For a surface area of 1 ft^2 (12"x12"=144 in^2=0.0929 m^2), EVS-Compass predicts that:



(1) the time to first leak or perforation of the 12.7 mm plate is 882 days;

(2) after 11 years (4015 days), the number of leaks or perforation holes is 63 (675x0.0929=63);

(3) the time to ***100***th leak or perforation is 8871 days (24.3 years);

(4) the hole area at 11 years is 9.955% of the total surface area;

(5) the depth of the largest pit at 11 years is 24.532 mm;

(6) the depth of the ***100***th largest pit at 11 years is 8.999 mm;

(7) the number of pits exceeding 0.5 mm at 11 years is 215 (2318x0.0929=215);

(8) the time for the first 100 pits to exceed 0.5 mm is 5 days;

(9) the probability of failure at 11 years for wall thickness of 12.7 mm is 100%;

(10) the service life for wall thickness of 12.7 mm at 5% probability of failure is 170 days;

(11) For partial coverage inspection (PCI), the maximum area of EVS extrapolation under the current settings is 2.01 m^2.

EVS-Compass is designed with end-users in mind without the usual learning curve associated with a new software. Users simply enter the basic information such as material, service environment, area of coupons or inspection blocks, total surface area of the structure, exposure time and durations, and the maximum pit depth for each coupon or inspection block at each exposure duration. Figures 2-5 show the options for materials, service environments, exposure time, and type of charts to display.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Carbon Steels		Note on Data Entry				
Service environment	Carbon Steels / Low Alloy Steels / Stainless Steels / Nickel-base Alloys / Aluminum Alloys / Copper Alloys / Others		1. Enter the actual remaining wall thickness in mm.				
Remaining wall thickness, d		12.700	2. Enter the surface area of the coupon or inspection block in m2.				
Area of coupons or inspection blocks, A_C		0.00258	3. Enter the exposure time in **ascending order** from dataset 1.				
Total surface area of the structure, A_T		100.0000	4. Enter the maximum pit depth in mm in **ascending order**.				
			5. Each dataset consists of a number of coupons or inspection blocks.				
			Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Days		2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction		3	0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days	365.000	0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	787		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	No./m^2	0		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	814		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	0.000%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	9.095					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.963					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	0					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	0					1.768

Figure 2 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: option for Material of Construction

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Carbon Steels		Note on Data Entry				
Service environment	Chemicals		1. Enter the actual remaining wall thickness in mm.				
Remaining wall thickness, d	Atmosphere / Water Immersion / Underground Chemicals	12.700	2. Enter the surface area of the coupon or inspection block in m2.				
Area of coupons or inspection blocks, A_C		0.00258	3. Enter the exposure time in **ascending order** from dataset 1.				
Total surface area of the structure, A_T	m^2	100.0000	4. Enter the maximum pit depth in mm in **ascending order**.				
			5. Each dataset consists of a number of coupons or inspection blocks.				
			Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Days		2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction		3	0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days	365.000	0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	787		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	No./m^2	0		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	814		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	0.000%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	9.095					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.963					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	0					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	0					1.768

Figure 3 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: option for Service Environment.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Stainless Steels		Note on Data Entry 1. Enter the actual remaining wall thickness in mm. 2. Enter the surface area of the coupon or inspection block in m2. 3. Enter the exposure time in **ascending order** from dataset 1. 4. Enter the maximum pit depth in mm in **ascending order**. 5. Each dataset consists of a number of coupons or inspection blocks.				
Service environment	Chemicals						
Remaining wall thickness, d	mm	12.700					
Area of coupons or inspection blocks, A_C	m^2	0.00258					
Total surface area of the structure, A_T	m^2	100.0000	Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset		Days	2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction			0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days		0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	787		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	$No./m^2$	0		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	814		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	0.000%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	9.095					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.963					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	$No./m^2$	0					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	0					1.768

Figure 4 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: option for Exposure Time.

Probability of Failure (POF)						1.776
Probability of failure at time t and wall thickness d, $POF_{t,d}$	100.000%					
Service life for wall thickness d, t_d	Days	49				
at the user defined POF threshold of	5.000%					
EVS for Optimization of Partial Coverage Inspection (PCI)						
Max area (m^2) of EVS extrapolation under the current settings	2.010					
Two options to extend EVS extrapolation to the total area of the structure:						
1. Increase the number of inspection blocks from 15 to	29					
OR 2. Increase the min. area (sq.m) of inspection blocks to	0.1284					

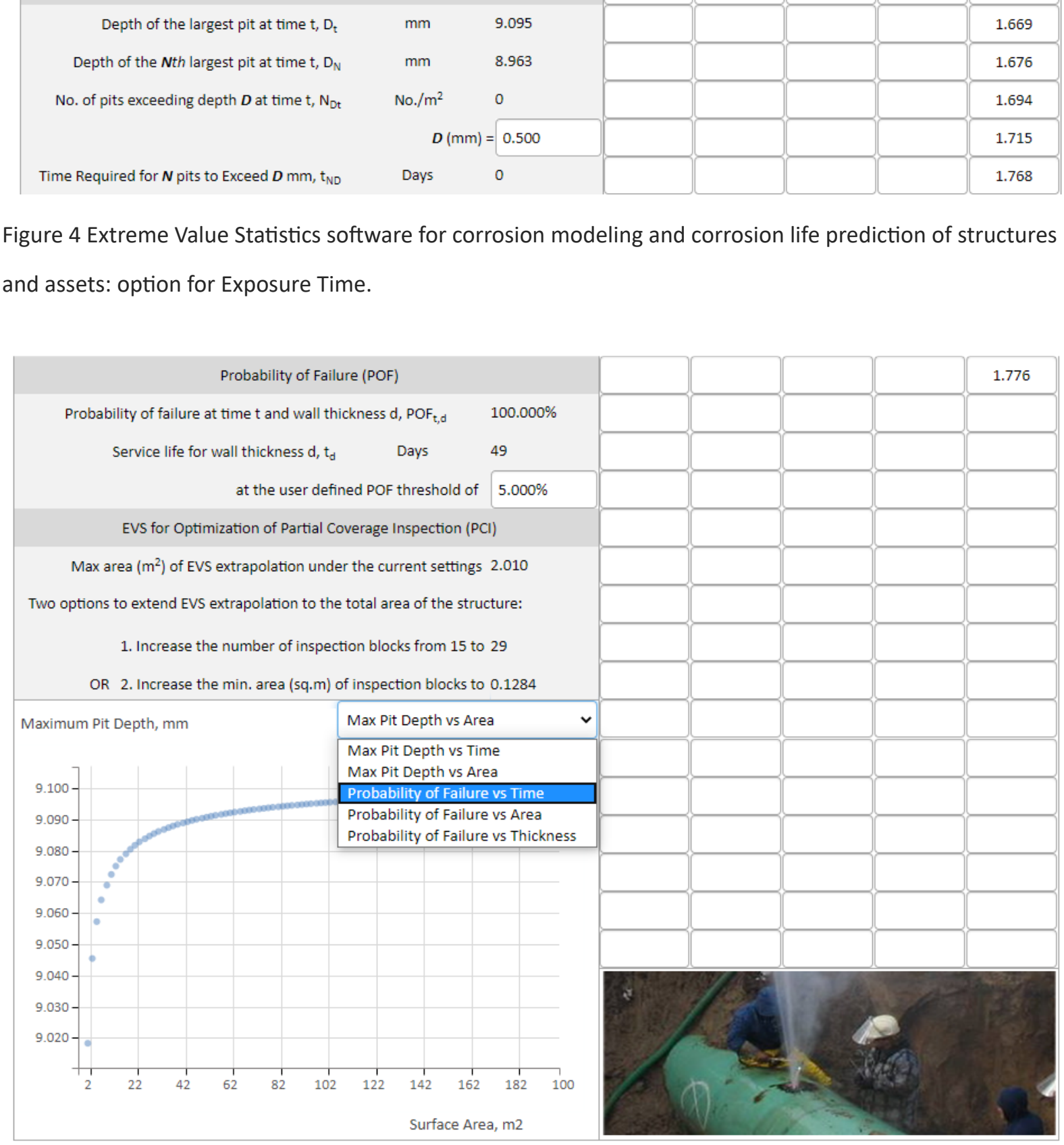


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Figure 5 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: option for different types of plots.

EVS extrapolation in space and in time: The surface area of coupons used in laboratory tests was 4 in^2 (0.00258 m^2) for a maximum duration of 22 days. Figure 6 shows prediction results by EVS-Compass when the surface area is extrapolated to 2.58 m^2 (1000 times) and the exposure time to 365 days. The time to first leak or perforation is 800 days, the time to ***100***th leak or perforation is 1028 days. For partial coverage inspection (PCI), EVS-Compass determines that the maximum surface area for extrapolation is 2.02 m^2. EVS-Compass recommends two options to extend the extrapolation to the total surface area of the structure: (1) by increasing the number of inspection blocks from the current 15 to 16; or by increasing the minimum surface area of the inspection blocks from the current 0.00258 m^2 to 0.0033 m^2. The probability of failure vs. service life is selected in Figure 6. In Figure 7, the probability of failure vs. surface area is selected. Figure 8 show the plot of the probability of failure vs. wall thickness.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Stainless Steels		Note on Data Entry				
Service environment	Chemicals		1. Enter the actual remaining wall thickness in mm.				
Remaining wall thickness, d	mm	12.700	2. Enter the surface area of the coupon or inspection block in m2.				
Area of coupons or inspection blocks, A_C	m^2	0.00258	3. Enter the exposure time in **ascending order** from dataset 1.				
Total surface area of the structure, A_T	m^2	2.5800	4. Enter the maximum pit depth in mm in **ascending order**.				
			5. Each dataset consists of a number of coupons or inspection blocks.				
			Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Days		2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction		3	0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days	365.000	0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	800		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	No./m^2	0		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	1028		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	0.000%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	9.029					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.099					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	0					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	1					1.768
Probability of Failure (POF)							1.776
Probability of failure at time t and wall thickness d, $POF_{t,d}$		100.000%					
Service life for wall thickness d, t_d	Days	86					
at the user defined POF threshold of		5.000%					
EVS for Optimization of Partial Coverage Inspection (PCI)							
Max area (m^2) of EVS extrapolation under the current settings		2.010					
Two options to extend EVS extrapolation to the total area of the structure:							
1. Increase the number of inspection blocks from 15 to		16					
OR 2. Increase the min. area (sq.m) of inspection blocks to		0.0033					

Probability of Failure — Probability of Failure vs Time

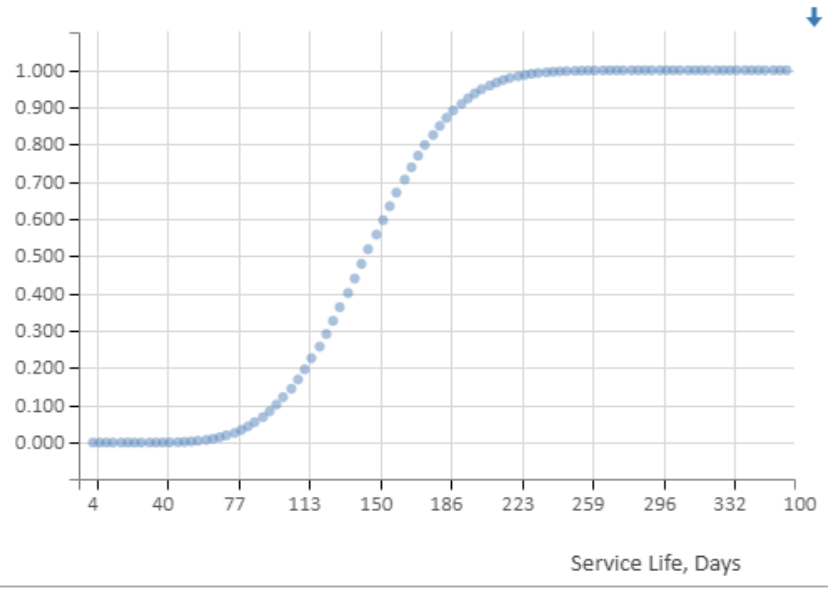

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Figure 6 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: Probability of Failure vs. Service Life.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Stainless Steels		Note on Data Entry				
Service environment	Chemicals		1. Enter the actual remaining wall thickness in mm.				
Remaining wall thickness, d	mm	12.700	2. Enter the surface area of the coupon or inspection block in m2.				
Area of coupons or inspection blocks, A_C	m^2	0.00258	3. Enter the exposure time in **ascending order** from dataset 1.				
Total surface area of the structure, A_T	m^2	50.0000	4. Enter the maximum pit depth in mm in **ascending order**.				
			5. Each dataset consists of a number of coupons or inspection blocks.				
			Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Days		2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction		3	0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days	365.000	0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	788		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	No./m^2	0		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	828		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	0.000%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	9.090					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.899					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	0					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	0					1.768
Probability of Failure (POF)							1.776
Probability of failure at time t and wall thickness d, $POF_{t,d}$		100.000%					
Service life for wall thickness d, t_d	Days	54					
at the user defined POF threshold of		5.000%					
EVS for Optimization of Partial Coverage Inspection (PCI)							
Max area (m^2) of EVS extrapolation under the current settings		2.010					
Two options to extend EVS extrapolation to the total area of the structure:							
1. Increase the number of inspection blocks from 15 to		26					
OR 2. Increase the min. area (sq.m) of inspection blocks to		0.0642					

Probability of Failure — Probability of Failure vs Area

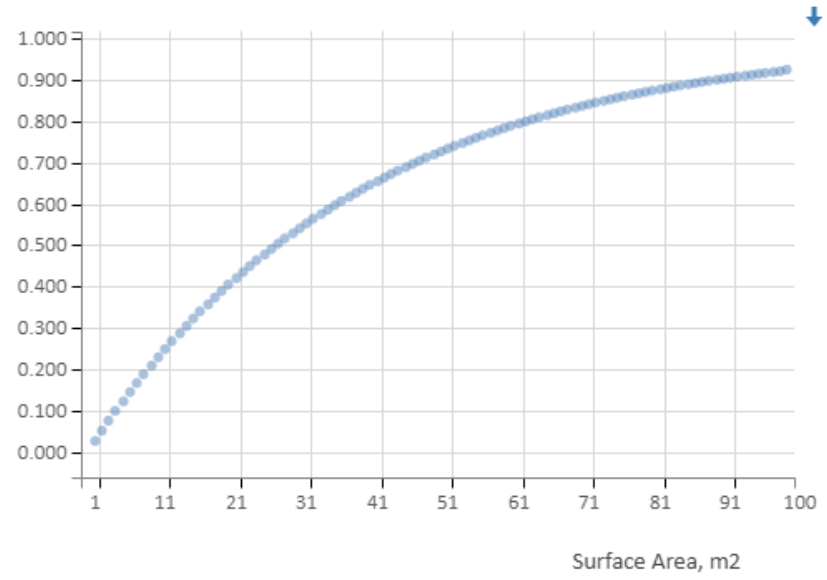

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Figure 7 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: Probability of Failure vs. Surface Area.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Type 316L stainless steel coupons in chloride soultion at 50oC						
Material of construction	Stainless Steels		Note on Data Entry				
Service environment	Chemicals		1. Enter the actual remaining wall thickness in mm.				
Remaining wall thickness, d	mm	25.000	2. Enter the surface area of the coupon or inspection block in m2.				
Area of coupons or inspection blocks, A_C	m^2	0.00258	3. Enter the exposure time in **ascending order** from dataset 1.				
Total surface area of the structure, A_T	m^2	2.5800	4. Enter the maximum pit depth in mm in **ascending order**.				
			5. Each dataset consists of a number of coupons or inspection blocks.				
			Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset		Days	2.063	6.007	15.771	18.885	22.000
Number of datasets used for analysis and prediction		3	0.531	0.930	0.902	1.478	1.181
Prediction of Leaks or Perforations			0.640	1.011	1.135	1.552	1.389
Service life or exposure time for prediction, t	Days	365.000	0.775	1.011	1.273	1.651	1.397
Time to first leak or perforation, t_1	Days	3803		1.011	1.344	1.857	1.443
Number of leaks or perforations at time t, N_t	$No./m^2$	0		1.036	1.379	1.857	1.461
Time to ***N**th* leak or perforation, t_N	Days	4885		1.054	1.506	2.030	1.542
	N =	100		1.118	1.613	2.030	1.577
Area of perforation holes, A_H	% total	0.000%		1.326	1.641	2.101	1.588
Prediction of Maximum Depth of Pits							1.595
Depth of the largest pit at time t, D_t	mm	9.029					1.669
Depth of the ***N**th* largest pit at time t, D_N	mm	8.099					1.676
No. of pits exceeding depth ***D*** at time t, N_{Dt}	$No./m^2$	0					1.694
	D (mm) =	0.500					1.715
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	1					1.768
Probability of Failure (POF)							1.776
Probability of failure at time t and wall thickness d, $POF_{t,d}$		2.617%					
Service life for wall thickness d, t_d	Days	409					
at the user defined POF threshold of		5.000%					
EVS for Optimization of Partial Coverage Inspection (PCI)							
Max area (m^2) of EVS extrapolation under the current settings		2.010					
Two options to extend EVS extrapolation to the total area of the structure:							
1. Increase the number of inspection blocks from 15 to		16					
OR 2. Increase the min. area (sq.m) of inspection blocks to		0.0033					

Probability of Failure — Probability of Failure vs Thickness

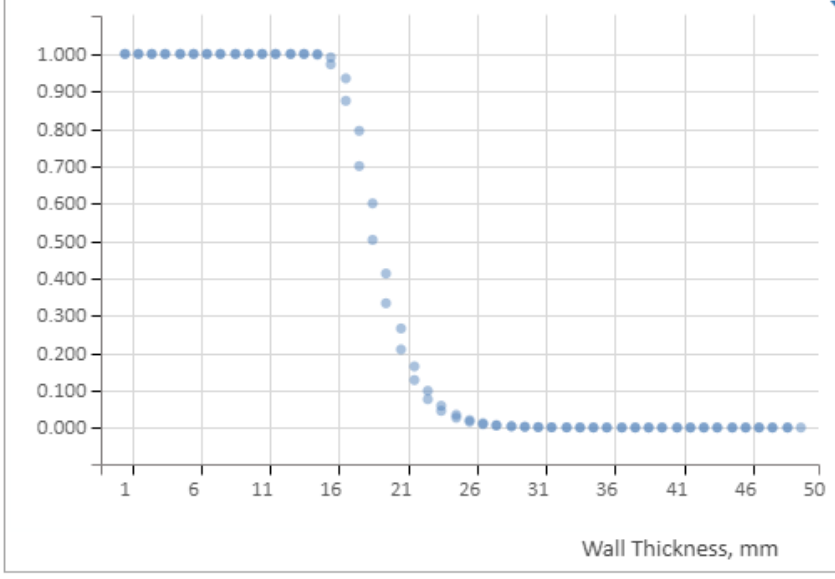

Figure 8 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: Probability of Failure vs. Wall Thickness.

EVS-Compass Application Example No.2

Prediction of Pitting Corrosion in Aluminum Alloy: EVS Extrapolation in Space and in Time

Figures 9 and 10 show another application example of EVS-Compass in corrosion modeling and life prediction. Aluminum alloy Alcan 2S-O coupons of 129 cm^2 were immersed in Kingston tap water at 25^oC for various durations from 7 to 365 days. Maximum pit depth on each coupon at 5 exposure durations is entered into EVS-Compass as shown in Figure 9 below. For a large structure with an area of 1000 m^2 (that is 77,519 times of the area of coupons) and a wall thickness of 2.54 mm, EVS-Compass predicts that:

(1) the time to first leak or perforation is 991 days;

(2) the number of leaks or perforation after 5 years (1825 days) is 24/m^2;

(3) the time to the ***100***th leak or perforation is 997 days;

(4) the hole area after 5 years exposure is 21% of the total surface area;

(5) the depth of the largest pit on the 1000 m^2 surface area after 5 years is 3.09 mm;

(6) the number pits exceeding 1.27 mm after 5 years is 108/m^2;

(7) the time required for the first 100 pits to exceed 1.27 mm is 98 days;

(8) the probability of failure at 5 years for the wall thickness of 2.54 mm on the 1000 m^2 surface is 100%;

(9) the service life for the wall thickness of 2.54 mm in the 1000 m^2 surface is 3 days at the POF of 5%;

(10) for partial coverage inspection, the maximum area of extrapolation is 0.809 m^2;

(11) EVS-Compass recommends two options to extend EVS extrapolation to the entire surface area of the structure: (a) by increasing the number of coupons or inspection blocks from the current 10 to 32; (b) by increasing the area of coupons or inspection blocks to 15.9438 m^2 (shown in Figure 10 below);

(12) the maximum pit depth vs. service life is plotted in Figure 9.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Alcan 2S-O coupons immersed in Kingston tap water at 25oC							
Material of construction	Aluminum Alloys		Note on Data Entry 1. Enter the actual remaining wall thickness in mm. 2. Enter the surface area of the coupon or inspection block in m2. 3. Enter the exposure time in **ascending order** from dataset 1. 4. Enter the maximum pit depth in mm in **ascending order**. 5. Each dataset consists of a number of coupons or inspection blocks.					
Service environment	Water Immersion							
Remaining wall thickness, d	mm	2.540						
Area of coupons or inspection blocks, A_C	m^2	0.01290						
Total surface area of the structure, A_T	m^2	1000.0000	Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5	
Service life or exposure time for each dataset	Days		7.000	30.000	90.000	180.000	365.000	
Number of datasets used for analysis and prediction		5	0.180	0.460	0.480	0.620	0.640	
Prediction of Leaks or Perforations			0.266	0.500	0.578	0.620	0.680	
Service life or exposure time for prediction, t	Days	1825.000	0.290	0.510	0.610	0.620	0.700	
Time to first leak or perforation, t_1	Days	991	0.306	0.580	0.610	0.680	0.760	
Number of leaks or perforations at time t, N_t	No./m^2	24	0.334	0.580	0.610	0.680	0.800	
Time to ***N**th* leak or perforation, t_N	Days	997	0.340	0.640	0.660	0.720	0.810	
	N =	100	0.340	0.654	0.690	0.740	0.820	
Area of perforation holes, A_H	% total	21.081%	0.410	0.680	0.718	0.740	0.840	
Prediction of Maximum Depth of Pits			0.410	0.692	0.760	0.760	0.840	
Depth of the largest pit at time t, D_t	mm	3.050	0.545	0.692	0.798	0.760	0.900	
Depth of the ***N**th* largest pit at time t, D_N	mm	3.044						
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	108						
	D (mm) =	1.270						
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	98						
Probability of Failure (POF)								
Probability of failure at time t and wall thickness d, $POF_{t,d}$		100.000%						
Service life for wall thickness d, t_d	Days	3						
at the user defined POF threshold of		5.000%						
EVS for Optimization of Partial Coverage Inspection (PCI)								
Max area (m^2) of EVS extrapolation under the current settings		0.809						
Two options to extend EVS extrapolation to the total area of the structure:								
1. Increase the number of inspection blocks from 10 to		32						
OR 2. Increase the min. area (sq.m) of inspection blocks to		15.9438						

Maximum Pit Depth, mm — Max Pit Depth vs Time

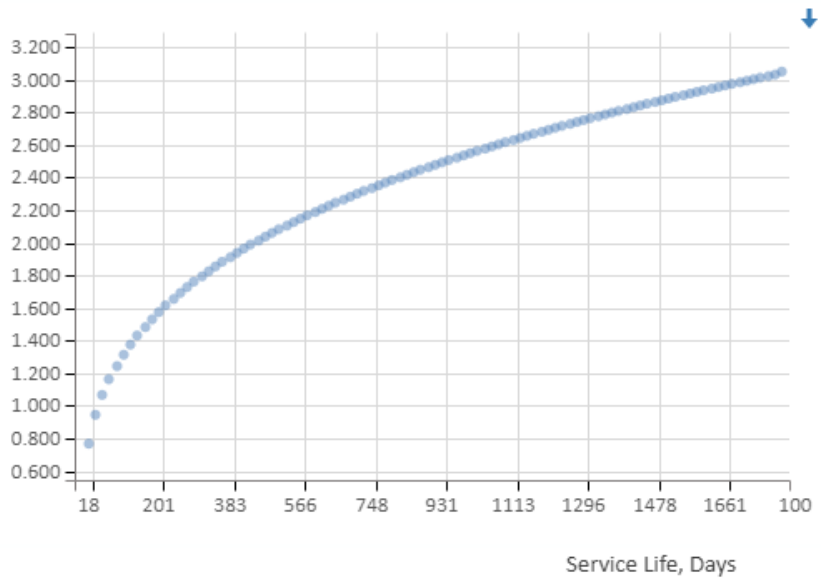

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Figure 9 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: aluminum alloy in Kingston tap water.

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Alcan 2S-O coupons immersed in Kingston tap water at 25oC						
Material of construction	Aluminum Alloys		Note on Data Entry 1. Enter the actual remaining wall thickness in mm. 2. Enter the surface area of the coupon or inspection block in m2. 3. Enter the exposure time in **ascending order** from dataset 1. 4. Enter the maximum pit depth in mm in **ascending order**. 5. Each dataset consists of a number of coupons or inspection blocks.				
Service environment	Water Immersion						
Remaining wall thickness, d	mm	2.540					
Area of coupons or inspection blocks, A_C	m^2	15.94380					
Total surface area of the structure, A_T	m^2	1000.0000	Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Days		7.000	30.000	90.000	180.000	365.000
Number of datasets used for analysis and prediction		5	0.180	0.460	0.480	0.620	0.640
Prediction of Leaks or Perforations			0.266	0.500	0.578	0.620	0.680
Service life or exposure time for prediction, t	Days	1825.000	0.290	0.510	0.610	0.620	0.700
Time to first leak or perforation, t_1	Days	1038	0.306	0.580	0.610	0.680	0.760
Number of leaks or perforations at time t, N_t	$No./m^2$	0	0.334	0.580	0.610	0.680	0.800
Time to ***N**th* leak or perforation, t_N	Days	32853	0.340	0.640	0.660	0.720	0.810
	N =	100	0.340	0.654	0.690	0.740	0.820
Area of perforation holes, A_H	% total	0.017%	0.410	0.680	0.718	0.740	0.840
Prediction of Maximum Depth of Pits			0.410	0.692	0.760	0.760	0.840
Depth of the largest pit at time t, D_t	mm	3.007	0.545	0.692	0.798	0.760	0.900
Depth of the ***N**th* largest pit at time t, D_N	mm	1.069					
No. of pits exceeding depth ***D*** at time t, N_{Dt}	$No./m^2$	0					
	D (mm) =	1.270					
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Days	3245					
Probability of Failure (POF)							
Probability of failure at time t and wall thickness d, $POF_{t,d}$		100.000%					
Service life for wall thickness d, t_d	Days	22					
at the user defined POF threshold of		5.000%					
EVS for Optimization of Partial Coverage Inspection (PCI)							
Max area (m^2) of EVS extrapolation under the current settings		1000.003					

Maximum Pit Depth, mm — Max Pit Depth vs Time

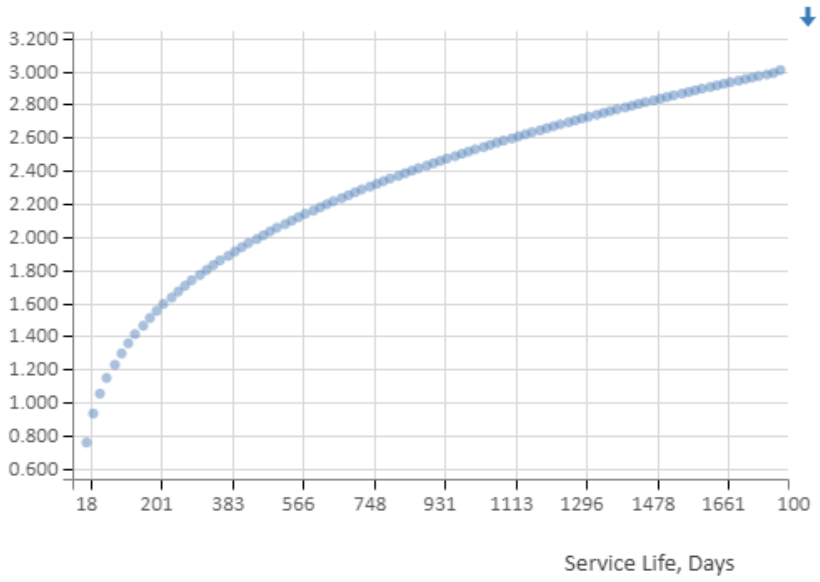

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Figure 10 Extreme Value Statistics software for corrosion modeling and corrosion life prediction of structures and assets: Optimization of Partial Inspection Coverage

EVS-Compass Application Example No.3

Partial Coverage Inspection of Pitting Corrosion in Oil Tank Bottom Plate: EVS Extrapolation in Space

Inspection of a large oil tank carbon steel base plate of 6 mm in thickness was carried out to determine the maximum pit depth distribution. The whole surface area of the oil tank plate was 1040 m^2. Due to time,

cost, and accessibility considerations, partial coverage inspection using 10 blocks of 1.85 m^2 each was randomly selected for pit depth measurements. The maximum pit depth on each of the inspection blocks was entered into EVS-Compass (one block showed no pitting and is not included in the data entry). Based on the maximum pit depth data measured using small inspection blocks of 1.85 m^2, EVS-Compass predicts that the maximum pit depth in the 1040 m^2 base plate is 4.297 mm (Figure 11). The chart in Figure 11 shows the pit depth vs. surface area of the base plate. Other time-based predictions are not applicable in this application example for EVS extrapolation in space that has only one dataset available. For EVS extrapolation in time or in time and in space, at least two datasets collected at two different exposure times are required (Figures 1-10 above).

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Pitting in Oil Tank Bottom Plate							
Material of construction	Carbon Steels		Note on Data Entry 1. Enter the actual remaining wall thickness in mm. 2. Enter the surface area of the coupon or inspection block in m2. 3. Enter the exposure time in **ascending order** from dataset 1. 4. Enter the maximum pit depth in mm in **ascending order**. 5. Each dataset consists of a number of coupons or inspection blocks.					
Service environment	Water Immersion							
Remaining wall thickness, d	mm	6.000						
Area of coupons or inspection blocks, A_C	m^2	1.85000						
Total surface area of the structure, A_T	m^2	1040.0000	Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5	
Service life or exposure time for each dataset	Years		5.000	0.000	0.000	0.000	0.000	
Number of datasets used for analysis and prediction		1	0.500					
Prediction of Leaks or Perforations			0.500					
Service life or exposure time for prediction, t	Years	5.000	0.500					
Time to first leak or perforation, t_1	Years	n/a	1.000					
Number of leaks or perforations at time t, N_t	No./m^2	n/a	1.000					
Time to ***N**th* leak or perforation, t_N	Years	n/a	1.000					
	N =	100	1.500					
Area of perforation holes, A_H	% total	n/a	1.500					
Prediction of Maximum Depth of Pits			3.000					
Depth of the largest pit at time t, D_t	mm	4.297						
Depth of the ***N**th* largest pit at time t, D_N	mm	n/a						
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	n/a						
	D (mm) =	0.500						
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Years	1						
Probability of Failure (POF)								
Probability of failure at time t and wall thickness d, $POF_{t,d}$		1.849%						
Service life for wall thickness d, t_d	Years	6						
at the user defined POF threshold of		5.000%						
EVS for Optimization of Partial Coverage Inspection (PCI)								
Max area (m^2) of EVS extrapolation under the current settings		4.283						
Two options to extend EVS extrapolation to the total area of the structure:								
1. Increase the number of inspection blocks from 9 to		74						
OR 2. Increase the min. area (sq.m) of inspection blocks to		449.2028						

Maximum Pit Depth, mm — Max Pit Depth vs Area

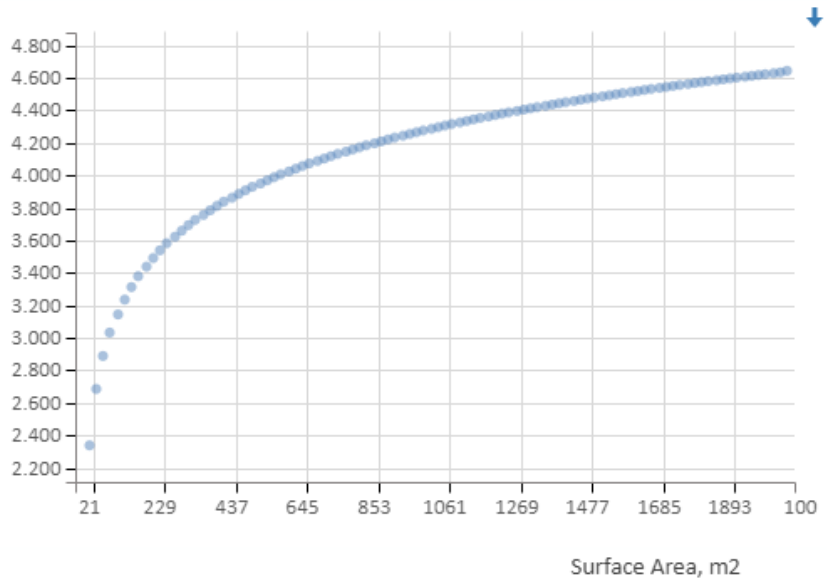

Figure 11 EVS-Compass predicts pitting depth in a large oil tank base plate of 1040 sq.m surface based on the partial coverage inspection.

EVS-Compass Application Example No.4

Pitting Corrosion of Carbon Steel in Natural Seawater: EVS Extrapolation in Space and in Time

Carbon steel coupons of 75 mm x 50 mm were immersed in natural seawater for durations of 1.0, 1.5, 2.0, 3.0 and 4.0 years. Maximum pit depth for each coupon at each exposure duration is entered into EVS-

Compass (Figure 12). Note that the surface area of a coupon (with 2 sides) is 0.0075 m^2 (75 cm^2). EVS Extrapolation of the pit depth to a surface area of 75 m^2 (10000 times of the coupon area) and the a future time of 10 years produces the following results:

(1) the time to first leak or perforation is 9.084 years;

(2) the number of leaks or perforation at 10 years is 2772 (75x36.954);

(3) the time to 100th leak or perforation is 9.122 years;

(4) the hole area at 10 years is 8.762%;

(5) the time required for 100 pits to exceed 3 mm depth is 5.311 years;

(6) the depth of the largest pit at 10 years is 6.786 mm;

(7) the depth of the 100th largest pit is 6.75 mm;

(8) the number of pits exceeding 3 mm depth at 10 years is 15358 (75x204.773);

(9) the probability of failure at 10 years and 6mm thickness is 100%;

(10) the service life for wall thickness of 6 mm at POF of 5% is 2.658 years

EVS-Compass® 9.20 Extreme Value Statistics for Service Life Prediction of Corrodible Structures

Structure ID	Carbon Steel Coupons Immersed in Natural Seawater at 20oC						
Material of construction	Carbon Steels		Note on Data Entry 1. Enter the actual remaining wall thickness in mm. 2. Enter the surface area of the coupon or inspection block in m2. 3. Enter the exposure time in **ascending order** from dataset 1. 4. Enter the maximum pit depth in mm in **ascending order**. 5. Each dataset consists of a number of coupons or inspection blocks.				
Service environment	Water Immersion						
Remaining wall thickness, d	mm	6.000					
Area of coupons or inspection blocks, A_C	m^2	0.00750					
Total surface area of the structure, A_T	m^2	75.0000	Dataset 1	Dataset 2	Dataset 3	Dataset 4	Dataset 5
Service life or exposure time for each dataset	Years		1.000	1.500	2.000	3.000	4.000
Number of datasets used for analysis and prediction		5	0.046	0.239	0.259	0.200	0.320
Prediction of Leaks or Perforations			0.049	0.302	0.311	0.201	0.472
Service life or exposure time for prediction, t	Years	10.000	0.097	0.324	0.380	0.228	0.571
Time to first leak or perforation, t_1	Years	9.084	0.098	0.326	0.447	0.350	0.637
Number of leaks or perforations at time t, N_t	No./m^2	36.954	0.169	0.394	0.559	0.427	0.693
Time to ***N**th* leak or perforation, t_N	Years	9.122	0.233	0.523	0.638	0.472	0.702
	N =	100	0.244	0.540	0.648	0.541	0.759
Area of perforation holes, A_H	% total	8.762%	0.341	0.600	0.851	0.546	0.816
Prediction of Maximum Depth of Pits			0.359	0.669	0.876	0.558	0.822
Depth of the largest pit at time t, D_t	mm	6.786	0.501	0.700	0.885	0.560	1.048
Depth of the ***N**th* largest pit at time t, D_N	mm	6.750	0.504	0.717	0.901	0.602	1.080
No. of pits exceeding depth ***D*** at time t, N_{Dt}	No./m^2	204.773	0.532	0.772	0.938	0.624	1.117
	D (mm) =	3.000	0.556	0.823	1.117	0.674	1.133
Time Required for ***N*** pits to Exceed ***D*** mm, t_{ND}	Years	5.311	0.626	0.909	1.235	0.746	1.441
Probability of Failure (POF)				0.982	1.534	0.895	1.631
Probability of failure at time t and wall thickness d, $POF_{t,d}$		100.000%		1.038		0.943	2.208
Service life for wall thickness d, t_d	Years	2.658				1.081	
at the user defined POF threshold of		5.000%				1.963	
EVS for Optimization of Partial Coverage Inspection (PCI)							
Max area (m^2) of EVS extrapolation under the current settings		0.107					
Two options to extend EVS extrapolation to the total area of the structure:							
1. Increase the number of inspection blocks from 18 to		220					
OR 2. Increase the min. area (sq.m) of inspection blocks to		5.2695					

Maximum Pit Depth, mm — Max Pit Depth vs Area

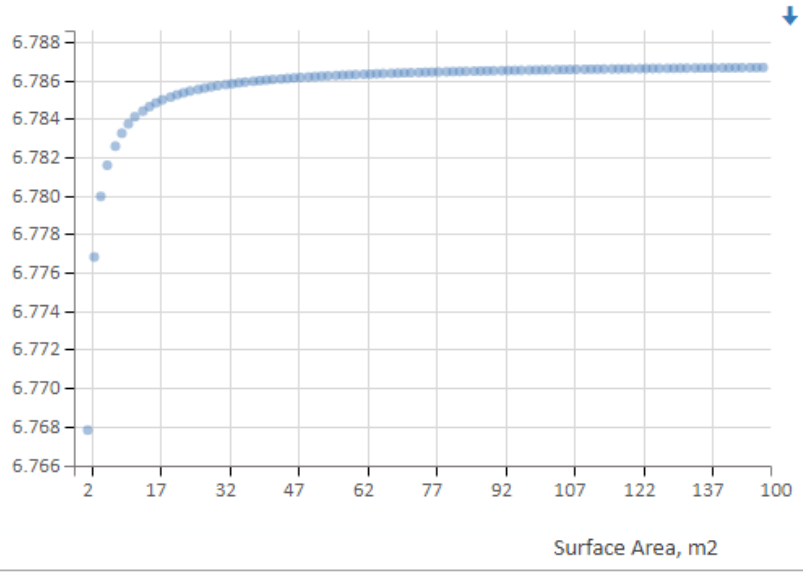

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Figure 12 EVS-Compass predicts pitting corrosion of carbon steel in natural seawater with EVS extrapolation in space and in time.

The powerful applications of EVS-Compass are truly unlimited in engineering design, materials selection, process operation, inspection and maintenance, corrosion modeling and corrosion life prediction of structures and plant assets.

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