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DECONTAMINATION TESTING OF HIGHLY CONTAMINATED PROTECTIVE COATINGS

G. A. West
C. D. Watson

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CHEMICAL TECHNOLOGY DIVISION

Unit Operations Section

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G. A. West
C. D. Watson

DATE ISSUED

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ABSTRACT

Decontaminability measurements of 34 protective coatings (primarily vinyls and epoxies) and 10 comparative control surfaces (metals, glass, and plastics) highly contaminated with either mixed fission products from typical Purex waste or Oak Ridge National Laboratory Thorex waste did not indicate any unusual improvement over coatings tested in 1950 (AECD-2996). These measurements and chemical resistance tests were made of the protective coatings in common acids, alkalis, and deionized water at 81 and 120°F as a guide in the selection of coatings for radiochemical plant applications and to determine if coatings containing water vehicles could be substituted for coatings containing more hazardous organic solvent vehicles. Vinyl base coatings were superior in both decontaminability and chemical resistance. The two water-vehicle coatings evaluated were markedly inferior to organic-vehicle vinyls. A vinyl "wallpaper" was decontaminated poorly with the reagents used. Water and 3 M HNO_3 removed Purex contaminants relatively efficiently but were relatively ineffective for the removal of Thorex contaminants.

Coatings determined to be sufficiently decontaminated from Purex waste by a water flush and acid scrub and to be of superior resistance to common acids and alkalis are: DuBois Peel-Filmite; Nukemite-33, -40; Amercoat-31, -33HB, -23, -55 and 33; Polyclad 120-1 DG; Ucilon-K; DEL Series A; du Pont Eng. 6200 system 1 and 2; Polychem-1500. Only Ucilon-K, Amercoat-31, Peel-Filmite, Nukemite-40 and possibly Amercoat-35 and Polychem-1500 appeared useful in the presence of Thorex contamination.

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1.0 INTRODUCTION

The purpose of this test program, which was made at the request of the Savannah River Operations Plant, was to re-evaluate some of the coatings investigated in 1950[1-3] and to extend the empirical test data to include high contamination levels, especially in view of claims by some manufacturers that their contemporary coatings are improved versions of those tested in 1950. Protection of the working and structural surfaces in radiochemical environments with some type of chemically resistant easily decontaminable renewable barrier is a continuing problem. Protective coatings correctly applied are chemically resistant to common laboratory reagents, and the 1950 work showed that their surfaces can be washed relatively free of radioactivity with selected chemical reagents used in conjunction with a proper cleaning technique. Subsequent practical experience has borne this out. A coating for radiochemical environments should be chosen partly on the relative ease with which it can be decontaminated by simple washing techniques.

In addition, water-vehicle coatings and plastic wallpaper were examined to determine if they could be substituted for coatings containing organic vehicles now in use at the SRO. All coatings tested were supplied by SRO. The control surfaces were obtained from Oak Ridge National Laboratory stores. A total of 46 different protective coatings and materials of construction were selected for testing. The test was, in principle, a comparison of decontaminability and chemical resistance of vinyl and epoxy coatings systems; however six additional coatings of different basic resins were included along with 10 materials of construction. Four of the 10 materials of construction tested—347 stainless steel, plate glass, polyethylene, and Teflon—were chosen as standard decontaminable surfaces to which all other materials were compared.

The overall testing program consisted of three phases: decontamination of surfaces contaminated with concentrated Purex waste, decontamination of surfaces contaminated with Thorex waste solution from reprocessing of short-decayed thorium slugs, and chemical resistance tests.

A recognized standard test method to measure the decontaminability of a surface does not exist; therefore a simple washing procedure and reagents were arbitrarily selected, based on a few exploratory tests and past experience.

2.0 DECONTAMINATION TESTING

Empirical decontamination measurements were made of 46 different surfaces consisting of protective coatings, metals, and plastics, comparing the cleaning efficacy of a simple water flush followed by a 3 M nitric acid scrub for removing radiochemical contamination deposited separately from Purex waste and Oak Ridge National Laboratory Thorex waste mixed—fission product solutions. These tests were made in order to determine which, if any, of the surfaces could be decontaminated sufficiently to justify the selective use of one surface over another in radiochemical environments; whether coatings containing

water vehicles* could be substituted for the more hazardous organic vehicles which are toxic and flammable; and, generally, whether a difference of contaminant markedly affects the decontaminability of a surface.

2.1 Effect of Flushing with Water

A group of vinyl coatings, of which Amercoat-31 and Nukemite-40 appear to be outstanding, containing undesirable organic solvents were superior to the other materials in all decontamination tests (Table 1-3, Figures 1 and 2). This is in agreement with previous work[1] with tracer-level contamination. A vinyl "wallpaper," Victrex, and two water-vehicle coatings, Penkote-500 and Amercoat-88, were decontaminated very poorly in comparison to the best vinyls. The use of these two coatings in areas subject to high levels of contamination from solution spillage is questionable at best.

An impartial comparison of the relative decontaminability of surfaces can be made, in the absence of standard test methods, by the amount of radioactive contamination remaining on the surface following a simple water flush of the surface.

Ten coatings, nine of which are vinyls, retained only from 0.005% to 0.026% of the Purex contaminant after they were flushed with water (Table 1). These quantities were further reduced to 0.001% to 0.01% following a 3 M nitric acid scrub. All coatings listed in Table 1 are sufficiently freed from Purex waste by the water flush or combined water and acid washes to be considered useful in Purex contaminated environments. For the Purex waste, a decontamination factor (DF) of $\sim 7.0 \times 10^3$ or greater is desirable.

None of the coatings, metals or plastics were sufficiently freed of Thorex waste contaminant by the water flush alone to make their use advantageous in Thorex environments. The amount of activity remaining on the coated surfaces was as much as from 2.0 to 6.7%. Following the acid scrub, these quantities were further reduced to 0.04 to ~0.14%. Coatings whose decontamination factor was $\sim 2.0 \times 10^2$ or greater and retained no more than ~0.5% of the activity or less is considered to be more desirable than the other coatings. In the absence of definitive experimental evidence, it seems reasonable to assume that the poor decontamination from Thorex waste results from the presence of relatively large amounts of protactinium.

2.2 Effect of Scrubbing with 3 M HNO_3

In general, scrubbing the contamination remaining on a surface after the water flush with 3 M HNO_3 resulted in decontamination factors from both Purex and Thorex wastes 2 to 10 times greater than those with water alone (Tables 2 and 3, Figures 2 and 3). In most instances the acid scrub seemed to be more effective on surfaces which had responded favorably to the water flush. In a few cases, either no additional decontamination was attained or factors much larger than 10 were attained.

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* A vehicle[4] is usually divided into two parts: (a) the film forming portion of the coating and (b) the diluents, solvents, wetting agents, etc.

As a result of the combined water flush and acid scrub, five coatings—Ucilon-K, Amercoat-31, Nukemite-40, Polychem-1500 and Peel-filmite—were sufficiently decontaminated from Thorex wastes (Table 1) to be considered useful in a Thorex contaminated environment. This again seems to show that surfaces responding unfavorably to the water flush, in the main, do not respond adequately to the acid flush. It may not be unreasonable, therefore, to suggest that, if the water flush is not effective in removing contamination, a reagent be selected immediately that will remove a surface layer of the coating or material in question. If possible, this reagent should be so selected as not to destroy the integrity of the protective coating film or produce detrimental pitting or corrosion of metallic surfaces.

3.0 CHEMICAL RESISTANCE TESTING

The protective coatings were subjected to chemical resistance tests by immersion separately in acids (3 M HNO_3, 3 M HCl, 3 M H_2SO_4) and caustic (3 M NaOH) and deionized water at 81 and 120°F. Although the chemical resistance tests are not particularly severe ones, the vinyls, as in the decontaminability tests, excelled the other coatings (Figure 3, Table 4). The results of the coatings in the 120°F solutions were not appreciably different from those with the solutions at 81°F. The control surfaces were not evaluated.

4.0 EXPERIMENTAL

The protective coatings evaluated were air-dried coatings systems applied on 16-gauge mild steel panels, 2.5 in. square, for use in the decontamination tests. The test coatings were compared to uncoated reference materials of polyethylene, Teflon, plate glass, and stainless steel. Corrosion tests were performed by immersing the coatings, applied on carbon steel rods, 3/8-in. dia x 5-in. long, in various laboratory reagents for a 30 day test period.

4.1 Preparation of Test Specimens

The test specimens were prepared by the Savannah River Operations Plant maintenance department according to the manufacturer's specifications; the coatings manufacturer supplied duplicate specimens, factory applied, for control comparison. The protective coating was applied on all surfaces of the panel specimens for the decontamination tests. The corrosion test rods were rounded on the end so that a smooth, continuous layer of coating could be applied. To eliminate bias, both the decontamination and chemical resistivity specimens were assigned a number code so that personnel actually performing the tests did not know the names of the coatings being evaluated.

4.2 Test Procedure

Decontamination Test. The decontamination test was designed to compare the various coatings and materials as to the ease of removing radiochemical activity from the surface by first using a simple water flush and then by scrubbing with an acid solution. The decontamination factor was obtained

by dividing the activity (radiation in millirems* per hour) remaining into the original activity reading. Separate specimens were used for the Purex and Thorex wastes.

The decontamination reagent selected for the test was 3 M HNO_3. A saturated solution of Oakite-120, a commercial alkaline cleaning powder, ~1.0 N acid deficient, was also considered. The nitric acid solution was a factor of 3 more efficient than the Oakite solution in removing activity in trial decontaminations. Therefore the acid solution was chosen for use in the paint decontamination tests.

The stepwise decontamination test procedure used was:

1. The center of each panel was contaminated with 200 μl of radiochemical waste solution (either thorium or uranium, Tables 5 and 6) by using a remote Servo-controlled pipetter, ORNL model Q-1348.

2. The contaminant on the panels was allowed to evaporate to dryness at a temperature of 75-85°F in air passing at about 50 ft^3/min over the surface of the panels.

3. The panels were uniformly flushed with tap water for 2 minutes. The jet effect of the water stream was not utilized to aid in removal of the activity.

4. The panels were again dried as in step 2, and the remaining activity (radiation in millirem/hr) was recorded on an ionization chamber and an electrometer, ORNL model Q-1102B. The instrument was calibrated against radium to detect radiation to ± 10% and for conversion of its readings in microamperes to millirem/hr.

5. A final decontamination was made with a 3 M HNO_3 solution at room temperature, 75-85°F. The panels were scrubbed with a brush (Chinese hog bristles) in the acid solution for 5 min using a Gardner Wear Testing Machine, model 1725. The brushes, 4.43 $in.^2$ surface area, were weighted to exert a total pressure of 1 lb on the panels. Each panel was scrubbed for 370 passes (37 complete cycles per minute) of the brush over the panels which traveled 13 in. per pass. The machine was equipped with duplicate trays and brushes which allowed 8 panels (4 per tray) to be decontaminated in one operation. A 500-ml volume of acid was used per tray, which fixed the liquid level at 1/16 in. above the surface of the panels. Trays were flushed after each operation to remove residual radioactivity that may have settled in the tray, and fresh acid was added before the next decontamination scrub.

6. The decontaminated panels were rinsed by a water flush and dried as in step 2. The final activity (millirem/hr) was recorded as in step 4.

7. The decontamination factors calculated were corrected to account for decay of the contaminant. The final (overall) decontamination factor is expressed as the ratio

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* The rem[5] (roentgen equivalent man) corresponds to an energy absorption or dose of ionizing radiation of 100 ergs per gram of tissue.

$$\frac{\text{initial radiation (millirem/hr)} - \text{decay (millirem/hr)}}{\text{radiation remaining (millirem/hr)}}$$

Corrosion Resistance Test. Immersion rods (3/8-in. dia by 5-in. long, carbon steel with rounded ends) were immersed at both 81°F (room temperature) and 120°F in five separate mediums: 3 M HNO_3, 3 M HCl, 3 M H_2SO_4, 3 M NaOH, and deionized water. The coated rods were immersed in 30 ml test tubes containing 15 ml of the test solution, which was replaced every third day. The test on the coated rods at 120°F was conducted with the test tubes in an oil bath maintained at 120°F ± 3°. The test coatings remained immersed until failure occurred or until 30 days had elapsed. The coatings were rated by judging the degree of chemical attack by each of 6 different effects: blistering, cracking, peeling, softening, dissolution, and liquid discoloring. The rating of each material was:

	Corrosion Rating
E (excellent): no attack in 30 days	4
G (good): slight attack	3
F (fair): more pronounced attack	2
P (poor): complete failure	1

The letter system was used to evaluate specific corrosion resistance (Table 4) to each reagent and the number system to determine a composite rating (Figure 3) for all five reagents. The highest and poorest complete composite ratings possible were 20 and 5, respectively. Failures, in some cases, may have been caused by the application of the coating on rods of inferior surfaces. Several of the bar stock specimens contained pits and peaks which resulted in pin holes developing in the coating. The reagents could pass through the pin holes and cause failure by blistering. This fact should be noted when comparing identical coatings prepared by the two different laboratories (Table 4).

5.0 REFERENCES

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Table 1. Relative Decontaminability of Coatings Rating Excellent in Chemical Resistance Tests

Coating	Purex Waste						Thorex Waste					
	After Water Flush			After Acid Scrub			After Water Flush			After Acid Scrub		
	mrem/hr	Decontamination Factor	Activity Remaining (%)	mrem/hr	Decontamination Factor	Activity Remaining (%)	mrem/hr	Decontamination Factor	Activity Remaining (%)	mrem/hr	Decontamination Factor	Activity Remaining (%)
Amercoat-31 (Amercoat Corp.)	92	2×10^4	0.005	50	4.5×10^4	0.002	3,840	0.46×10^2	2.17	300 1250	7×10^2 1.7×10^2	0.143 0.59
Amercoat-55 (Amercoat Corp.)	126 2000	1.8×10^4 1.1×10^3	0.0055 0.091	35 450	6.6×10^4 5.2×10^3	0.0015 0.00196	14,000	0.15×10^2	6.67	2700 3050	0.7×10^2 0.6×10^2	1.43 1.67
Nukemite-40 (Nukem Products)	161	1.7×10^4	0.0059	42	8.4×10^4	0.0012	2,800	0.63×10^2	1.59	373	4.5×10^2	0.222
Amercoat-33 (Amercoat Corp.)	197	1.1×10^4	0.0091	70	3.2×10^4	0.0031	7,600	0.27×10^2	3.7	1100 2825	1.93×10^2 0.6×10^2	0.52 1.67
Amercoat-33HB (Amercoat Corp.)	210	1.1×10^4	0.0091	56	4×10^4	0.0025	4,400	0.55×10^2	1.82	975	2.2×10^2	0.455
Nukemite-33 (Nukem Products)	225	1.1×10^4	0.0091	21	8.4×10^4	0.0012	8,120	0.22×10^2	4.55	1900 2400	0.9×10^2 0.7×10^2	1.11 1.43
Amercoat-35 (Amercoat Corp.)	242 700	1×10^4 3.3×10^3	0.01 0.03	70 220	3.3×10^4 1×10^4	0.003 0.01	1,900 7,000	1×10^2 0.28×10^2	1.0 3.58	325 2350	6×10^2 0.8×10^2	0.167 1.25
Amercoat-23 (Amercoat Corp.)	260	1×10^4	0.01	85	3.7×10^4	0.0027	8,120	0.25×10^2	4.0	500 1100	3.3×10^2 1.9×10^2	0.303 0.526
Polyclad 120-1 DG (Carboline Co.)	400	7×10^3	0.014	72 225	3.1×10^4 1.1×10^4	0.0032 0.0091	7,125	0.25×10^2	4.0	2925 4500	0.42×10^2 0.65×10^2	2.38 1.54
Polychem-1500 (Dittbrenner Associates)	500	6×10^3	0.0167	30	8.4×10^4	0.0012	5,750	0.19×10^2	5.27	425	2.5×10^2	0.4
Eng. 6200, system 1 (du Pont)	440	5.2×10^3	0.019	190	1.2×10^4	0.0083	15,500	0.13×10^2	7.8	5250	0.6×10^2	1.67
Polyclad 933-1 DG (Carboline Co.)	513	4.2×10^3	0.024	245	1×10^4	0.01	8,000	0.23×10^2	4.35	1850 2350	0.9×10^2 0.7×10^2	1.11 1.43
Eng. 6200, system 2 (du Pont)	590	4×10^3	0.025	256	1.1×10^4	0.009	8,750 11,000	0.23×10^2 0.18×10^2	4.35 5.55	3350	0.59×10^2	1.7
DEL Series A (David E. Long Corp.)	775	3.9×10^3	0.026	155	1.7×10^4	0.0059	7,125	0.26×10^2	3.85	3700	0.9×10^2	1.11
Peel-Filmite (DuBois and Co., Inc.)	700 3025	4.2×10^3 9.7×10^2	0.024 0.10	9	5×10^5	0.0002	5,750 7,500	0.19×10^2 0.15×10^2	5.27 6.67	561	1.9×10^2	0.526
Ucilon-K (Metal and Thermit Corp.)	2900	1×10^3	0.10	140	1.8×10^4	0.0055	2,575 262	0.43×10^2 3.66×10^2	2.33 0.274	85 40	1.3×10^3 2.3×10^3	0.08 0.04

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Table 2. Decontamination Tests on Protective Coatings

Contaminant: Purex waste solution 1AW, 2.2 N acid
Activity applied: 200 μl volume (3,025 to 2,284 Rem/hr) due to decay
Specimens: coated steel panels, 2.5 in. × 2.5 in. × 16 gauge.
Column A refers to Savannah River Plant prepared panels;
Column B refers to manufacturer prepared panels
Table listing is in decreasing order of D. F.'s

Material	Film Thickness Mils		Decontamination Factor						
			Water Flush		Acid Scrub		Overall		Avg
	A	B	A	B	A	B	A	B	
Vinyl Base									
Peel-Filmite (DuBois)	7	9	973	4,200	174	201	168,000	842,000	5.05×10^5
Nukemite-33 (Nukem Products)	6	8	17,800	11,000	14	7	252,290	79,000	1.66×10^5
Nukemite-40 (Nukem Products)	4	6.5	12,850	21,300	10	2	128,500	38,900	8.37×10^4
Amercoat-31 (Amercoat Corp.)	4	10		20,490		2		45,100	4.51×10^4
Amercoat-33HB (Amercoat Corp.)	4	10	10,850		4		40,300		4.03×10^4
Amercoat-23 (Amercoat Corp.)	10	16	9,695	11,300	2	5	17,796	56,400	3.71×10^4
Amercoat-55 (Amercoat Corp.)	6.2	7	1,144	18,350	4	4	5,200	66,200	3.57×10^4
Amercoat-33 (Amercoat Corp.)	8	10		11,600		3		32,200	3.22×10^4
Amercoat-35 (Amercoat Corp.)	5	5.5	3,270	9,970	3	3	10,250	33,100	2.17×10^4
Polyclad 120-1 DG (Carboline Co.)	8	8	6,060	7,750	2	4	11,650	31,300	2.15×10^4
Ucilon-K (Metal and Thermit)	14	-	1,042		17		18,000		1.80×10^4
Series A (David E. Long Corp.)	7	-	3,910		4		16,940		1.69×10^4
Eng. 6200, system 1 (du Pont)	6.5	9	5,080	5,380	2	2	11,850	11,850	1.18×10^4
Eng. 6200, system 2 (du Pont)	5.5	11	3,150	5,080	2	3	6,020	16,700	1.14×10^4
Polyclad 933-1 DG (Carboline Co.)	18	8	4,520	4,040	3	2	12,500	8,620	1.06×10^4
Ucilon-T (Metal and Thermit)	-	4		2,260		4		8,100	8.10×10^3
Victrex (L. E. Carpenter) (wallpaper)	20	-	1,550		3		4,210		4.21×10^3
Series A (Prufcoat Laboratories)	15	-	835		4		2,970		2.97×10^3
Eng. 1200 (du Pont)	4.5	9	35	30	94	28	3,260	843	2.05×10^3
Amercoat-88 (Amercoat Corp.)	7	8	28	34	2	2	73	60	0.67×10^2
Epoxy Base									
Amercoat-74 (Amercoat Corp.)	17	14	2,070	3,930	1	1	2,740	4,220	3.48×10^3
Devran-600 (Truscon Labs.)	11	4	992	1,042	1	1	1,440	1,485	1.46×10^3
Series EP (Prufcoat Laboratories)	7	-	672		1		935		9.35×10^2
No. 180-57 (Carboline Co.)	15	13	91	327	2	4	177	1,420	7.98×10^2

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Table 2 (continued)

Manufacturer and Trade Name	Film Thickness Mils		Decontamination Factor						Avg
			Water Flush		Acid Scrub		Overall		
	A	B	A	B	A	B	A	B	
Epoxy Base									
Series E (D. E. Long Corp.)	12	-	433		1		553		5.53×10^2
Eng. 6426 (du Pont)	8	9	352	378	1	1	361	440	4.00×10^2
Unichrome XL-2535 (Metal and Thermit)		9		137		2		215	2.75×10^2
Amercoat-66 (Amercoat Corp.)		14		119		1		154	1.54×10^2
Lacquer									
Polychem-1500 (Dittbrenner Associates)	4	-	6,050		14		84,250		8.43×10^4
Polyester									
Liquid Tile (Evershield Corp.)	-	30		560		3		1,565	
				3,920		1		5,400	3.48×10^3
Amercoat-1679 (Amercoat Corp.)		29		93		2		145	
				97		2		145	1.45×10^2
Polyethylene									
100-E-47394, Hypalon (du Pont)	5	5.5	6,500	7,625	2	2	14,100	12,900	1.35×10^4
Saran									
Penkote-500 (Peninsula Chem.)	4	-	379		3		1,295		1.30×10^3
Phenolic									
Eng. 6102 (du Pont)	8	9	1,780	1,950	2	1	2,680	2,380	2.53×10^3
Phenoline-305 (Carboline Corp.)	21	17	100	336	1	5	122	1,440	7.81×10^2
Alkyd									
Eng. 5102 (du Pont)	7	10	183	110	1	1	225	157	1.91×10^2

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Table 2 (continued)

Manufacturer and Trade Name	Decontamination Factor								
	Film Thickness Mils		Water Flush		Acid Scrub		Overall		Avg
	A	B	A	B	A	B	A	B	
Controls									
Teflon sheet, 1/8 in. thick				12,650		6			
				14,450		5		77,200	7.72×10^4
Plate glass, grade B				6,900		8		57,800	
				19,550		3		51,400	5.46×10^4
Polyethylene sheet, 1/8 in. thick				36,100		5		28,200	
				14,650		3		38,500	3.34×10^4
347 Stainless steel, 2-B finish				522		27		14,000	
				2,930		11		33,100	2.36×10^4
Titanium-55				7,570		4		33,100	
				6,300		4		23,135	2.81×10^4
Rigid polyvinylchloride				823		28			
				6,170		4		23,134	2.31×10^4
Haynes-25 alloy				2,470		10		25,700	
				2,230		7		14,450	2.01×10^4
Miscellaneous									
Polyester Fiberglas (du Verre)				3,920		4		16,500	
				18,950		1		20,200	1.84×10^4
Type 53 glass (Pfaudler Co.)				532		5		2,500	
				232		10		2,375	2.44×10^3
Epoxy Concrete, Chemfast (Truscon Labs.)				219		2		486	
				250		2		512	4.99×10^2

Table 3. Decontamination Tests on Protective Coatings

Contaminant: Thorex waste solution (IAWC) 1.0 N H^+
Activity applied: 200 μl volume 226 to 107.5 rem/hr due to decay
Specimens: coated-steel panels 2.5-in. × 2.5-in. × 16 gauge
Columns A & B as in Table 2
Table listing is in decreasing order of D.F's

Material	Film Thickness (mils)		Decontamination Factor						
			Water Flush		Acid Scrub		Overall		
	A	B	A	B	A	B	A	B	Average
			Vinyl Base						
Ucilon-K (Metal and Thermit)	4	-	43	-	30	-	1266	-	1.8×10^3
			366	-	6	-	2350	-	
Amercoat-31 (Amercoat Corp.)	4	10	40	52	11	15	418	825	6.21×10^2
Nukemite-40 (Nukem Products)	4	6.5	60	66	8	8	480	418	4.54×10^2
Amercoat-35 (Amercoat Corp.)	5	5.5	28	104	3	6	83	600	3.42×10^2
Amercoat-23 (Amercoat Corp.)	10	16	23	27	15	7	334	193	2.64×10^2
Amercoat-33HB (Amercoat Corp.)	4	10	69	41	3	5	212	223	2.18×10^2
Peel-Filmite (DuBois)	7	9	21	15	9	13	189	195	1.92×10^2
Amercoat-33 (Amercoat Corp.)	8	10	22	32	3	6	59	193	1.25×10^2
Series-A (Prufcoat Laboratories)	15	-	18	-	6	-	102	-	1.02×10^2
Polyclad 933-1 DG (Carboline Co.)	8	8	26	20	4	4	90	71	0.8×10^2
Nukemite-33 (Nukem Products)	6	8	22	24	4	3	100	78	0.79×10^2
Amercaat-55 (Amercoat Corp.)	6.2	7	20	11	4	6	72	64	0.68×10^2
Eng. 6200, system 2 (du Pont)	5.5	11	18	21	4	3	62	55	0.66×10^2
Eng. 6200, system 1 (du Pont)	6.5	9	12	13	3	2	37	37	0.59×10^2
Series A (D. E. Long)	7	-	22	26	1	4	28	89	0.59×10^2
Ucilon-T (Metal and Thermit)	-	4	-	11	-	5	-	55	0.55×10^2
Victrex (wall paper) (L. E. Carpenter)	20	-	16	-	3	-	53	-	0.53×10^2
Polyclad 120-1 DG (Carboline Co.)	8	8	25	26	2	2	57	37	0.47×10^2
Amercoat-88 (Amercoot Corp.)	7	8	12	13	3	3	37	37	0.37×10^2
Eng. 1200 (du Pont)	4.5	9	3	3	(acid attacked coating)				-

Table 3 (continued)

Material	Film Thickness (mils)		Decontamination Factor						
			Water Flush		Acid Scrub		Overall		
	A	B	A	B	A	B	A	B	Average
Epoxy Base									
Series EP (Prufcoat Labs)	7	-	30	-	7	-	196	-	1.96×10^2
Amercoat-74 (Amercoat Corp.)	17	14	28	28	8	4	244	122	1.83×10^2
Devran-600 (Truscon Labs)	11	4	14	62	5	3	64	160	1.12×10^2
Series-E (D. E. Long)	12	-	26	-	4	-	89	-	0.89×10^2
Eng. 6426 (du Pont)	8	9	20	33	3	3	63	98	0.81×10^2
Unichrome XL-2535 (Metal and Thermit)	-	9	-	16	-	2	-	30	0.3×10^2
No. 180-57 (Carboline Co.)	15	13	14	4	2	3	30	11	0.21×10^2
Amercoat-66 (Amercoat Corp.)	-	14	-	7	-	3	-	21	0.21×10^2
Lacquer									
Polychem-1500 (Dittbrenner Assoc.)	4	-	19	-	13	-	253	-	2.58×10^2
Polyethylene									
100-E-47394, Hypalon (du Pont)	5	5.5	32	16	4	7	135	118	1.26×10^2
Saran									
Penkote-500 (Peninsular Chemical)	4	-	36	-	1.4	-	52	-	0.52×10^2
Phenolic									
Eng. 6102 (du Pont)	8	9	20	11	2	2	39	18	0.29×10^2
Phenaline-305 (Carbaline Co.)	21	17	8	6	4	2	32	11	0.22×10^2
Alkyd									
Eng. 5102 (du Pont)	7	10	12	11	2	2	20	19	0.2×10^2

Table 4. Chemical Resistance of Protective Coatings

Test conditions: Carbon steel rods, $\frac{3}{8}$ in. dia by 5 in. long, immersed in 15 ml of reagent for 30 days; specimens prepared by two different laboratories, (A) Savannah River Operations Plant, and (B) paint manufacturer; discrepancies in ratings due to pitted and rough surfaces of metal rod in some cases; film thickness measured at ORNL by an Elcometer (magnetic) instrument

Resistance rating: E = excellent, no attack; G = good, very slight attack; F = fair, more pronounced attack; P = poor, complete failure

Methods of attack: (1) liquid discolored, (2) coating discolored, (3) blistering, (4) peeling, (5) cracking, (6) softening, (7) dissolution

Coating		Lab	Preparation		Test Temp, °F	Resistance Rating				
Name	Color		No. of Coats	Film Thickness mils		3 M HNO_3	3 M HCl	3 M H_2SO_4	3 M NaOH	Deionized Water
				Vinyl Base						
Amercoat-23 (Amercoat Corp.)	Gray	A	5	4	81	E	E	E	E	-
	Gray	B	5	11	81	E	E	E	E	E
	Gray	B			120	E	E	E	E	E
Amercoat-31 (Amercoat Corp.)	Black	A	6	7	81	E	E	E	E	-
	Black	B	6	5	81	E	E	E	E	E
	Black	B			120	E	E	E	E	E
Amercoat-33 (Amercoat Corp.)	Gray	A	4	6	81	E	E	E	E	-
	Gray	B	4	5	81	E	E	E	E	E
					120	E	E	E	E	E
Amercoat-33HB (Amercoat Corp.)	Gray	A	3	7	81	P(3,4)	E	E	E	-
	Gray	B	3	6	81	E	E	E	E	E
					120	E	E	E	E	E
Amercoat-35 (Amercoat Corp.)	Gray	A	4	4	81	P(3)	P(3)	P(3)	E	-
	Gray	B	4	5	81	F(3)	E	E	E	E
					120	P(3)	E	E	E	E
Amercoat-55 (Amercoat Corp.)	Gray	A	7	7	81	E	E	E	E	-
	Black	B	7	3	81	E	E	E	E	E
					120	E	E	E	E	E
Amercoat-88 (Amercoat Corp.)	White	A	4	7	81	P(3,5)	P(3,5)	P(3)	P(2,6)	-
	White	B	4	3	81	P(3,4)	P(3,6)	P(3,6)	P(2,6)	F(2,3)
					120	P(3,4)	P(3,4)	P(3,4)	P(2,6)	F(2,3)
Eng. 6200, system 1 (du Pont)	White	A	3	4	81	E	E	E	E	-
	White	B	3	5	81	G(3)	E	E	E	G(3)
					120	F(3)	E	E	E	G(3)
Ibid., system 2	White	A	3	6	81	G(3)	E	E	E	-
	White	B	3	9	81	E	E	E	E	G(3)
					120	E	E	E	E	G(3)
Eng. 1200 (du Pont)	White	A	4	9	81	P(6)	P(3)	P(3)	P(1,2)	-
	White	B	4	7	81	P(3,6)	P(3)	P(3,6)	P(3,6)	E
					120	P(3,6)	P(3,6)	P(3)	P(2,6)	G(3)
Polyclad 933-1 DG (Carboline Co.)	Gray	A	3	7	81	E(3)	E	E	E	-
	Gray	B	3	6	81	E	E	E	E	G(3)
					120	P(3)	E	E	E	G(3)

Table 4 (continued)

Coating		Lab	Preparation		Test Temp, °F	Resistance Rating				
Name	Color		No. of Coats	Film Thickness mils		3 M HNO_3	3 M HCl	3 M H_2SO_4	3 M NaOH	Deionized Water
				Phenolic Base						
Eng. 6102 (du Pont)	Gray	A	4	4	81	P(2,3)	F(2,3)	P(2,3)	P(2,6)	-
	Gray	B	4	5	81	P(2,3)	E(2)	E	P(2,6)	F(2,3)
					120	P(2,3)	P(2,3)	E(2)	P(2,6)	P(2,3,6)
Phenoline 305 (Carboline)	Gray	A	3	17	81	F(3)	P(3)	E	E	-
	Gray	B	3	13	81	F(3)	E	E	E	F(3)
					120	P(3)	P(3)	F(3)	E	G(3)
				Alkyd Base						
Eng. 5102 (du Pont)	Gray	A	4	2	81	P(3)	P(3)	P(3,6)	P(2,6)	-
	Gray	B	4	5	81	P(3)	P(3)	F(3,6)	P(2,6)	G(3)
					120	P(3,6)	P(3,6)	P(3)	P(6)	G(3)
				Saran Base						
Penkote-500 (Peninsular Chemical)	Gray	A	4	3	81	P(2,3)	P(3)	P(3)	P(7)	P(3)
				Lacquer Base						
Polychem-1500 (Dittbrenner Associates)	Gray	A	5	5	81	E	E	E	E	G
				Polyethylene Base						
100-E-47394, Hypalon (du Pont)	White	A	3	7	81	G(2)	E	E	P(2,3)	-
	White	B	3	8	81	G(2)	E	E	P(2,3)	E
					120	P(2,5)	E	E(2)	P(3)	E

Table 4 (continued)

Coating Name	Color	Lab	Preparation No. of Coats	Preparation Film Thickness mils	Test Temp, °F	Resistance Rating 3 M HNO_3	3 M HCl	3 M H_2SO_4	3 M NaOH	Deionized Water
Polyclad 120-1 DG	Gray	A	3	3	81	P(3)	P(2,3)	P(3)	P(3)	-
(Carboline Co.)	Gray	B	3	5	81	E	E	E	E	E
					120	P(3)	F(3)	E	G(3)	G(3)
Series A (D. E. Lang Corp.)	Gray	A	6	5	81	E	E	E	E	E
Nukemite-33 (Nukem Products)	Gray	A	6	3	81	E	E	E	E	-
	Gray	B	6	6	81	E	E	E	E	E
					120	E	E	E	E	E
Nukemite-40 (Nukem Products)	Gray	A	6	3	81	E	E	E	E	-
	Gray	B	6	6	81	E	E	E	E	E
					120	E	E	E	E	E
Series A, Prufcoat Labs	Gray	A	4	15	81	E	E	E	E	E
Ucilon-K (Metal and Thermit)	Red	A	5	10	81	E	E	E	E	-
Ucilon-T (Metal and Thermit)	Gray	B	3	4	81	F(3)	G(3)	F(3)	P(3,5)	E
					120	P(2,3)	P(2)	E	P(2,4)	E
Victrex (wallpaper) (L. E. Carpenter)	White	A	2	18	81	E	E	E	E	E
Peel-Filmite (DuBois)	White	A	5	7	81	E	E	F(2,3)	E	-
					81	E	E	F(3,6)	E	E
					120	E	E	E(3)	E	E
Epoxy Base										
Amercoat-74 (Amercoat Corp.)	Gray	A	5	7	81	G(2,3)	E	E	E	-
	Gray	B	5	8	81	G(2,3)	E	E	E	E
					120	P(2,3)	E	F(3)	E	E
Amercoat-66 (Amercoat Corp.)	Gray	B	3	10	81	P(2,3)	P(2,3)	P(3,5)	E	E
					120	P(2,3)	P(3)	P(3,6)	E	E
Eng. 6426 (du Pant)	Gray	A	3	6	81	F(2,3)	E	P(2,3)	E	-
	Gray	B	3	6	81	G(2,3)	G(3)	G(2)	E	E
					120	P(3,4)	F(3)	P(2,3)	E	G(2,3)
No. 180-57 (Carboline Co.)	Gray	A	3	17	81	P(3)	P(3)	P(3)	E	-
	Gray	B	3	11	81	P(3)	P(3)	F(3)	F(3)	F(3)
					120	P(3)	P(3)	P(3)	G(3)	G(2,3)
Series E (D. E. Long Corp.)	Gray	A	3	8	81	P(3)	P(3)	P(2,3)	E	E
Series EP (Prufcoat Labs.)	Gray	A	3	6	81	P(3)	E	G(2,3)	E	F(3)
Unichrome XL-2535	Gray	B	2	8	81	G(2,3)	E	E	E	E
(Metal and Thermit)					120	P(3)	E	E	E	E
Devan-600, (Truscon Labs)	Gray	A	4	10	81	F(3)	E	E	G(3)	-
	Gray	B	4	6	81	F(2,3)	E	G(2)	G(2)	G(2)
					120	F(2,3)	G(2)	G(2)	G(2)	G(2)

Table 5. Analysis of Oak Ridge National Laboratory Thorex (1AWC) Waste Solution

Elements	Concentration
Gross β	3.69×10^{10} c/m/ml
Gross γ	3.59×10^{10} c/m/ml
Pa^{233}	3.0×10^{10} c/m/ml
Ru^{106}	4.18×10^{8} c/m/ml
$Zr\text{-}Nb^{95}$	3.25×10^{9} c/m/ml
I^{131} β	1.26×10^{5} c/m/ml
TRE β	$\sim 3 \times 10^{9}$ c/m/ml
U^{233}	1.68×10^{4} c/m/ml
Th	4.7 mg/ml
H^{+}	1.0 N

Table 6. Typical Purex Waste Solution (1AW)

Element	Concentration
Gross β	4.23×10^{10} c/m/ml
Gross γ	8.48×10^{9} c/m/ml
U	0.40 mg/ml
Mn	8.0 mg/ml
Fe	2.35 mg/ml
PO_4	1.22 mg/ml
H^+	2.2 N

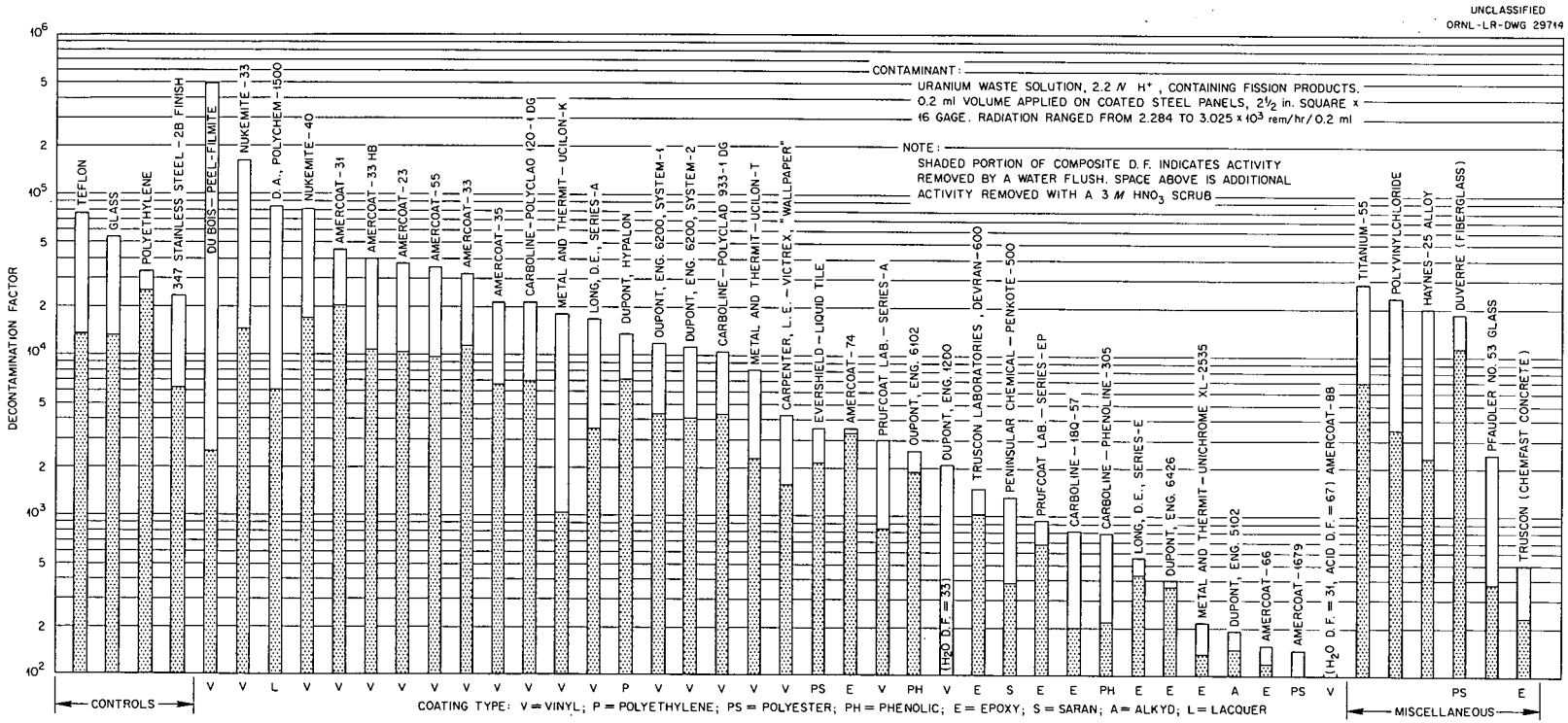


Fig. 1. Composite Decontamination Rating of Various Protective Coatings.

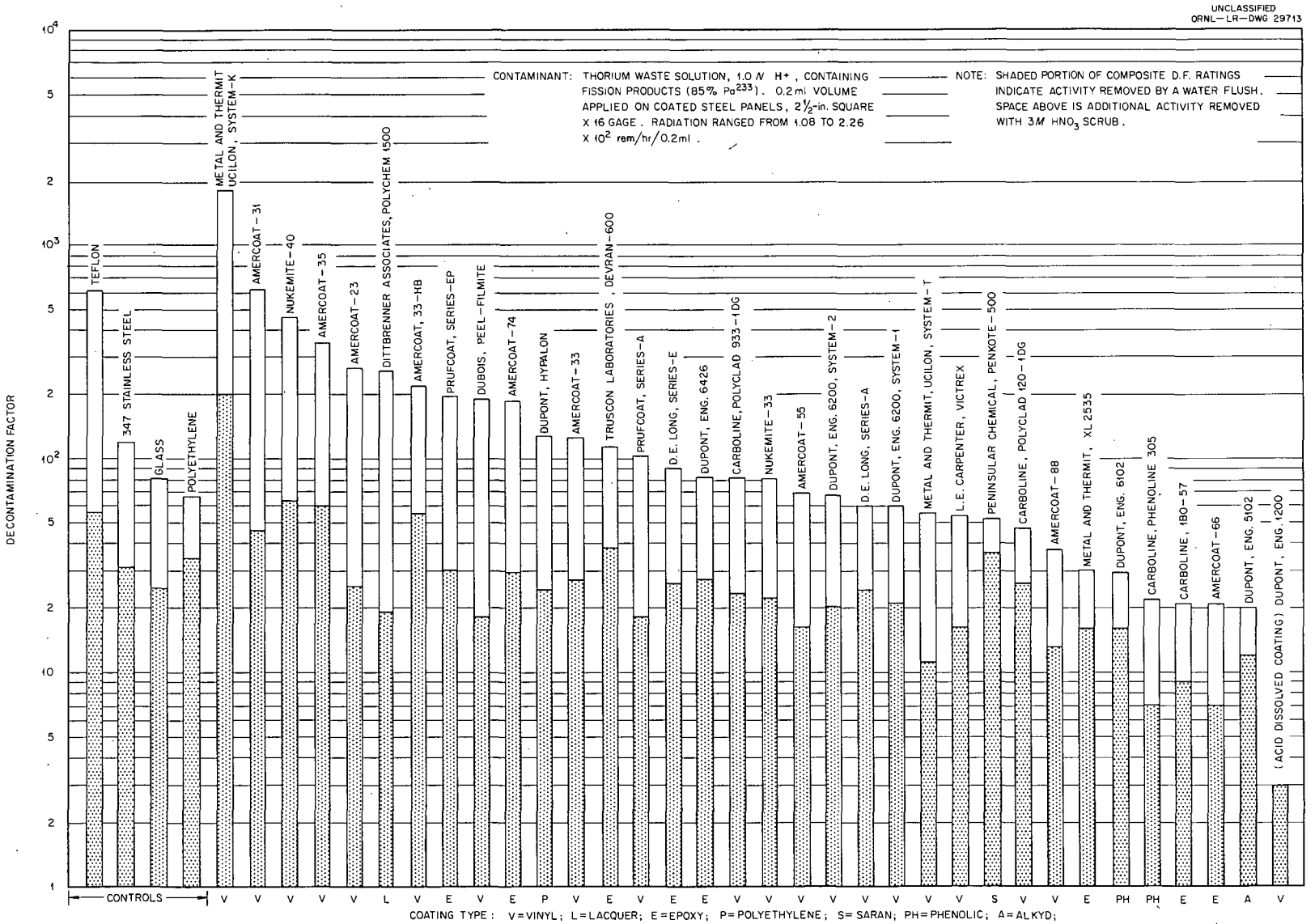
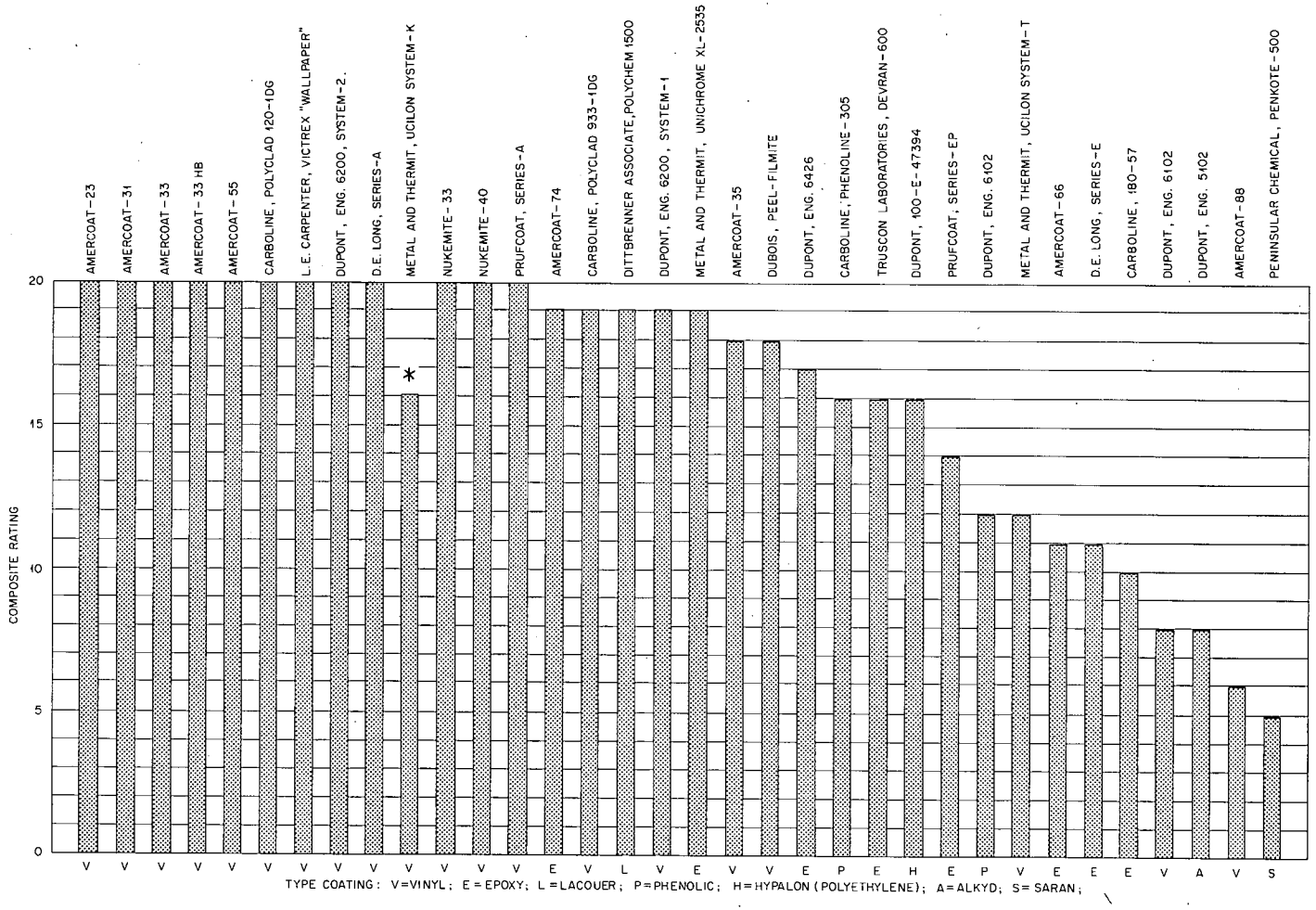


Fig. 2. Composite Decontominotion Rating of Various Protective Coatings.



CONDITIONS: 1 - CARBON STEEL RODS COATED AND IMMERSED IN:
(A) DE-IONIZED WATER AND 3M, (B) HNO_3,
(C) HCl, (D) H_2SO_4, (E) NaOH.

2 - SOLUTION TEMPERATURE: 81°F

3 - TEST PERIOD: 30 DAYS

RATING SYSTEM: EXCELLENT = 4 POINTS, GOOD = 3 POINTS, FAIR = 2 POINTS, POOR = 1 POINT. MAXIMUM POSSIBLE RATING IS 20 (EXCELLENT RESISTANCE IN ALL 5 MEDIA), LOWEST POSSIBLE RATING IS 5.

* SPECIMEN NOT AVAILABLE FOR TESTING IN DE-IONIZED WATER.

Fig. 3. Composite Chemical Resistance Rating of Various Protective Coatings.

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