Technical Research

Evaluation of
Thixotropic Vinyl Ester Resins
According to ASTM C581
for Use in
Corrosive Environments

INTERPLASTIC CORPORATION
Thermoset Resins Division

ABSTRACT

Although thixotropic vinyl ester resins have been commercially available for many years, they have not been recommended for corrosion resistant applications. In this work, a bisphenol A-ephicholorhydren thixotropic vinyl ester resin (CoREZYN® COR VE8117) was evaluated side-by-side with its non-thixotropic counterpart (CoREZYN COR VE8101-45). Coupons made to ASTM C581 standards were exposed at 77°F/25°C, 160°F/71°C, and 200°F/93°C, to several aqueous acidic and basic media, and deionized water. The results showed little to no degradation in a majority of the media.

Thixotropic vinyl ester resins offer handling advantages over their non-thixotropic counterparts. One major advantage is the ease of spraying with standard spray-up equipment used by fiberglass reinforced plastic (FRP) manufacturers. A second advantage thixotropic vinyl esters have is the ability manufacturers have to make parts with vertical and semi-vertical areas without having resin drainage problems. These properties should help manufacture a higher quality, vinyl ester FRP part.

INTRODUCTION

Thixotropic isophthalic resins have been used for years to manufacture corrosion resistant FRP tanks, pipe, and other parts. FRP manufacturers have the equipment and the experienced workers to capably use them.

Vinyl ester resins have previously been difficult to use due to their non-thixotropic nature. Spraying the resin was difficult and after it was applied, the resin would drain on vertical and semi-vertical surfaces. The technology to make vinyl ester resins thixotropic has been available for over 30 years. Many companies incorporate thixotropic additives at their work sites to give them the handling characteristics they desire. However, vinyl ester resin manufacturers have not recommended using these additives when manufacturing corrosion resistant FRP parts because of possible degradation of the corrosion resistant properties.

Several additives have been used in the past and present to make vinyl ester resins thixotropic. Materials used to impart thixotropy in corrosion resistant isophthalic resins do not have the same effectiveness in vinyl ester resins because of the nature of the vinyl ester resin's polymer backbone. These materials include the standard hydrophilic fumed silicas and clays, which also tend to quickly settle out.

Thixotropic additives are available that are effective in vinyl ester resins. Chemical thixotropes, hydrophobic fumed silicas, synergists used with hydrophilic fumed silicas, precipitated silicas, and milled fibers, as well as ceramic fibers, have all been used as thixotropes for vinyl ester resins.

These products are effective in making vinyl ester resins thixotropic, but each one has drawbacks. Due to the size of the particles, the filled fibers and ceramics are easily removed from the resin with standard filtration equipment. Special precautions also have to be taken to ensure additives are not filtered out of the resin solution by in-line and other filtering processes used in manufacturing FRP.

The silicas can be attacked in certain environments. Carefully determine the suitability of the resin's corrosion resistance to the specific environments.

The resin solution's viscosity is very difficult to control and stabilize with chemical thixotropes. When using chemical thixotropes, the degradation of the laminate's corrosion resistance must be evaluated in the specific media in which the finished composite will be used.

Interplastic Corporation has sold thixotropic vinyl ester resins since the early 1980s. The majority of these resins have been successfully used in boat and swimming pool construction as a blister barrier immediately behind the gel coat. The vinyl ester resin provides a hydrolytically-stable barrier between the gel coat and the structural laminate. Its research has shown the CoREZYN COR VE8110 family of resins to have low water absorption and excellent stability in an aqueous environment.

Interplastic's laboratory analysis concluded that after 15 years of immersion in water at ambient temperatures, laminate panels constructed with 100% CoREZYN vinyl ester resin or a vinyl ester skin coat showed no signs of blistering. The

CoREZYN vinyl ester resin created a hydrolytically stable barrier that prevented osmotic blistering.

An additional study concluded that these same panels retained their original physical properties as well. Flexural strength, flexural modulus and Izod impact strength were measured.

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EXPERIMENTAL

The same lot of vinyl ester resin was used to make the thixotropic and non-thixotropic laminates to isolate the effects of the thixotropic additives. The thixotropic resin (COR VE8117) was made and adjusted to viscosity, gel time, and cure development. A second portion of the resin was then adjusted to approximately the same styrene content, as well as gel time and cure development, of the thixotropic resin. The COR VE8101-45 was used as the non-thixotropic resin in the study.

A Brookfield model LVT viscometer (spindle #3 at 6 and 60 rpm) was used to check the viscosity of the resins. The thixotropic index is the 6 rpm viscosity divided by the 60 rpm viscosity.

Fifteen coupons were made with each resin according to ASTM C581. A Nexus® synthetic veil, made by Precision Fabrics Group, Inc., was used in place of the C-glass. This is especially critical in the sodium hydroxide environment, where C-glass is not recommended because it is attacked quite rapidly by sodium hydroxide.

The coupons were cut into 5-inch (127 mm) by 4-inch (102 mm) rectangles and engraved in their upper right corner. The coupons were edge-coated and the engraving was sealed with the same resin to prevent wicking solutions into any exposed areas of the coupon and eliminate this as a factor in the corrosion resistant testing.

These coupons were then post-cured. The post-cure cycle consists of a four-hour ramp up to 250°F/121°C to minimize thermal stresses developing in the coupons as they heat up, two hours at 250°F/121°C, and then a two hour cool-down to room temperature to again minimize thermal stresses.

The weights of the coupons were taken on a Sartorius Model 1204 MP electronic balance and recorded to the hundredths of a gram.

The thicknesses were measured with a Starrett micrometer on the three corners that were not engraved and the average value recorded to the thousandths of an inch (hundredths of a mm).

The initial flexural strengths for calculating retention over the test period were established by testing thick, medium and thin coupons.

Seven corrosive environments were used for this study. The coupons were immersed in 15% hydrochloric acid, 25% sulfuric acid, 25% acetic acid, 5% nitric acid, 5% sodium hydroxide; and 100% deionized water at 77°F/25°C, 160°F/71°C, and 200°F/93°C. A 10% sodium hydroxide was only evaluated at 77°F/25°C.

Samples were taken out of the solutions and tested at one, three, six, and 12 months. When the samples were taken from the solutions, they were rinsed with fresh water, patted dry, and their weights and the thicknesses were measured. Then the coupons were stored in a sealed container for conditioning at room temperature for at least 40 hours and no longer than 72 hours before flexural strength testing.

One-eighth-inch-thick (3.2 mm) castings of the resins were made. The resins were catalyzed with 1.2% by volume of L-50 by Akzo Chemie of America (now Akzo Nobel), stirred for 30 seconds and then allowed to rest for five minutes, to allow the air bubbles to dissipate. After that, the resins were poured into molds made from a 1/8-inch-thick (3.2 mm) rubber splines held between two 14 in. (356 mm) by 14 in. (356 mm) glass plates.

The castings were allowed to gel and cure at room temperature. They were aged for 24 hours at room temperature and then post-cured. The post cure cycle consisted of a four hour ramp up to 250°F/121°C, held for two hours at 250°F/121°C, and then a final two hour cool down to room temperature. The castings were conditioned at room temperature for 40 hours before retention of flexural strength testing.

Static physical properties of the coupons and of the clear castings were tested according to

ASTM D790 (flexural) and ASTM D638 (tensile) on an Instron model 4505 Universal Tester. Heat distortion points were evaluated under a constant stress of 264 psi/1.82 MPa, with a Tinius Olsen heat distortion apparatus, according to ASTM D648. Hardness was tested with a Barber Colman Barcol Impressor 934-I gauge according to ASTM D2583.

RESULTS & DISCUSSION

The same lot of base resin was used to make the COR VE8117 (thixotropic version) and COR VE8101-45 (non-thixotropic version) resins. The only difference between the two resins was the thixotropic additive package. This was done to isolate the effect of the thixotropic additives on corrosion resistance. The change in the liquid resin caused by these additives can be seen in the viscosities of the liquid resins. COR VE8101-45 has a viscosity of 245 cps at 6 and 60 rpm, while the COR VE8117 has a viscosity of 530 cps at 60 rpm and a thixotropic index of 2.72. Thixotropy allows the end user to use gun pressures of 30 psi to 40 psi (0.21MPa to 0.28 MPa) rather than 70 psi to 80 psi (0.48 MPa to 0.55 MPa), as well as giving a much better fan pattern. Also, the resin will not drain or sag as rapidly as its non-thixotropic counterpart.

Clear casting and ASTM C581 panel physical properties for both resins are listed in Tables 1 and 2. The only difference in the clear casting physicals shows up as a slight decrease in the percent elongation for the thixotropic resin of 3.5% from 4.6%.

The initial flexural strengths for these two resins are 15,600 psi/107.6 MPa and 18,000 psi/124.4 MPa for the thixotropic and non-thixotropic resins. The data used to determine the typical properties is compiled in Table 2.

The percent retention of flexural strength, thickness change, and weight change data collected during the immersion of the coupons in 15% hydrochloric acid, 25% sulfuric acid, 5% nitric acid, 25% acetic acid, 5% sodium hydroxide, deionized water, and 10% sodium hydroxide are listed in Tables 4 through 17 respectively. A trend seen in the retention of flexural strength for the different environments appeared to be related to corrosion bath temperature. The lowest temperature had the highest retention of flexural strength and the highest temperature the lowest retention. This

trend is graphically shown in Figures 1 and 2. They show how COR VE8117 and COR VE8101-45 performed in the 15% hydrochloric acid. Both resins had approximately the same decrease in properties during the 12 month test period.

The coupons typically gained weight up to six months, and then an equilibrium state was reached as shown in the flattening out of the curve after the six month point. The trends for COR VE8117 and COR VE8101-45 exposed to 15% hydrochloric acid are illustrated in Figures 3 and 4. The two resins showed some significant differences in sodium hydroxide and a slight difference in deionized water. This will be discussed in more detail later.

The thickness change of the two resins showed larger increases at the higher temperature up to six months, and then reached an equilibrium state indicated by the leveling off. Figures 5 and 6 graphically show how COR VE8117 and COR VE8101-45 coupons increase in thickness when exposed to 15% hydrochloric acid. Sodium hydroxide was again a special case and will be discussed later.

The relationship between the retention of flexural strength and weight gain can be seen in Figures 7, 8, and 9. The retention of flexural strength and weight gain for COR VE8117 in 15% hydrochloric acid are plotted in the Y axis and time on the X axis. As the coupons increase in weight, their flexural strength decreases. The measurements plateau once the coupons equilibrate in the media.

Performance Results in 5% Sodium Hydroxide

The general trends in 5% sodium hydroxide were similar to those already mentioned, but the two resins did not perform exactly the same.

The coupons made with the thixotropic vinyl ester resin had severely degraded to the state of failure between three and six months at 160°F/71°C and 200°F/93°C. They were however, still performing well at 77°F/25°C after 12 months.

Lower water absorption for the non-thixotropic vinyl ester resin was seen at all three temperatures after six months. The coupons of the non-

thixotropic resin had degraded to failure at 200°F/93°C between six and 12 months. They appeared to level off after six months of exposure at 77°F/25°C and 160°F/71°C.

Performance Results in 10% Sodium Hydroxide

The weight gains of the two resins in 10% sodium hydroxide at 77°F/25°C were similar up to six months. However, the thixotropic vinyl ester resin gained 4.5% additional weight, while the non-thixotropic resin seemed to plateau between six and 12 months. The continual increase in weight and thickness is a sign that the cured thixotropic resin had not reached equilibrium after 12 months. More degradation of the coupons was seen in the thixotropic vinyl ester resin coupons in this 12 month span, and failure was inevitable.

Overall Performance Results in Sodium Hydroxide

The sodium hydroxide environments resulted in a significant decrease in the corrosion resistance of the thixotropic resin compared to its non-thixotropic counterpart. The typical maximum operating temperatures range from 150°F/66°C to 180°F/82°C for parts manufactured with a bisphenol-A epichlorohydrin vinyl ester resin intended for 5% sodium hydroxide service. The non-thixotropic resin used is rated up to 180°F/82°C. It performed well up to 160°F/71°C, but failed between six and 12 months at 200°F/93°C.

The thixotropic resin failed between three and six months at 200°F/93°C, significantly faster than its non-thixotropic version. It also failed between three and six months at 160°F/71°C. This is clearly a significant drop off in corrosion resistance. Further investigation into this type of media needs to be done to determine to what extent the thixotropic resin can be used in sodium hydroxide environments.

The results of the exposure to 100% deionized water were somewhat unexpected. Slightly less weight was gained by the non-thixotropic vinyl ester resin at the two elevated temperatures. Results are shown in Tables 14 and 15. The COR VE8117 had a significant decrease in flexural strength and increase in thickness, while the COR VE8101-45 did not. The thixotropic resins performed poorly in this environment. Further work is needed to confirm these results.

Conclusion

The thixotropic vinyl ester resin was equivalent to or better than the non-thixotropic version in almost every environment. The exception was in sodium hydroxide. The degradation was attributed to the thixotrope used in the resin. Further work needs to be done to establish whether these resins can successfully and safely be used in sodium hydroxide environments.

The thixotropic vinyl ester can be directly substituted in place of the non-thixotropic vinyl ester resin for most aqueous environments. Caution must be used in this substitution to ensure that the best resin is selected for the corrosive environment. Non-thixotropic vinyl ester resins are still the choice for applications requiring premium corrosion resistance.

The commercial availability of thixotropic vinyl ester resins for corrosion applications should increase the productivity, and improve the quality of corrosion resistant FRP parts manufactured using hand lay-up and stray-up techniques.

References

This paper is based on the original work of the same title, written by David J. Herzog and Reynaldo E. de la Rosa on behalf of Interplastic Corporation for the 1992 SPI Conference. The original paper is available from the American Composites Manufacturers Association (ACMA).

Table 1: Clear Casting Physical Properties

	COR VE8117 Thixotropic Resin	COR VE8101-45 Non-thixotropic Resin
Flexural Strength, ASTM D790, psi/MPa	18,000/124.1	17,400/120.0
Flexural Modulus, ASTM D790, psi/MPa	480,000/3,310	483,000/3,331
Tensile Strength, ASTM D638, psi/MPa	12,100/83.45	12,500/86.21
Tensile Modulus, ASTM D638, psi/MPa	490,000/3,379	480,000/3,310
Percent Elongation, ASTM D638	3.5	4.6
Heat Distortion, ASTM D648, °F/°C	211/99	213/101
Barcol Hardness, ASTM D2583, 934-1 Impressor Gauge	38 - 42	39 - 44

1/8 in.(3.2 mm)-thick castings at room temperature.

Table 2: ASTM C581 Coupon Physical Properties

	COR VE8117 Thixotropic Resin	COR VE8101-45 Non-thixotropic Resin
Flexural Strength, ASTM 790, psi/MPa	15,600/107.6	18,000/124.1
Flexural Modulus, ASTM D790, psi/MPa	840,000/5,793	853,000/5,883
Tensile Strength, ASTM D638, psi/MPa	13,900/95.86	13,200/91.03
Tensile Modulus, ASTM D638, psi/MPa	990,000/6,898	970,000/6,690
Percent Elongation, ASTM D638	1.8	1.9
Barcol Hardness, ASTM D2583, 934-1 Impressor Gauge	40 - 45	38 - 44

1/8 in. (3.2 mm)-thick castings at room temperature.

Table 3: Flexural Strength of ASTM C581 Specimens

SAMPLE NUMBER	COR VE8117 THIXOTROPIC RESIN psi/MPa	COR VE8101-45 NON-THIXOTROPIC RESIN psi/MPa
1	14,700/101.4	18,200/125.5
2	14,600/101.1	18,500/127.6
3	15,700/108.3	18,300/126.2
4	15,300/105.5	17,700/122.1
5	15,200/104.8	17,300/119.3
6	14,900/102.8	17,700/122.1
7	15,100/104.1	18,100/124.8
8	15,600/107.6	18,400/126.9
9	15,400/106.2	19,200/132.4
10	14,500/100.0	17,600/121.4
11	17,450/120.3	17,900/123.4
12	17,080/117.8	18,200/125.5
13	16,400/113.1	18,300/126.2
14	16,600/114.5	17,200/118.6
15	15,600/107.6	17,400/120.0

Table 4: COR VE8117 Thixotropic Resin Immersed in 15% Hydrochloric Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	104	106	115
3	64	75	120
6	56	68	97
12	76	86	99
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-1.22	-0.51	0.29
3	1.65	1.48	0.75
6	1.76	1.79	0.74
12	1.70	1.70	0.68
PERCENT THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	1.69	0.91	0.57
3	3.67	4.23	0.67
6	1.50	0.79	1.38
12	2.60	2.30	1.50

Table 5: COR VE8101-45 Non-thixotropic Resin Immersed in 15% Hydrochloric Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	66	88	107
3	68	70	107
6	45	64	91
12	61	70	94
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	0.00	-0.50	0.61
3	2.11	1.67	0.78
6	1.47	1.22	1.27
12	1.49	1.00	0.70
PERCENT THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	1.20	0.45	1.34
3	2.65	1.64	1.16
6	4.05	3.14	1.57
12	4.89	3.40	0.40

Table 6: COR VE8117 Immersed in 25% Sulfuric Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	119	116	103
3	108	109	134
6	70	79	90
12	113	111	107
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	0.60	0.02	0.61
3	0.57	-0.61	0.79
6	0.54	0.52	0.60
12	0.33	0.46	0.75
PERCENT THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	0.50	0.42	0.64
3	1.60	2.29	1.42
6	5.26	2.22	0.00
12	4.30	2.30	1.70

Table 7: COR VE8108-45 Immersed in 25% Sulfuric Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	97	93	100
3	80	103	98
6	68	84	80
12	71	93	125
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-1.33	-0.50	0.62
3	0.32	0.62	0.82
6	0.31	0.82	1.01
12	0.24	0.50	0.80
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	0.56	0.45	0.00
3	0.68	1.44	2.30
6	3.82	1.36	3.73
12	1.20	1.40	3.70

Table 8: COR VE8117 Immersed in 25% Acetic Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	88	93	98
3	65	88	95
6	72	75	87
12	62	83	110
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	2.16	1.31	0.67
3	3.50	3.32	-1.02
6	4.20	4.69	1.48
12	4.10	5.40	1.00
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	2.99	1.97	-4.20
3	4.10	3.10	-2.84
6	4.70	6.03	1.77
12	4.80	7.50	1.50

Table 9: COR VE8101-45 Immersed in 25% Acetic Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	121	110	108
3	86	101	131
6	63	83	94
12	58	82	117
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	1.33	0.68	-0.14
3	4.24	2.84	-0.82
6	12.8	4.67	0.93
12	7.60	5.20	0.90
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	2.65	1.45	0.72
3	3.57	2.77	-0.70
6	2.41	5.71	2.86
12	6.90	7.50	3.30

Table 10: COR VE8117 Immersed in 5% Nitric Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	70	67	106
3	36	71	106
6	Failed	Failed	94
12	Failed	Failed	90
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-0.48	-0.25	0.66
3	23	1.46	0.91
6	Failed	Failed	1.25
12	Failed	Failed	1.00
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	0.98	0.98	-0.19
3	0.64	0.64	0.51
6	Failed	Failed	1.59
12	Failed	Failed	1.90

Table 11: COR VE8101-45 Immersed in 5% Nitric Acid

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	63	92	152
3	52	81	157
6	Failed	Failed	85
12	Failed	Failed	100
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-2.22	-1.40	0.74
3	1.58	1.68	3.49
6	Failed	Failed	0.79
12	Failed	Failed	1.80
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	1.69	1.00	0.74
3	1.90	1.75	3.49
6	Failed	Failed	0.79
12	Failed	Failed	1.80

Table 12: COR VE8117 Immersed in 5% Sodium Hydroxide

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	63	92	152
3	52	81	157
6	Failed	Failed	85
12	Failed	Failed	100
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-2.22	-1.40	0.74
3	1.58	1.68	3.49
6	Failed	Failed	0.79
12	Failed	Failed	1.80
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	1.69	1.00	0.74
3	1.90	1.75	3.49
6	Failed	Failed	0.79
12	Failed	Failed	1.80

Table 13: COR VE8101-45 Immersed in 5% Sodium Hydroxide

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	66	75	115
3	62	89	106
6	48	67	90
12	Failed	Failed	91
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-1.97	-0.28	0.73
3	-0.80	-1.15	0.87
6	1.87	1.27	1.27
12	Failed	Failed	0.10
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	0.66	0.72	-1.10
3	1.55	0.59	0.70
6	2.17	1.27	2.50
12	Failed	Failed	3.30

Table 14: COR VE8117 Immersed in 100% Deionized Water

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	86	67	114
3	74	80	115
6	56	72	91
12	53	81	106
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	-0.62	-0.18	0.72
3	-1.36	1.15	2.44
6	1.83	1.23	1.31
12	1.70	1.60	0.90
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	1.17	1.11	-1.72
3	0.64	1.60	3.10
6	3.30	1.70	1.40
12	2.60	2.40	3.10

Table 15: COR VE8101-45 Immersed in 100% Deionized Water

Temperature	@200°F/93°C	@160°F/71°C	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH			
Month	PERCENT	PERCENT	PERCENT
1	114	99	103
3	88	87	120
6	68	65	100
12	90	90	100
WEIGHT CHANGE			
Month	Percent	Percent	Percent
1	0.26	0.50	-0.56
3	1.13	1.11	0.85
6	2.07	1.15	0.80
12	1.40	1.40	0.90
THICKNESS CHANGE			
Month	Percent	Percent	Percent
1	1.06	1.11	0.82
3	2.20	1.40	0.70
6	1.29	4.27	1.39
12	1.90	1.90	1.50

Table 16: COR VE8117 Immersed in 10% Sodium Hydroxide

Temperature	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH	
Month	PERCENT
1	102
3	104
6	92
12	91
WEIGHT CHANGE	
Month	Percent
1	0.54
3	-0.78
6	1.02
12	0.80
THICKNESS CHANGE	
Month	Percent
1	-0.05
3	2.25
6	0.53
12	1.60

Table 17: COR VE8101-45 Immersed in 10% Sodium Hydroxide

Temperature	@77°F/25°C
RETENTION OF FLEXURAL STRENGTH	
Month	PERCENT
1	138
3	95
6	87
12	91
WEIGHT CHANGE	
Month	Percent
1	-0.74
3	-0.73
6	0.88
12	5.50
THICKNESS CHANGE	
Month	Percent
1	0.48
3	0.77
6	2.19
12	1.60

Figure 1: Retention of Flexural Strength COR VE8117 Immersed in 15% HCl

Months

★ 77°F/25°C   + 160°F/71°C   ⊕ 200°F/93°C
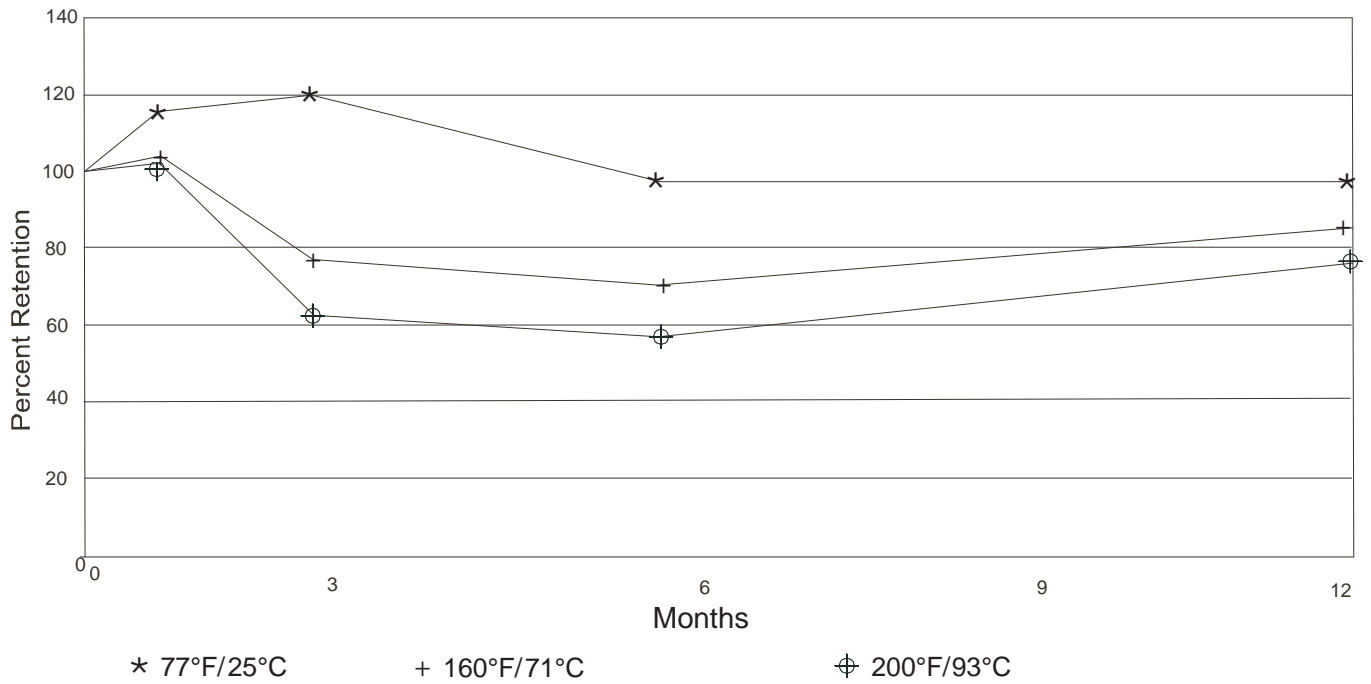
Figure 2: Retention of Flexural Strength COR VE8101-45 Immersed in 15% HCl

Months

★ 77°F/25°C   + 160°F/71°C   ⊕ 200°F/93°C

Figure 3: Percent Weight Change COR VE8117 Immersed in 15% HCl

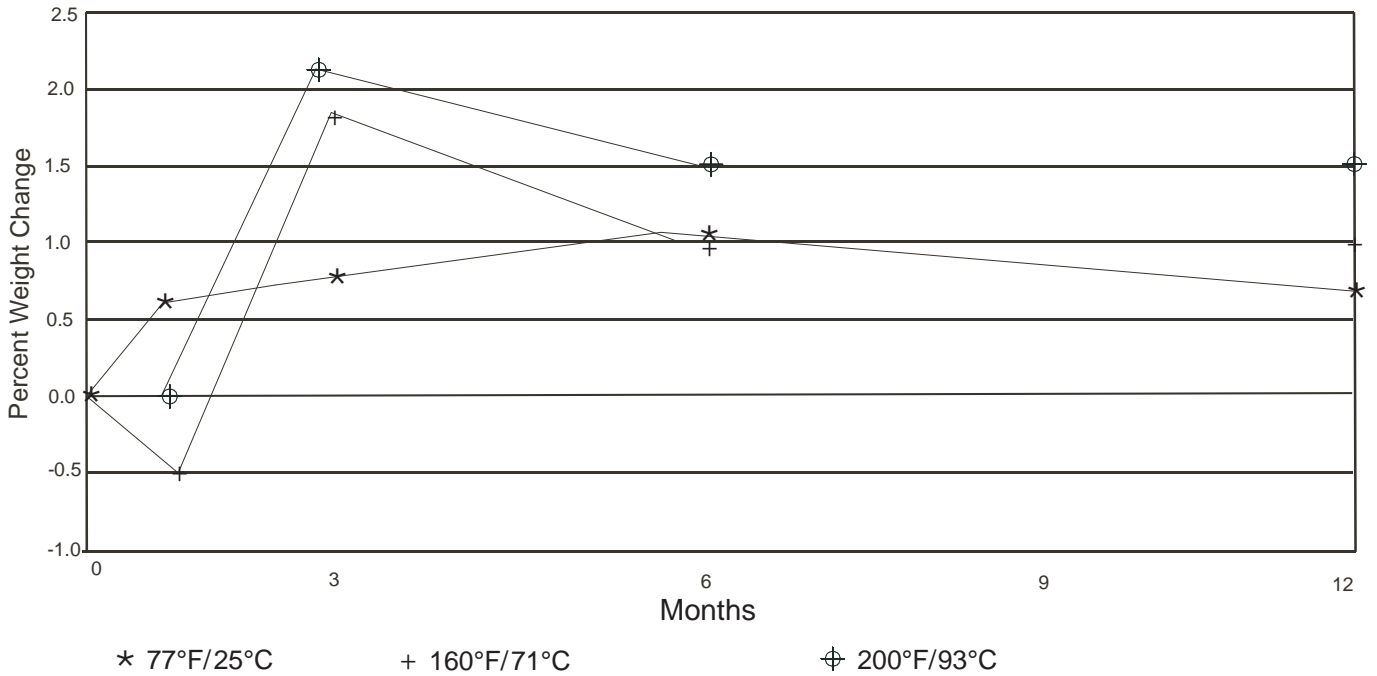Figure 3: Percent Weight Change COR VE8117 Immersed in 15% HCl

X-axis: Months
Y-axis: Percent Weight Change

Legend:
* 77°F/25°C   + 160°F/71°C   ⊕ 200°F/93°C
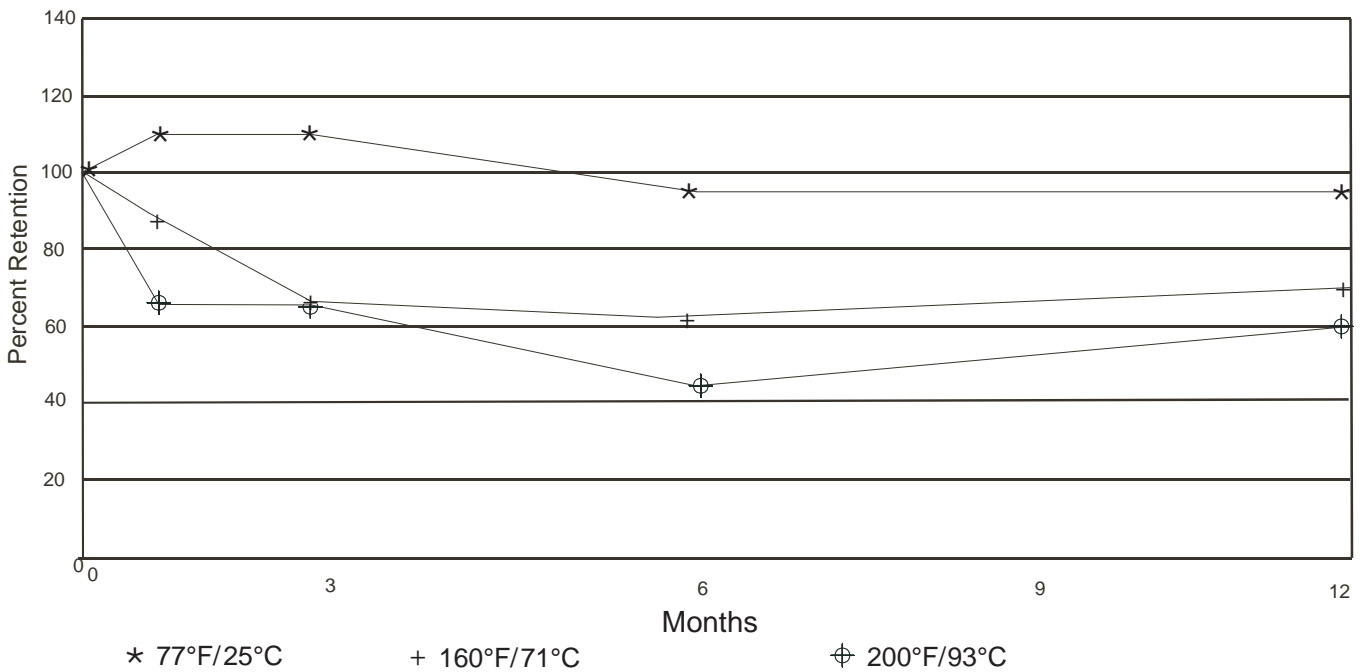
Figure 4: Percent Weight Change COR VE8101-45 Immersed in 15% HCl

Figure 4: Percent Weight Change COR VE8101-45 Immersed in 15% HCl

X-axis: Months
Y-axis: Percent Weight Change

Legend:
* 77°F/25°C   + 160°F/71°C   ⊕ 200°F/93°C
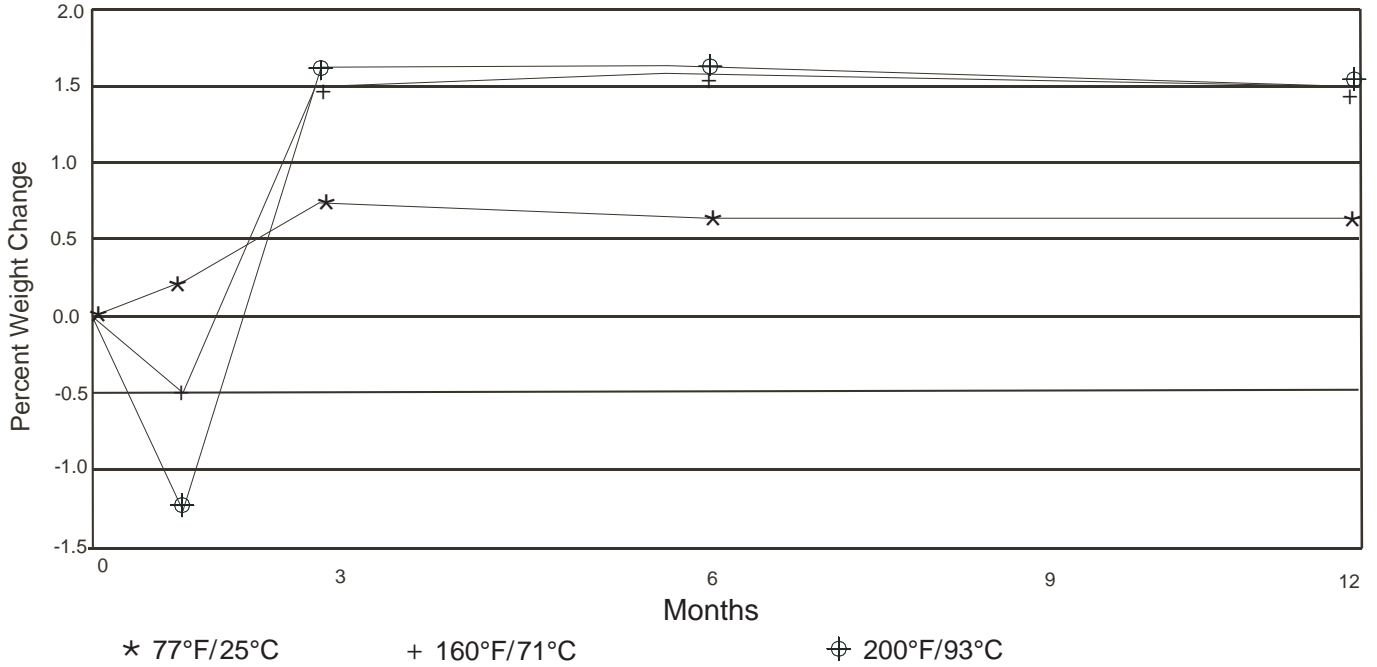
Figure 5: Percent Change in Thickness COR VE8117 Immersed in 15% HCl
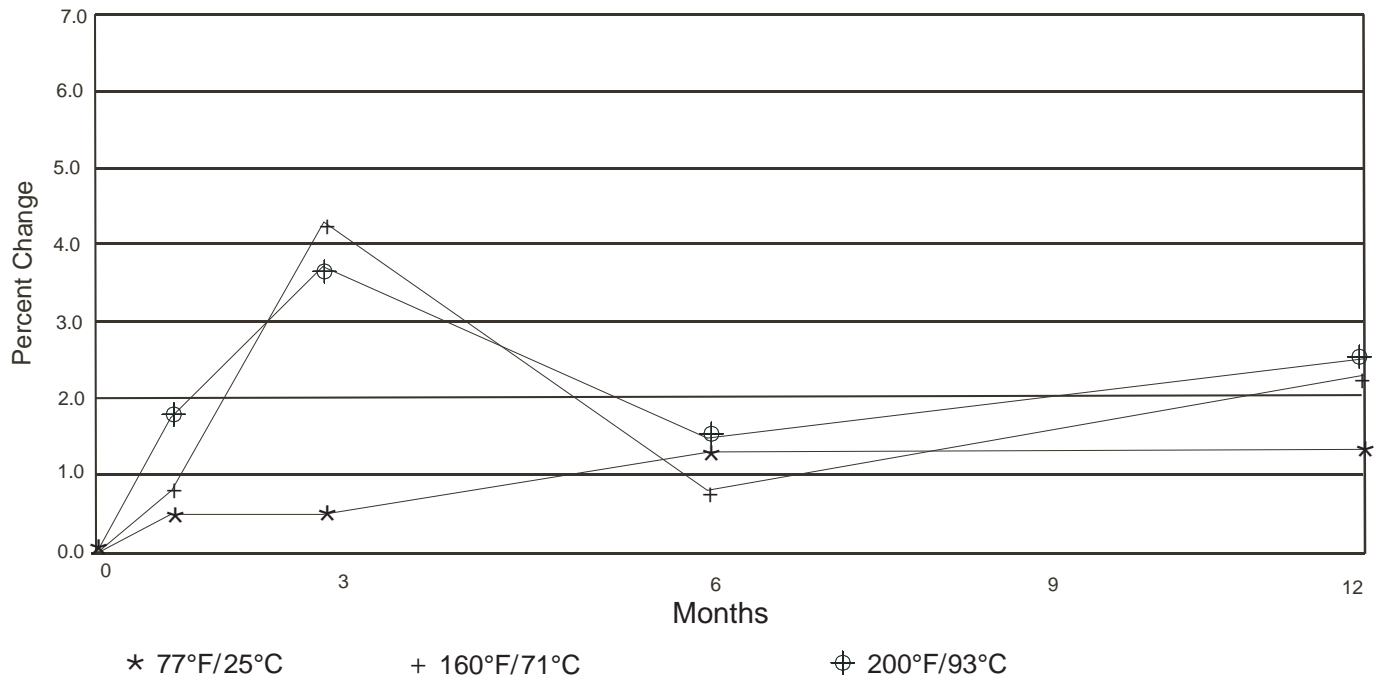
Figure 6: Percent Change in Thickness COR VE8101-45 Immersed in 15% HCl
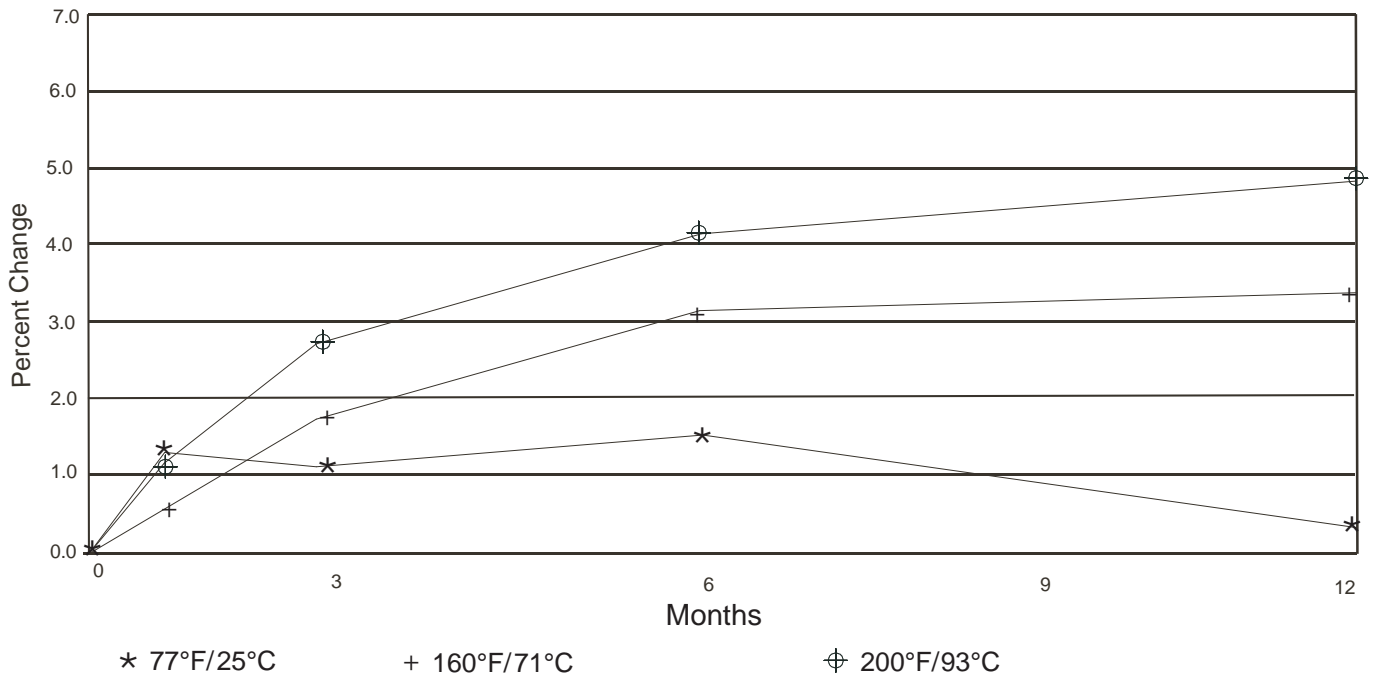
Figure 7: Percent Retention of Flexural Strength and Weight Change
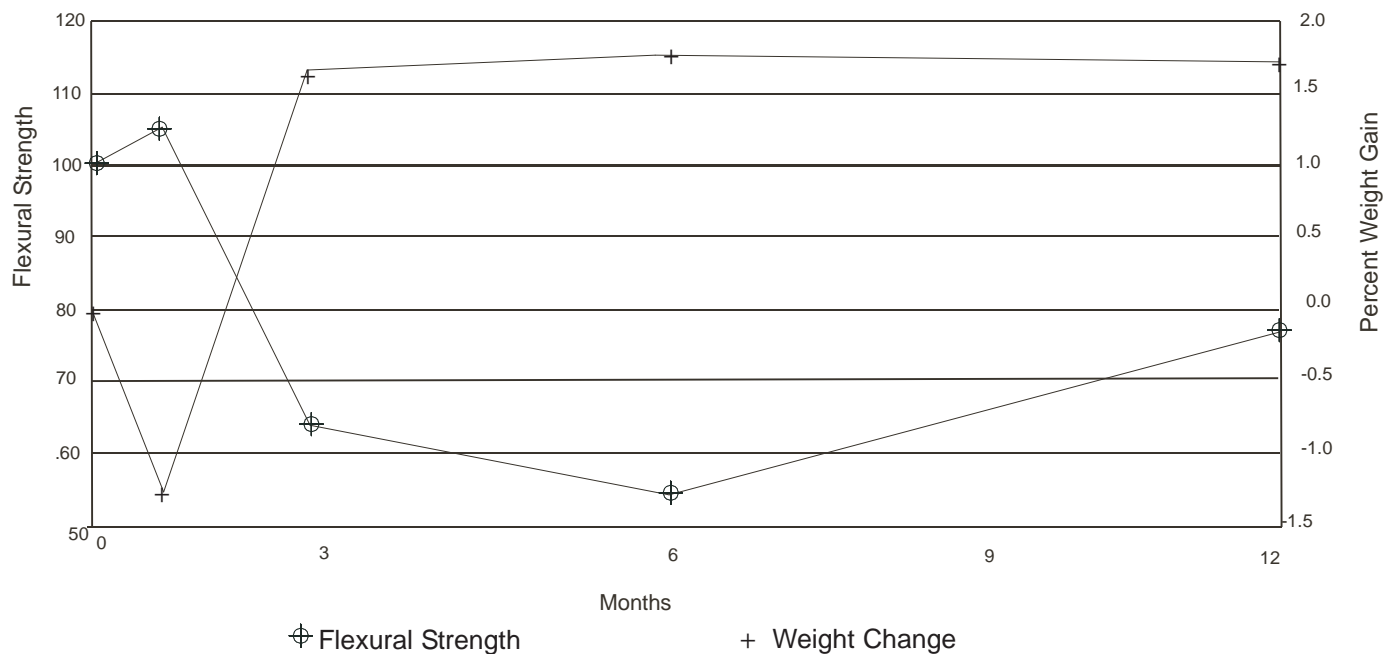### COR VE8117@ 200°F/93°C

Flexural Strength ⊕ Flexural Strength   + Weight Change

Figure 8: Percent Retention of Flexural Strength and Weight Change
COR VE8117 @ 160°F/71°C
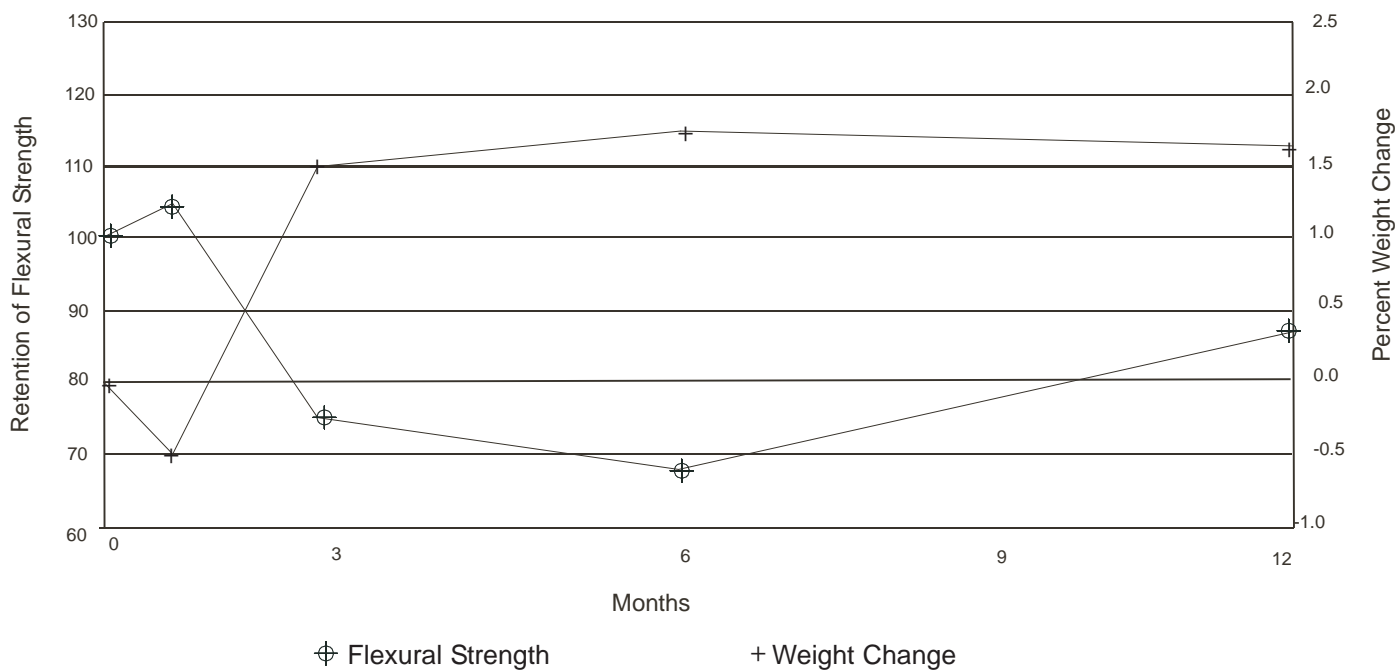

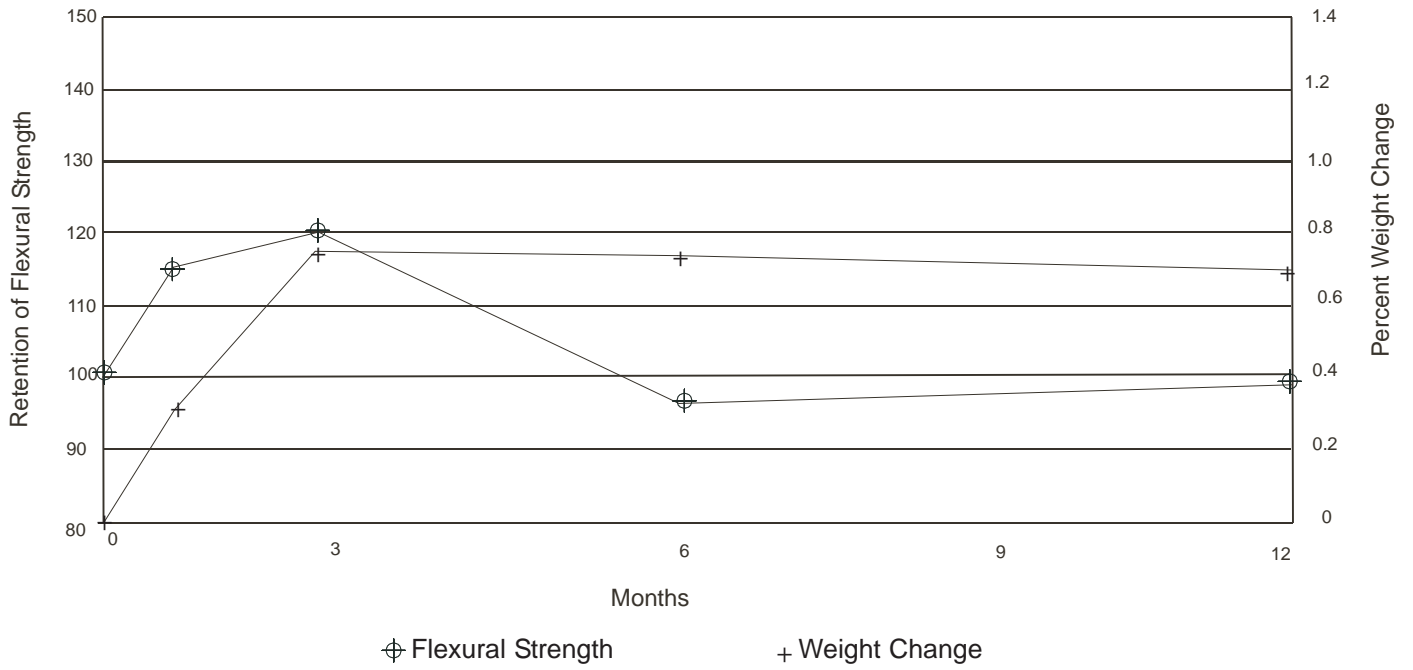⊕ Flexural Strength   + Weight Change

Figure 9: Percent Retention of Flexural Strength and Weight Change
COR VE8117 @ 77°F/25°C

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