4230-K Lafayette Center Drive
Chantilly, VA 20151, USA
+1 (703) 263 – 7100
info@lectromec.com

2015 F-16 Wire System Degradation Assessment

Interconnect Wiring, L.P.
5024 W. Vickery Blvd.
Fort Worth, TX 76107
817.377.9473
817.732.8667 (FAX)

Report Number
N503-R0001 Rev A

By

Lectromechanical Design Company, LLC.
4230-K Lafayette Center Drive
Chantilly, VA 20151 USA
Ph: (703) 263 7100
info@lectromec.com

Original Report Date: September 28, 2015
Revision Date: December 11, 2015

Prepare by: Stephen Traskos

Reviewed by: Michael Traskos

Revision	**Date**	**Edited by**	**Comments**
DRAFT	09/13/2015	Michael Traskos	Draft release
--	09/28/2015	Michael Traskos	Inclusion of Inherent Viscosity results and analysis
A	12/11/2015	Michael Traskos	Addition of DelTest results including: H16DW2805-01 H16DW2817-01 H16DW2819-03 H16DW2820-02 H16DW2822-501 H16DW2823-04 Update of associated recommendations and conclusions.

1 Executive Summary

Lectromec tested 23 electrical wire harnesses from an F-16 aircraft supplied by InterConnect Wiring. These harnesses were analyzed using the Lectromec DelTest™ and the Inherent Viscosity tests to evaluate the condition of the wire insulation.

The DelTest found 23 failures in the supplied harnesses corresponding to a failure rate of 8.12 breaches per 1000 feet of wire; more than was found in previous harnesses that were tested by Lectromec. The number of breaches per thousand feet for this aircraft was higher than the results of similar testing performed for InterConnect Wiring in 2006 in which a failure rate of 5.4 breaches per thousand feet was found and in 2008 with a failure rate of 4.3 breaches per thousand feet.

The Inherent Viscosity results found some degradation of the wiring system, but not to a point requiring immediate replacement. Recommendations are made to begin regular inspection of locations to reduce the likelihood of wire system failure.

2 Introduction

This report covers the work Lectromec performed in assessment of 23 electrical wire harnesses removed from F-16 aircraft by InterConnect Wiring. Two assessment types were performed on the wire harnesses: a laboratory DelTest™ and an Inherent Viscosity test.

- The laboratory DelTest™ detects breaches in the wire insulation that reach the conductor. It is a snapshot of the harness condition on the day it was removed from the airplane. Lectromec performed a DelTest™ on all wires from each of the 23 harnesses taken from the F-16. The DelTest™ process tests wires to within 1-3 inch of the connector back-shell; this assessment does not test inside the connectors. The DelTest™ was done without removing the Nomex™ braid. On a representative number of DelTest™ failure indications, Lectromec located and photographed a number of insulation breaches. More information on the DelTest™ is found in Appendix A.

- The Inherent Viscosity test detects wire insulation chemical changes due to environmental aging. The chemical analysis measurement is related to the elongation and other film performance characteristics. Coupled with Lectromec's degradation models, the results can also be used to predict future wire insulation reliability. Lectromec performed 24 Inherent Viscosity measurements.

  The Inherent Viscosity test is a destructive test and requires approximately six inches of wire sample. More information on the Inherent Viscosity test is found in Appendix B.

3 DelTest Results

The DelTest results presented in Table 1 are broken down according to harness. Those wires that indicated failure were double-checked by matching the failures at both termination points. Identified wire insulation breaches involving circuits connected to splices only counted as one wire failure. .

Table 1: Results of DelTest of 23 harnesses

Stockcode	Location	Total Length (ft)	# of Wires	# of Failures	% of Wires with Breaches
H16DW2801-02	LEFT WING-GENERAL PWR(N)	203	33	0	0%
H16DW2803-01	LEFT WING-GENERAL VIDEO	19	6	1	17%
H16DW2804-01	RIGHT WING-GENERAL VIDEO	17	6	0	0%
H16DW2805-01	LEFT WING GENERAL	276	43	0	0%
H16DW2806-01	RIGHT WING-GENERAL(B)	404	64	2	3%
H16DW2808-03	RIGHT WING GENERAL (B) (N)	466	76	0	0%
H16DW2809-04	STA 4 DISC(J812) TO MATRIX(N)	77	27	0	0%
H16DW2810-07	STA 6 DISC(J812) TO MATRIX (N)	76	25	2	8%
H16DW2812-06	STA 7 DISC(J812) TO MATRIX (N)	361	70	2	3%
H16DW2813-501	STA 3A DISC(J811) TO MATRIX	86	39	0	0%
H16DW2814-501	STA 7A DISC(J811) TO MATRIX	77	33	0	0%
H16DW2815-02	STA 1/2 DISC(J810) TO MATRIX	107	39	0	0%
H16DW2816-03	STA 8/9 DISC(J810) TO MATRIX	104	34	0	0%
H16DW2817-01	PWR L WING FUS DISC TO STA 3 DISC(J814)	1	1	0	0%
H16DW2818-01	PWR R WING FUS DISC TO STA 7 DISC(J814)	57	8	0	0%
H16DW2818-01	PWR L WING FUS DISC TO STA 4 DISC(J814)	57	8	0	0%
H16DW2819-03	PWR L WING FUS DISC TO STA 4 DISC(J814)	23	4	4	100%
H16DW2820-01	PWR R WING FUS DISC TO STA 6 DISC(J814)	23	4	0	0%
H16DW2821-502	STA 4 DISC(J813) TO MATRIX (N)	184	59	4	7%
H16DW2821-502	STA 1/2 DISC(J811) TO MATRIX	184	59	4	7%
H16DW2822-501	STA 8/9 DISC(J811) TO MATRIX	99	31	2	6%
H16DW2823-04	STA 4 DISC(J813) TO MATRIX (N)	38	12	0	0%
H16DW2824-04	STA 6 DISC(J816) TO MATRIX (N)	58	18	2	11%
Totals		2997	699	23	3.3%
Failures per 1000 feet		8.15			

The failure rates are based upon the cut lengths for the wires supplied to Lectromec by InterConnect. In practice, the actual wire lengths have been found to be shorter than the cut lengths; this has been previously confirmed in other F-16 wire harnesses assessments. The lengths provided by InterConnect were used as they were the only available length determinations. As such, the reported failure rates is lower than the 'exact' results.

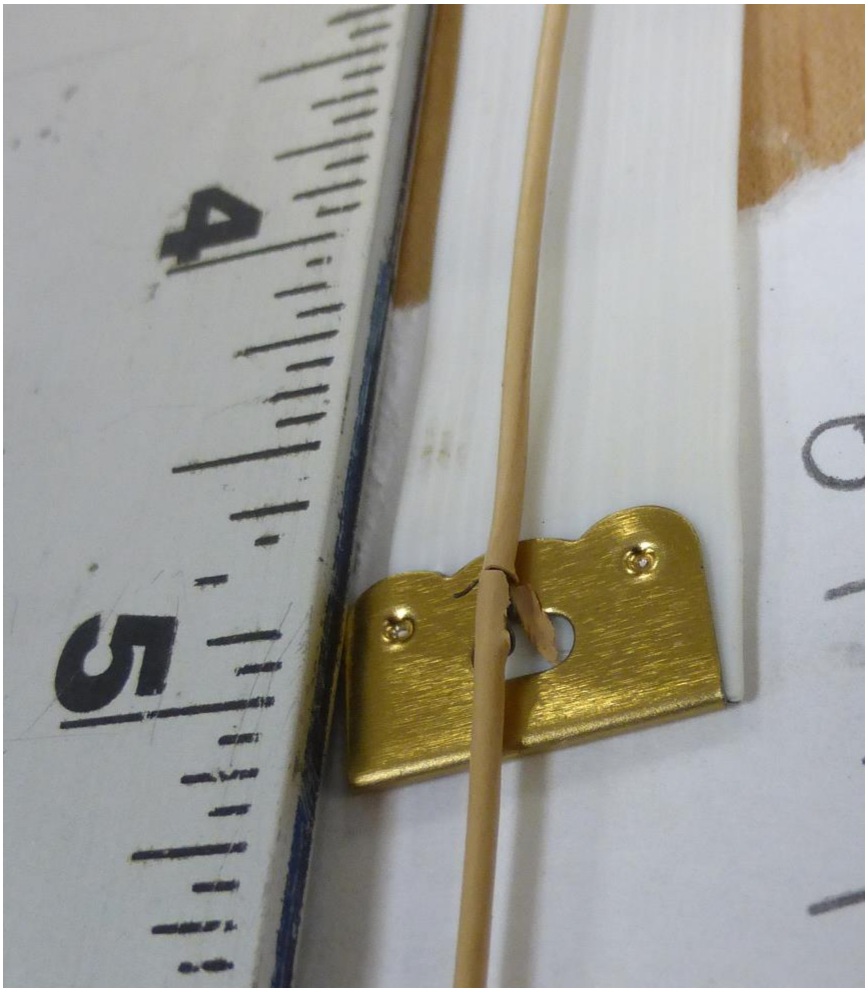


Figure 1: Radial crack in wire insulation. Breach of wire insulation down to the conductor (22 AWG wire).

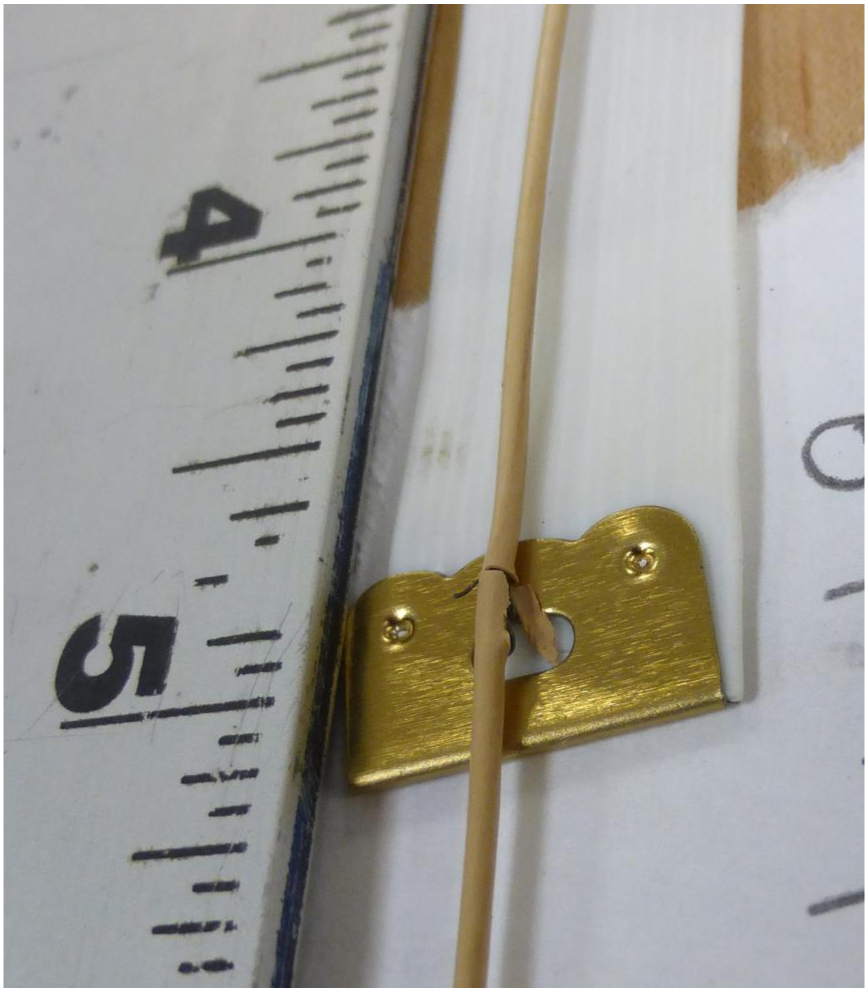


Figure 1 and Figure 2 show examples of the types of failures found with the DelTest. Both of these breaches were found within 6” of one another.

Figure 2: Harness H16DW2803-01. Breach in the wire insulation down to the conductor (22AWG wire).

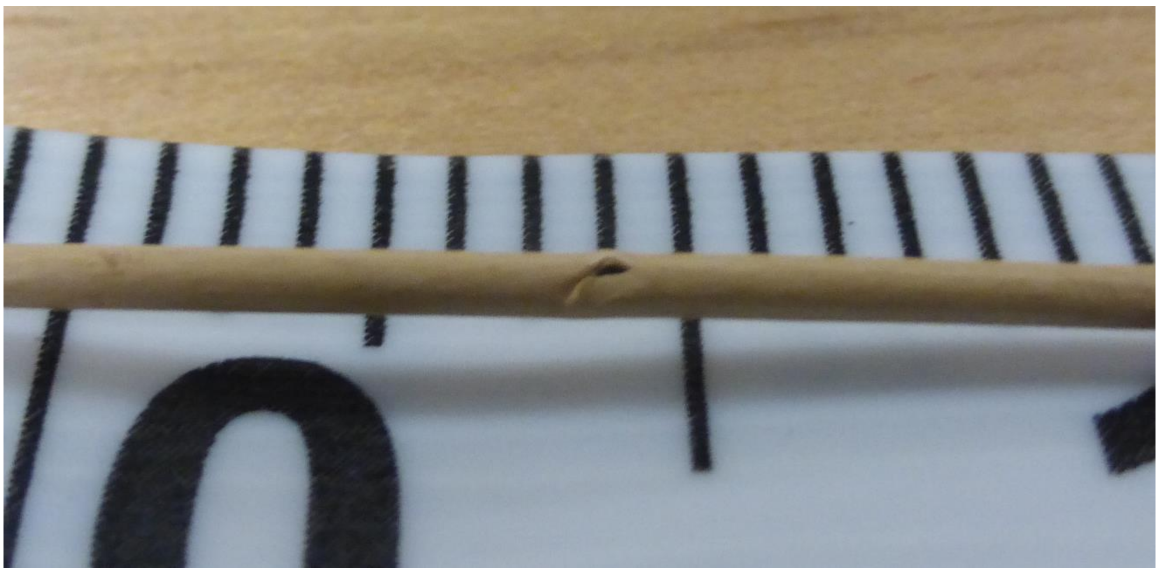


Figure 3: Breach in wire insulation. Likely result of mechanical damage to wire.

As the testing only identified failures within a single harness, visual inspections were only performed on the harness with failures. Several harnesses were retested to confirm the results and each harness yielded the same results.

3.1 Previous Results

Comparison between these DelTest results and past assessments is shown in Table 2. The best comparison to the current project would be the 2010 assessment; eleven of the 2015 harnesses were also tested in 2010. Testing performed on harnesses in 2006 and 2008 included harnesses taken from aircraft zones.

Note: Lectromec does not have wire harness age, flight hours, or maintenance condition for the aircraft tested. As such, no conclusions should be made beyond the harnesses tested in 2015 have more insulation breaches that similar aircraft.

Table 2: Results of harness assessment versus previous F-16 wire harness assessment

	Results from Previous F-16 Assessment			
Year Test Performed	2006	2008	2010	2015
Failure Rate per 1000 ft.	5.4	4.3	1	8.2
# of Harnesses Tested	33	33	24	23

4 Inherent Viscosity Results

4.1 Aging of Polyimide

The aging of polyimide insulation requires three factors: heat, humidity, and mechanical stress. Exposure to all three is most common while the aircraft is on the ground, and as such, the aging of polyimide primarily occurs while the aircraft is on the ground. Although overheating and mechanical stresses while in-flight can expedite degradation, this accounts for a small percentage of the degradation. Those aircraft stationed in locations with higher temperature/humidity will see shorter wire service life.

4.1.1 End of Life

The end of life is where the wire/cable can no longer perform its function without impacting the aircraft airworthiness. The wire end of life, as used in this report, is the point at which additional mechanical strain or other stressors are likely to cause a breach in the wire insulation. These stressors may come from mechanical bending/flexing, thermal shock, vibration, clamp stress, etc.

When a location is identified to have reached the end of life threshold (discussed in Section 4.1.2), it does not mean that the wires will fail at this age. This limit is the point at which the stressors are likely to generate insulation cracks (See Figure 4).

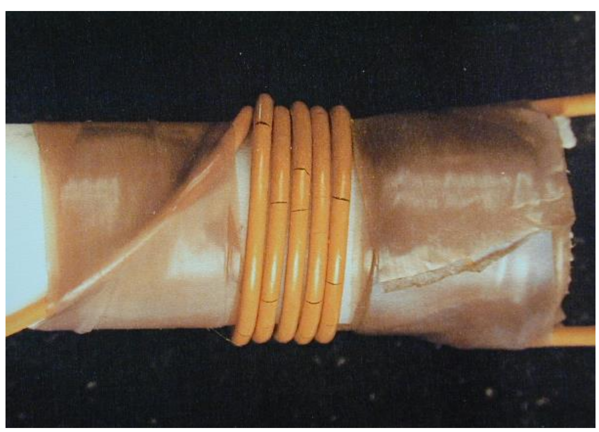


Figure 4: Example of radial cracks that can be found on aged polyimide insulated wires.

4.1.2 Inherent Viscosity Value Range

The process measures the molecular weight of the insulation polymer. As the polymer degrades, this molecular weight decreases and is closely correlated with the loss of mechanical properties.

The starting point for the polyimide insulation is typically found between 1.35 and 1.40. As the polymer ages, this value decreases corresponding to weaker mechanical properties.

4.1.2.1 Critical Values

There are four critical values that Lectromec has set for the IV assessment:

- 1.4: This is the starting value assumed for the IV of the polymer. Lectromec selects this value as the starting point as it will provide a higher degradation rate (discussed in section 3.1). If the lower bound of the starting IV rate is used (typically around 1.35), then the estimated degradation per year is lower. Use of the 1.75 value yields a less conservative result.
- 0.8: This IV value indicates a 50% reduction in polymer mechanical strength.
- 0.6: This IV value correlates with the minimum elongation to break strength of polyimide (discussed in Section 1.3.2.2).
- 0.45: This value corresponds to the threshold value for the testing and Lectromec has set this as the point at which replacement is recommended.

The recommended replacement value is not the point at which all wires in the zone are expected to fail, but IV value at which age-related failures (e.g. radial cracks shown in Figure 4) are anticipated to appear.

4.1.2.2 Degradation Categorization

Table 3 shows the ranges of IV values and provides a brief qualitative description of each range.

Table 3: Description of IV value ranges. Table color codes are shown here correlate to the colors used in the results tables.

Average IV Value Range	Condition Category	Condition Description
>= 1.25	Like New	The wire insulation displays no signs of degradation.
0.9 – 1.25	Good	The wire insulation has undergone limited degradation. Marginal reduction in insulation properties (electrical/ mechanical strength).
0.7 – 0.9	Fair	The insulation has undergone degradation and the mechanical strength has decreased by 50%. Age related breaches in wire insulation are unlikely at this stage.
0.45 – 0.7	Poor	Likely to start seeing flaking of the topcoat. Mechanical properties have been reduced. Planning for replacement should begin. Initiation of inspections should be considered at this point.
<= 0.45	Replacement Recommended	Significant degradation has occurred and replacement is strongly recommended. This value was selected as the threshold for replacement was that it is this value that Lectromec found that radial cracks begin to form in the insulation.

The intermediate ranges that are presented in Table 3 (0.7, 0.9, and 1.25) can be considered arbitrary, but were selected to provide a qualitative description of the samples within those ranges. The expectation is that the samples within each presented range would have relatively homogeneous properties; changes of ±0.05 on any of these values would not have a large impact on samples within a given range.

Research on the impact of insulation degradation on mechanical strength of polyimide is shown in Figure 5. The table shown in Figure 5 is divided into 3 categories: good condition (green), recommended inspection (yellow) and recommended replacement (red). According to the best-fit line, harness inspections are recommended when the IV value has reached 0.70 or the polyimide has reached 40% elongation to break. Replacement is recommended when the IV value has reached 0.45 or the polyimide has reached 20% elongation to break.

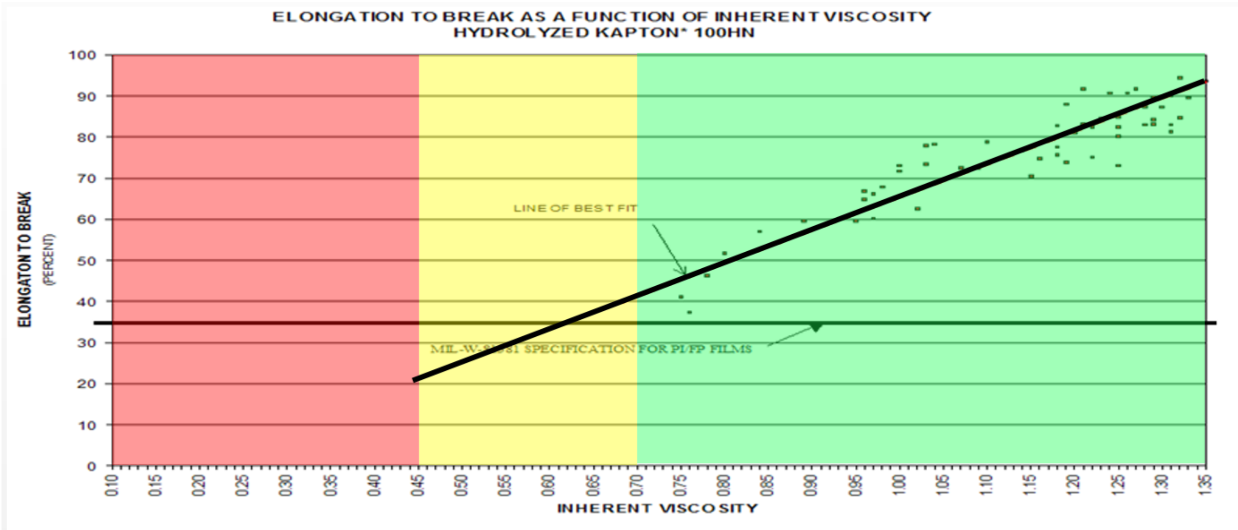


Figure 5: DuPont tests correlating IV measurements with elongation to break[1].

An item to note from Figure 5 is that the polyimide polymer can sustain a 65% reduction from new material strength and still meet the strength specification for MIL-W-81381. This gap between the material performance and minimum specification makes it possible for the insulation to have a large performance decrease and still perform above the performance requirements.

4.2 Definitions

Best Case Life Forecast: With the best case, the assumption considers practical and optimistic starting values for the wire insulation (based on historic testing of new wires). This is an optimistic assessment and should only be used to set in-service use limits.

Like New Wire: The starting IV values for polyimide insulation can vary depending on source and processing. Historic testing has shown that most new wires fall at or above an IV value of 1.3.

Remaining Wire Life: The 'remaining wire life' is a concept describing the wire condition relative to a standard device life cycle. This is not to say that the remaining life is the time at which all wires will fail (a failure defined as a breach that exposes the conductor); rather, this sets an expected threshold at which the degradation related failures would begin.

Worst Case Life Forecast: With the worst case, the assumption considers a practical and pessimistic starting IV value for the wire insulation (based on historic testing of new wires). As this is a pessimistic rating, it should be used as a guide to schedule replacement activities.

[1] Turner, N. H., LaCourt, P. R. *Chemical Manufacturer's Test Applied to Aged Aircraft MIL-W-81381 Type Wire Insulation*, Presented at the 2003 Aging Aircraft Conference.

Near Term Replacement/Inspection: This category describes locations that are recommended for replacement/inspection within 0-5 years.

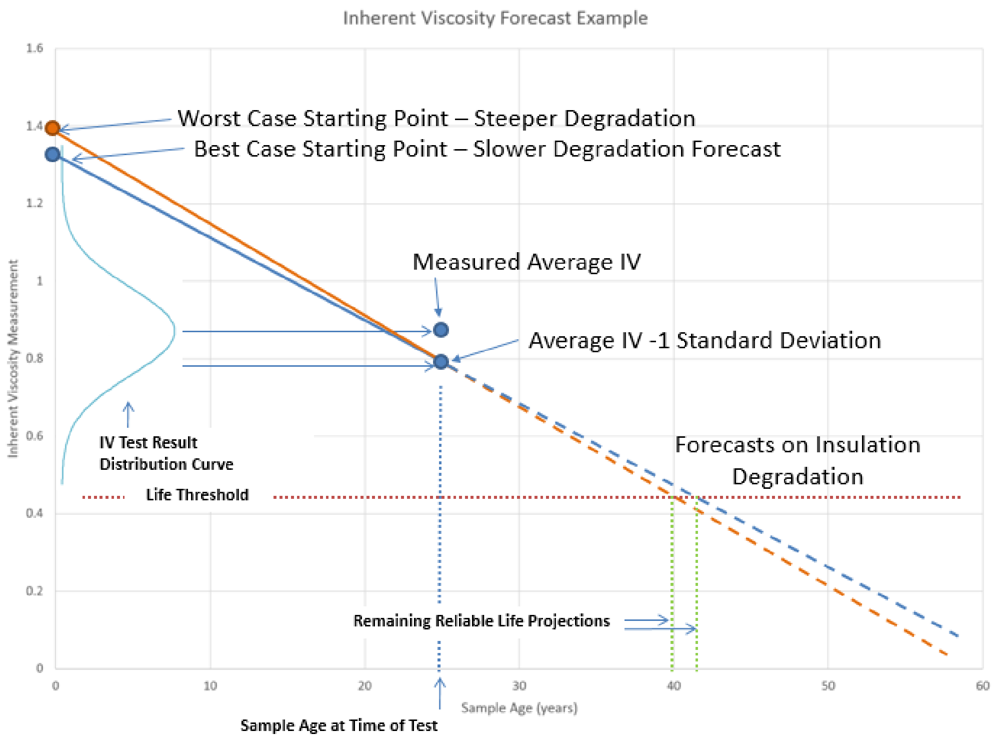
Long Term Replacement/Inspection: This category describes locations that are recommended for replacement/inspection in greater than 15 years.

Use Dependent Replacement/Inspection: This category describes all remaining locations (6-15 years). The projected remaining wire life will hold true under the assumption that flight usage and environmental conditions remain the same after the test date.

4.3 Linear Degradation

Figure 6 is an example of the degradation forecast used by Lectromec. Lectromec's research has found that the degradation can be considered linear over the IV interval of 0.4 – 1.4 (beyond IV value of 0.4, the IV degradation rate is significantly slowed). Using the assumption of linear degradation, the starting point for degradation projections assumes a starting value of 1.40. This is a common value for the starting point for the polymer (as discussed in Section 4.1.2).

Figure 6: Example polymer degradation prediction.



The example shown in Figure 6 shows a life prediction example for a group of 25 year old samples. The distribution shown on the left side shows the relative distribution of results with an average IV value of 0.9 and a standard deviation of ±0.1. The measured average and -1 standard deviation are shown along with the degradation slopes assuming different initial starting values. Typically, Lectromec recommends the use of the ‘worst case starting point’ as this provides a conservative degradation estimation.

Note that while the results presented in this report may show IV values less than 0.45 using a linear approximation, these values have no impact on the conclusion or recommendations. Once the forecast has reached the 0.45 threshold, further IV values are part of the mathematical projection and should not be taken as insights into the degradation.

4.4 Projection Limitation

Lectromec placed a 20 year limitation on the degradation model. Although the model can predict beyond a period of 20 years, the reliability beyond 20 years is uncertain; this is where Lectromec defines the limit of the degradation model. Further, based on variability in use, location, and other factors, it is believed that this is a reliable limit upon which fleet decisions can be made.

If projections beyond the 20 year limit are needed, it is recommended that an additional assessment are performed after 10 years from the original assessment. Depending on the variability of fleet data, it may be possible to perform the reassessment with a more narrow scope.

4.5 Standard Deviation from Center

The standard deviation is a determining factor for the projections for replacement and inspection. The replacement projection is based on one standard deviation and the inspection projection is based on three standard deviations from the average. The reason for which the inspection projection has a more conservative assessment is to ensure all components are assessed before they reach the end of reliable service life.

4.6 Result Preface

The inherent viscosity assessments and remaining life forecasts are typically based on 10 – 12 samples per location. In this effort, seven or fewer samples were tested per location. Additional testing is recommended for improved accuracy.

Further it is assumed that the harnesses tested were 27 years old. If the harnesses tested are in fact younger, then the projections provided here are conservative.

4.7 Results

The results of the inherent viscosity assessment are shown in Table 4. The wiring system shows chemical degradation, but it is not in a state that requires immediate replacement; each harness has a projected needed replacement greater than 20 years. The harness that showed the greatest degradation was H16DW2806-01.

Table 4: Results of Inherent Viscosity Assessment with percentage of remaining reliable life before inspection and replacement.

	H16DW2810-07	H16DW2806-01	H16DW2821-503	H16DW2824-04
Average IV	1.11	0.90	1.07	1.08
Std Dev IV	0.21	0.04	0.29	0.08
Count	6	5	7	6
	Age of Aircraft	**27 years**		
Best Case Aging Rate	0.009	0.017	0.011	0.010
Worst Case Aging Rate	0.011	0.018	0.012	0.012

	Years	H16DW2810-07	H16DW2806-01	H16DW2821-503	H16DW2824-04
Projected Worst Case Condition Until Replacement	**0**	47%	44%	35%	59%
	5	41%	34%	28%	53%
	10	36%	24%	22%	46%
	15	30%	15%	15%	40%
	20	24%	5%	9%	34%
	Years to 0.45 value	> 20 years	> 20 years	> 20 years	> 20 years

	Years	H16DW2810-07	H16DW2806-01	H16DW2821-503	H16DW2824-04
Projected Worst Case Condition Until Regular Inspection	**0**	3%	35%	0%	43%
	5	0%	26%	0%	37%
	10	0%	16%	0%	30%
	15	0%	6%	0%	24%
	20	0%	0%	0%	18%
	Years to 0.45 value	3	18	**immediate**	> 20 years

Also shown in Table 4 is the projected worst case condition until regular inspection is recommended. This is based on the likelihood of wire insulation breach and is impacted by the inherent viscosity average and the standard deviation. Those locations with the largest standard deviation are the most susceptible to degradation and impact on system reliability. For harnesses H16DW2810-07 and H16DW2821-503, the recommended regulation inspection of these locations is immediate.

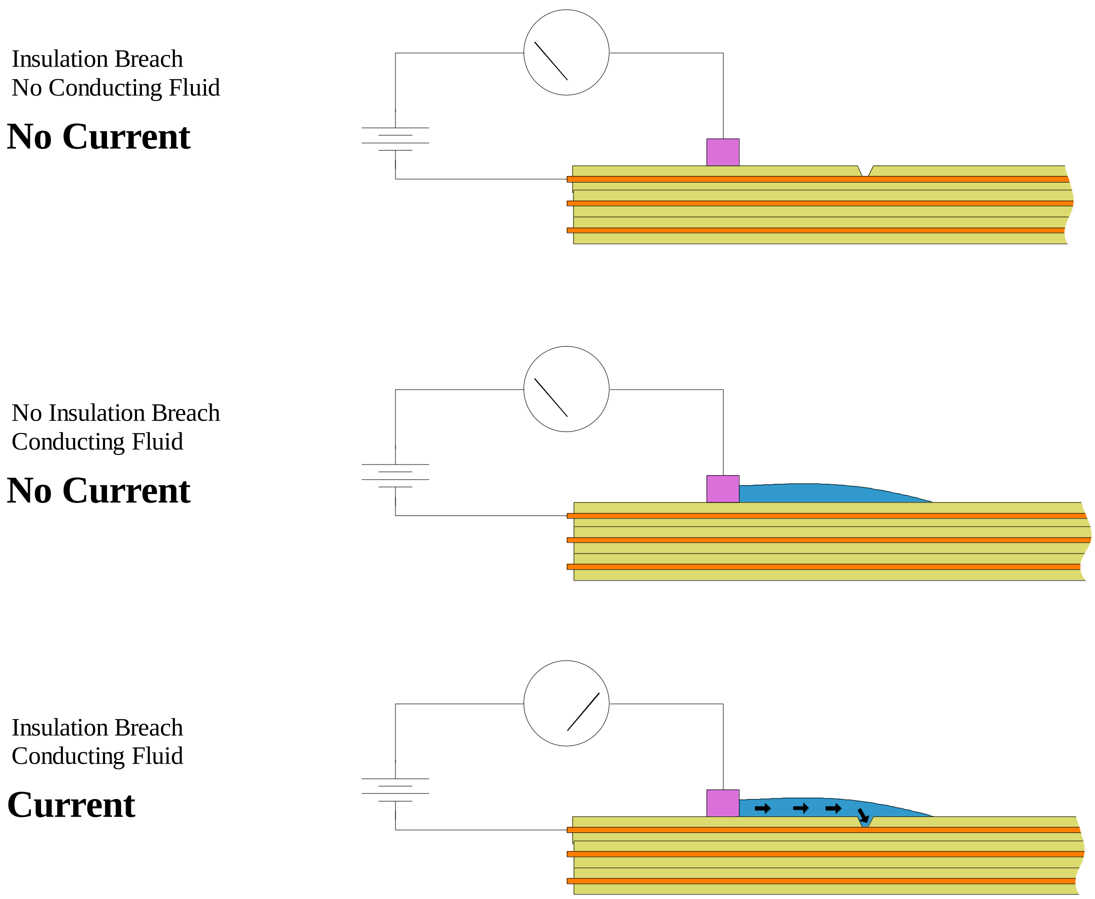
5 Summary

The results of the DelTest showed that the number of wire insulation breaches was 8.2 failures/1000ft; this result was lower than the results of the testing performed in 2006 (5.4failures/1000ft) and testing performed in 2008 (4.5 failures/1000ft). The DelTest evaluations identified a total of three breaches which were all found within a single harness. The failures were verified via visual examination of the harnesses.

Wire harness inspections should begin based on the timetables discussed in the inherent viscosity results section. Because visual inspection of the wiring is unlikely is hindered by the braided harness protection sleeves, it is recommended that Automatic Wire Test Systems (AWTS) or similar technologies be considered for harness assessments. The use of this equipment can help to identify and replace those wires with insulation breaches. The intervals proposed are provided as a baseline for progressively removing samples to limit the impact on aircraft airworthiness.

6 DelTest™

The DelTest™ is a procedure to find breaches in the insulation of a wire that reaches to the conductor. In this procedure, a conducting fluid is injected into the harnesses under test. A small test voltage is placed on the inner conductor of the wires in the harness. A return electrode is placed on the outside of the harness in contact with the conducting fluid. A current measured in the test circuit indicates a breach in the insulation. This is illustrated in the figure below.



1. In the first harness, there is a breach but there is no current measured because the surface resistance of the wire is too high.
2. In the second case, the conducting fluid is present but there is no breach in the insulation so again no current is measured.
3. In the third case, there is both a breach and conducting fluid present and a current is measured.

This process has been performed "in situ" on aircraft and in the laboratory on harnesses that have been removed from the aircraft. When doing the DelTest™ in the lab, the harness is placed in a water bath with the connectors secured above the water.

7 Inherent Viscosity

7.1 Introduction

The definition of a polymer is "a long molecule which contains a chain of atoms". This definition is very broad and encompasses life itself to highly sophisticated synthetic materials. While man has used polymers from prehistoric times, e.g., hides and fibers, polymer science dates to the early 20th century. It was from this time that truly man-made polymers were discovered and developed. These synthetic polymers have numerous uses in the modern technology and society in general. Organic polymers, due to their structure and composition, almost always are insulators, i.e., they have a band gap of approximately three or more electron-Volts. While there are naturally occurring polymers that are employed for insulation purposes, e.g., isoprene, most insulating materials used for wiring today are synthetic.

A widely utilized polymer for wire insulation in aircraft is the material derived from the reaction between pyromellitic dianhydride (PMDA) and 4,4'-diamino-diphenyl ether (ODA) and is an aromatic polyimide. The structural formula of the monomeric unit from this polymerization is shown Figure 7-1 and will be abbreviated as PMDA-ODA.

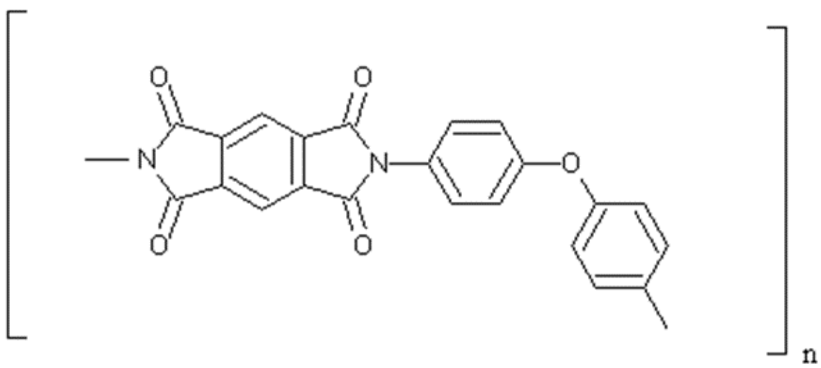


Figure 7-1. Structural formula for the monomeric PMDA-ODA.

The hydrogen and carbon atoms are not shown in the figure. Carbon atoms are at the vertices of two or more straight lines; hydrogen atoms are attached at vertices where three lines including the detached straight lines are located. The exception is at either end of the structure; these are where one complete PDMA-ODA unit is attached to another. The empirical formula for this monomer is $C_{22}H_{10}O_5N_2$. This polymer was synthesized by DuPont in the 1960's and has the trade name Kapton®. There are now added sources for this material. The United States Department of Defense specification designation for wires using this material is MIL-W-81381. Note: there were a few "slash numbers" of MIL-W-81381 that employed a different monomeric unit; however, these were removed from use a short time after their introduction.

The “n” shown with the structural diagram above is the degree of polymerization. Each individual polymer molecule will have its own “n”. With an aggregate of polymer molecules having the same monomeric unit, there will be a range of “n’s”. Depending on the polymer, “n” can start at less than 10. At the other extreme are polymers where “n” can be well above 10,000. For PMDA-ODA almost all of the “n’s” will be 200 or less. As would be expected, the molecular weight of a polymer is a very important property of a polymer. Thinking simply, if “n” is known, the molecular weight of a given polymer molecule can be calculated. However, the problem is much more difficult.

First, there is the definition of molecular weight for an aggregate of polymer molecules due to the distribution of “n’s”. The two most common definitions for polymer molecular weights are the number average molecular weight (NAMW) and the weight average molecular weight (WAMW). With polymers NAMW usually is less than WAMW with typical distributions; the exception is when there is a very narrow range of “n’s”. Then the NAMW and WAMW values will be close. Details about polymer molecular weights are available elsewhere. The second issue is how to measure NAMW or WAMW, since most techniques will measure only one of these quantities. With some polymers the number of procedures that can be employed will be very limited as well.

Organic materials, which include almost all polymers, will change over time. The usual change is for a break to occur somewhere in the chain. This would reduce the “n” for that polymer molecule. For example, if a break occurs with a polymer molecule with an “n” of 100 in the middle of the chain, then there would be two new polymer molecules each with an “n” of 50. Some of these breaks can be caused by simple environmental exposure, e.g., oxygen, water, or light. If there are a sufficient number of breaks, then the molecular weight (both NAMW and WAMW) will decline measurably. In addition, it would be expected that some physical properties of the material, e.g., flexibility or the formation of voids, will happen. Extensive degradation could result is loss of material in some instances. Such changes when a polymer is used for wiring insulation might be very serious.

For PMDA-ODA the only currently available method to determine molecular weight is viscosity. Viscosity is typically thought of as an end property of a material, e.g., how easily syrup pours or the oil in an engine. However, in polymer science viscosity can be employed to measure the molecular weight of a polymer. Viscosity measurements with a dissolved polymer give a value that is close to the WAMW. The difference between the true WAMW and the viscosity value typically is a few percent. The relationship between viscosity and molecular weight is given by the semi-empirical Mark-Houwink equation

$$MW = K\eta_{inh}^{(1/a)} \tag{1}$$

where MW is the viscosity average molecular weight, K and a are constants, and η_{inh} is the Inherent Viscosity[•]. Values for a range from 0.5 to 1.0, K is directly proportional to MW, and each polymer-solvent combination has its own values of K and a. Inherent viscosity is defined in equation (2).

$$\eta_{inh} = \left(\frac{1}{c}\right)\ln\left(\frac{t}{t_o}\right) \qquad (2)$$

where 't' and 't_o' are the respective times for the solution with and without polymer dissolved to go between two lines in a viscometer, and 'c' is the concentration of dissolved polymer. Typical units for η_{inh} are g/dl (dl is 0.1 liter). If η_{inh} decreases there is a decline in MW, and hence, a degradation of the polymer has occurred.

The physical properties of PMDA-ODA have many features that make it attractive for use as insulation. For example, the thermal stability at 275° C (based on the retention of film flexibility) is over a year. The material is insoluble in organic solvents and appears to resist damage due to ionizing radiation. When used as insulation, the thickness required is less than that of many other polymers, and this material is very flexible over a wide temperature range. These properties make PMDA-ODA especially attractive for use on aircraft.

7.2 Experimental Procedure

Two continuous strips of PMDA-ODA (often about 25 micrometers thick) are helically overlapped over the conducting material. The polyimide is coated with a thin fluoro polymer for adhesive purposes. On the outside of the outer PMDA-ODA film a "top-coat" is placed. Different materials have been used for the "top-coat. Before analysis, the top-coat is removed from the wire. Then, the PMDA-ODA tapes are separated from each other and the conductor. The tapes then are weighed, dissolved in concentrated H_2SO_4 following the previously developed method of Wallach.

A little less than 0.1 gram per specimen of PMDA-ODA is needed for analysis purposes. For the analyses in this project, only the inner tape was analyzed. This was done because there are possible difficulties with the top-coat are avoided. All of the films were 0.001 inches (0.025 mm) thick with the exception for wire number 1 in harness 685. This film was 0.002 inches (0.051 mm) thick. After dissolution of the film, the fluoro-polymer (not soluble in H_2SO_4) is separated from the solution. Then, η_{inh} of the dissolved PMDA-ODA is determined. A schematic diagram of the experimental equipment is shown in Figure 7-2.

The individual wires to be analyzed were chosen from harnesses that had been examined with the DelTest (results elsewhere in this report). Many of the wire had the same number in the same harness as those investigated in 2006 by Lectromec. All of the wires were either 20 or 22 gauge with one exception.

[•] The International Union of Pure and Applied Chemistry term for this quantity is the logarithmic viscosity number.

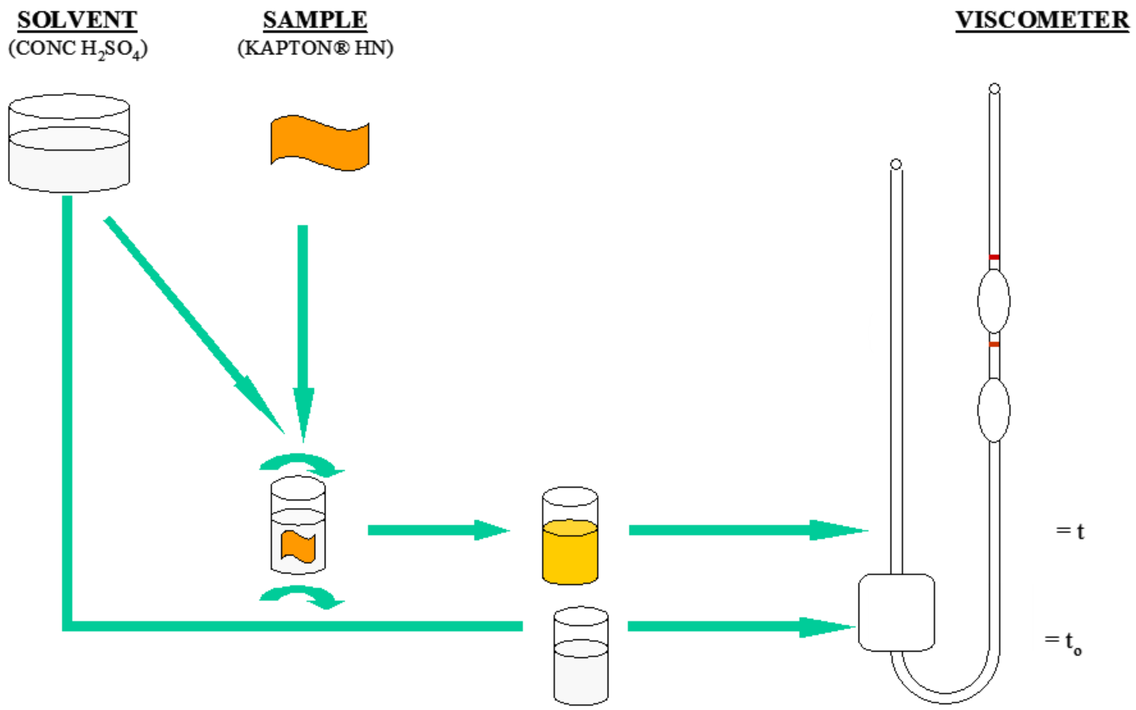


Figure 7-2. A schematic representation of the experimental equipment for viscosity measurements.

7.3 Understanding the Results

The graph below shows the comparison between elongation to break as a function of the Inherent Viscosity of the polymer with greater than 90% elongation to break corresponding to new polymer.

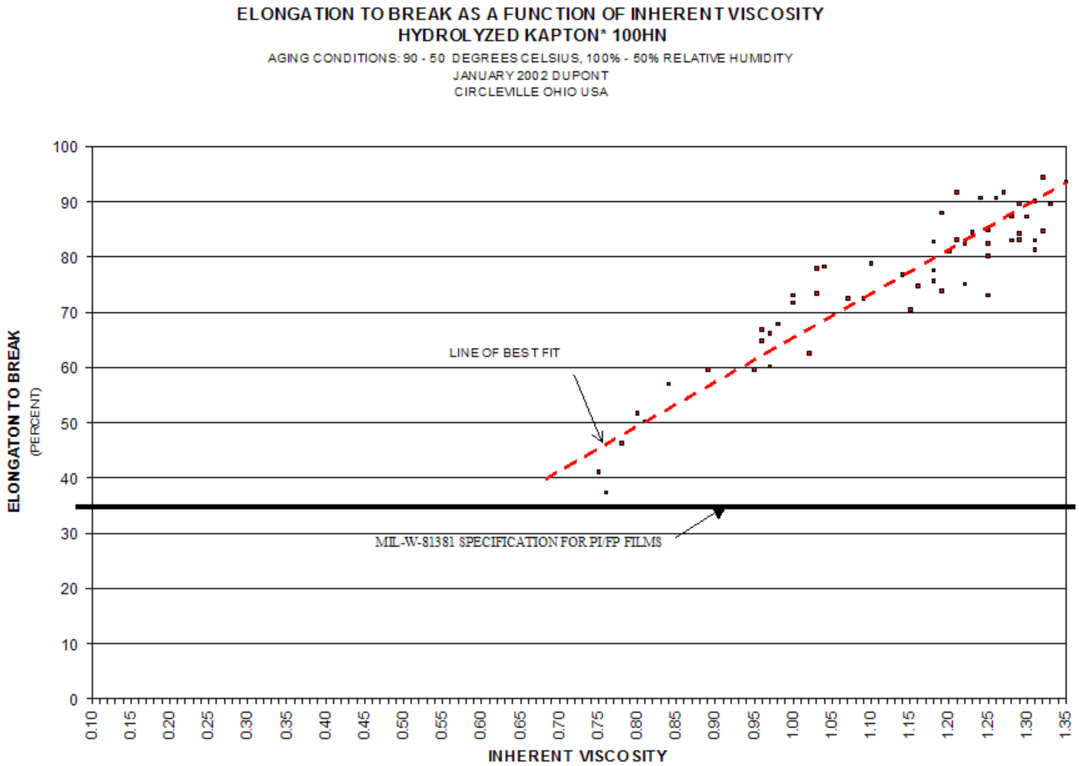


Figure 7-3: DuPont tests correlating Inherent Viscosity measurements with elongation to break.

These tests from the above figure were done on accelerated aged wire for various durations by DuPont. While this is greater than the value required meeting the specification requirements, this does correspond to a wire that is more likely to fail as the results of mechanical stress.