



InterConnect

Wiring

E-BOOK SERIES

The Wonderful World of Wiring

Kapton Wire, TKT, Aircraft Rewire & Refurbishment

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InterConnect's Why: Why Do We Do What We Do?
Because the only thing better than saving a project in danger
is doing it right in the first place!

Start with InterConnect.

A publication of InterConnect Wiring.

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Introduction

In 2017 InterConnect Wiring continued The Wonderful World of Wiring newsletter about various electrical wiring topics in the aerospace industry. This book is a compilation of some of the articles (blogs) and is divided as follows:

- Chapter 1:** Kapton Wiring: The Good, The Bad, and The Ugly
- Chapter 2:** Rewire Programs: The Whole Kit and Kaboodle
- Chapter 3:** Refurbishment Programs: Why Buy New When You Can Refurb?

This year we focused on the effects of Kapton Wire on military fixed-wing and rotary aircraft. Although we mostly concentrated on the F-16 Fighting Falcon, Kapton wire has been used across multiple platforms, both for commercial and defense aircraft.

To solve the problem of electrical wiring issues in the aerospace industry, InterConnect has developed Rewire Programs and Refurbishment Programs for aircraft users. You will find within this eBook very informative reasons why one would choose to Rewire or Refurbish their aircraft, as well as when and how to do the Rewire or Refurbishment.

I hope you enjoy reading this book and learning a thing or two about The Wonderful World of Wiring.

Enjoy!

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Chapter I

Kapton Wiring: The Good, The Bad, and The Ugly



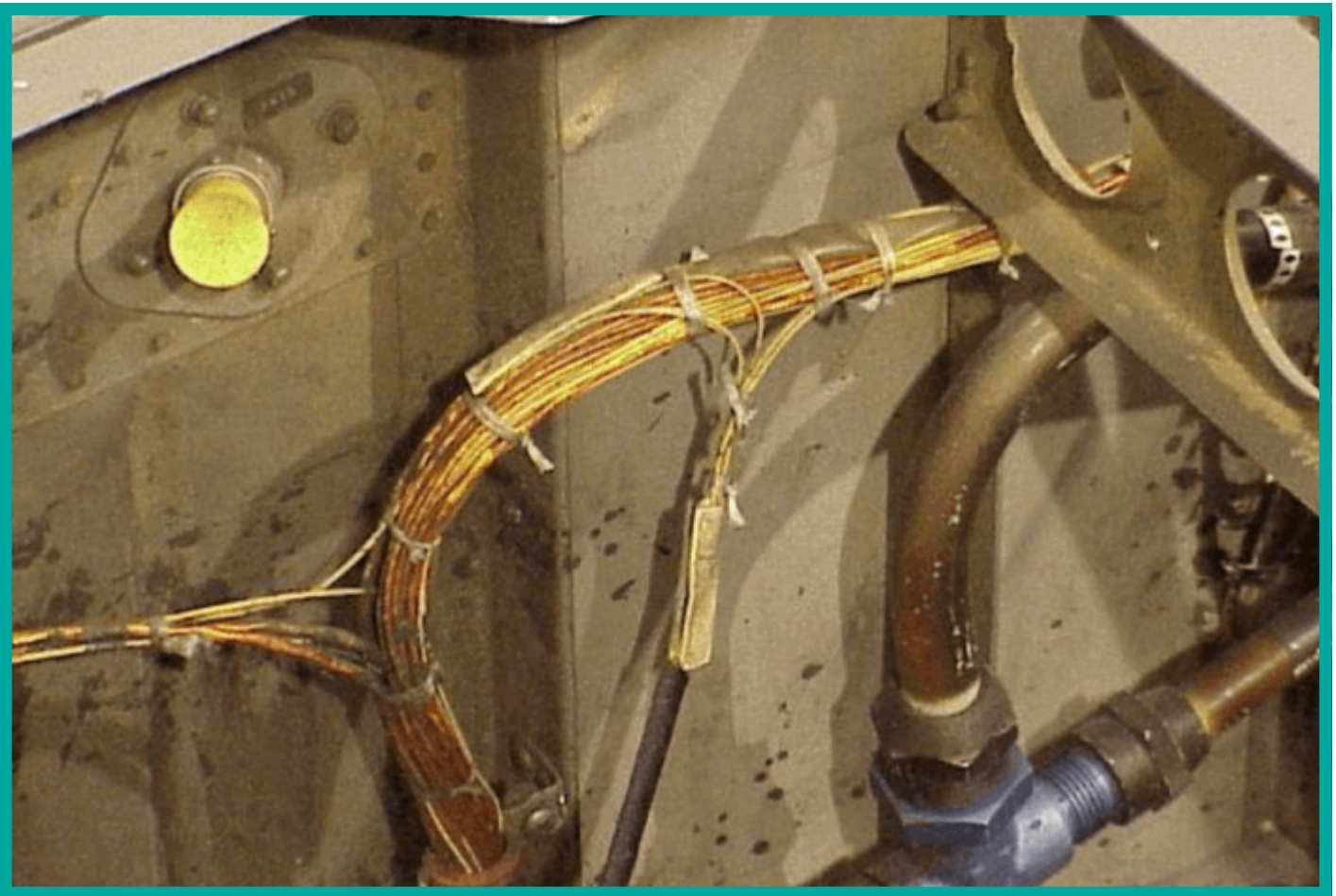
When Was Kapton Insulation for Wires Developed?

Around the late 1960s a polyimide film with a resistance to high heat called Kapton was developed. This material appeared stable over a wide range of temperatures and was gas, steam and water tight. These properties allowed it to be used across many different applications and environments.

Since Kapton was considered a good electrical isolator the electronics industry started implementing it in the manufacturing of wires as the insulation material. It was also used as an insulation and protective layer on sensitive electronic components.

Over the next few months InterConnect Wiring will be answering various questions about this wire insulation type which has been used on many aircraft platforms including the F-16, the UH-60 and the F-15. We will also advise when replacement of this wire is necessary.

Below is a photo of a harness bundle with Kapton wires that InterConnect removed from a UH-60A for the Army National Guard Rewire Program. This old wiring harness would later be replaced with a new harness bundle manufactured by InterConnect using TKT insulated wire.



Which Aircraft Have Kapton Insulated Wires?

Don't you hate it when the news or a TV program says; "Coming up next..." and then you have to wait another 30 minutes to see what you have been waiting to see from that teaser? Well, we are not going to tease you like that today. Instead, we are going to give you the answer to this question right away.

Which aircraft have Kapton™ insulated wire? First line fighter aircraft, as well as patrol, ASW, attack, transport, and helicopter aircraft are all subject to wiring problems because they possess Kapton™ insulated wire. Some aircraft involved on the military side include F-16, F-14, F-15, F-18, F-4, S-3, E-2C, P-3, EA-6, SH/UH-60, AH-64, and AH-1 models. Some examples on the commercial side include A310, A320, A330, A340, B727, B737, B747-400, B757, B767, DC-10, MD-8x, MD-11, L-1011, G-II, G-III, HSI 25-700, 212, 214, S-61, S-70B, S-76.

Now, why is this important? It was discovered that the older the Kapton™ wiring gets, the more brittle and vulnerable the insulation becomes. Cracking and embrittlement of Kapton™ wiring harness insulation is widespread and has caused short circuits in key aircraft systems. For these reasons Kapton™ wiring is being phased out of use in many new aircraft types. Unfortunately, countless aircraft are flying today with cracks in the insulation of wiring harnesses down to the metallic conductors, and are only replaced when the problem occurs as a result of this dangerous situation. The only really safe solution to the dangers posed by the use of Kapton™ is the replacement of ALL older aircraft with new ones not utilizing Kapton™ wiring.

Below is a host of information about the issues associated with Kapton™ aircraft wiring. Please contact Clare McGarrey (Vice President of InterConnect Wiring) at 1-817-377-WIRE, if you have an aircraft that contains this type of insulation.

References:

<http://www.tc.faa.gov/its/worldpac/techrpt/ar082.pdf>

https://www.mitreaasd.org/atrac/intrusive/Chapter_6.pdf

http://www.iasa.com.au/folders/Safety_Issues/Aircraft_Wire/SampsonCommentsontheFAAAdvisoryCircular.html

https://www.faa.gov/documentLibrary/media/Advisory_Circular/ac25-16.pdf

<https://www.fire.tc.faa.gov/1998Conference/presentations/BrucePike.pdf>

http://www.vision.net.au/~apaterson/aviation/Kapton_mangold.htm

http://www.vision.net.au/~apaterson/aviation/wire_types.htm

What are the Advantages of Kapton Insulated Wires?

If you have been reading the Wonderful World of Wiring newsletter over the past 18 months, you have seen that InterConnect Wiring, along with other companies (such as Lockheed Martin) and government agencies (such as the United States Navy) warn of the problems of polyimide AKA Kapton wire. When InterConnect briefs a country about their F-16 or UH-60 aircraft flying with Kapton wire, we are sometimes asked, “Why did military and commercial aircraft manufacturers use Kapton in the first place if it is so bad?” Today’s article addresses this question, “What are the advantages of Kapton insulated wire?”

Kapton insulated electrical wiring has been widely used in civil and military aircraft because it is lighter than other wires and has good insulating and temperature characteristics. This material possesses great abrasion and cut-through resistance. Weight is a very important factor to consider when dealing with miles of wire. Heavy wire, multiplied by the amount of wire, can add several hundred pounds of weight to a plane, especially if there are miles of wire required for the aircraft functionality. Additionally, the lighter the plane, the less fuel is needed to overcome the weight burden. This translates to savings on costs associated with fuel consumption. So, to be sure, there were many advantages to Kapton insulated wire when this polyimide film was created in the late 1960s.

The disadvantages of using Kapton in aircraft will be detailed in an upcoming article. Be sure to look for it. In the meantime, please do the following:

- Pull 4 hairs out of your head.
- Put those 4 strands of hair together.
- Feel the weight of those 4 strands.
- Feel the thickness of those 4 strands.
- Realize that that bundle of hair in your hand is the same size and weight as Kapton insulation!

The above steps demonstrate a true advantage of Kapton.



What Are the Disadvantages of Kapton Insulated Wires?

Today, we will present information about the Disadvantages of Kapton Insulated Wire. After years of use in many different civilian and military platforms including the F-16, UH-60, AH-1, F-15, and F-18, serious safety issues began to appear.

Once the Kapton wire was in service and started to age it was found to have very poor resistance to mechanical wear; mainly abrasion within cable harnesses due to aircraft movement and during normal maintenance. After the wire has been damaged and the brittle Kapton insulation layer is cracked, the wiring was found to be susceptible to three potential problems which appeared to be unique to polyimide (Kapton) insulated wire:

- **Hydrolysis** – a phenomenon characterized by cracking and breakdown of the insulation material through exposure to moisture; the speed of breakdown depending on both temperature and stress.
- **Wet Arc Tracking** – occurs when contaminating moisture or aircraft fluids create a short circuit between an exposed conductor and the aircraft structure or an adjacent exposed conductor at a different potential.
- **Dry Arc Tracking** – occurs in dry conditions when one or more conductors are shorted as a result of abrasion from the aircraft structure, wire to wire abrasion, and installation error or battle damage.

Either form of arc-tracking can create a very dangerous situation for any air vehicle. When arc tracking occurs it can destroy an entire wire bundle, and, since many bundles contain wiring for multiple systems, this can result in serious loss of functionality. In extreme cases entire aircraft could be lost. It was postulated by some that Swissair Flight 111 (which crashed in September 1998 killing 299 passengers and crew) was a result of an electrical fire caused by Kapton insulated wire.

Unfortunately there's no "easy fix" other than wire replacement. In many cases complete aircraft re-wiring is the best solution, especially for older airframes where the rewiring can be accomplished as part of an upgrade and Service Life Extension Program (SLEP).

Fortunately, InterConnect has the solution with one of its various wire replacement programs.



What is TKT Insulated Wire?

Today, you will learn about another wire type commonly used on commercial and military aircraft. This wire has a tape-wrapped construction consisting of one layer of fluropolymer-polyimide- fluropolymer and a second layer of polytetraflouroethylene (PTFE). This construction is commonly referred to as TKT (Teflon-KAPTON-Teflon). TKT has been installed in aircraft since the early 1990s.

It is widely used as a replacement for Kapton wire. Aged Kapton wire began experiencing many problems mainly due to abrasion and cracking beginning in the 1980s and continues to this very day. The US Navy, Air Force, Army, and Coast Guard have all had programs to remove their old wiring and replace it with TKT. InterConnect Wiring has assisted with those programs and continues to help our armed forces today as well as our NATO allies. If you have old wiring and are not sure what type it is, what the current state of the wire is, or if you would like to have it tested, send it to InterConnect Wiring at 5024 W. Vickery Blvd., Fort Worth, TX 76107 USA. We will provide you with the information you need.



What is Crosslinked Tefzel Insulated Wire and Spec 55 Wire?

Lately InterConnect's enlightening blogs have been focusing on Kapton insulated wire and TKT insulated wire. This time we will discuss a different type of wire used on F-15 and F-18 military jets as well as commercial aircraft including the Boeing B737, B747, B757, B767, B777 as well as the Airbus A320, A330, and A340.

Crosslinked Tefzel insulated wire is a Dupont™ wire also known as XL-ETFE. It has Tefzel insulation that has been subjected to heat or pressure in order to undergo a chemical change known as cross-linking. This chemical change ensures that the physical properties of the material are set. According to Dupont, if the crosslinked Tefzel insulation is subjected to heat again, the material will not melt, flow or drip.

SPEC 55 wire is insulated with modified radiation cross-linked ETFE (Ethylene tetrafluoroethylene) polymer. It uses a silver plated copper conductor and combines the easy handling of a flexible wire with excellent scrape abrasion and cut-through characteristics. It is the Raychem version of XL-ETFE.

Below is information about this wire type according to IPC's Insulation Selection Guidelines.

Crosslinked Ethylene Tetrafluoroethylene (X-ETFE / XL-ETFE) (DuPont™ Tefzel) (SPEC 55)	A modified version of ETFE used in applications requiring excellent electrical properties, and heat, flame, arc tracking, and cold flow resistance.	
	<ul style="list-style-type: none"> – Wire specifications: SAE AS22759/32, /33, /34, /35, /41, /42, /43, /44, /45, and /46. – Cable specifications: MIL-DTL-27500 types SB, SC, SD, SE, SM, SN, SP, SR, SS, and ST 	
	<u>ADVANTAGES</u> <ul style="list-style-type: none"> – Higher mechanical strength than extruded ETFE. – Resistant to cold flow and abrasion. – Resistant to radiation effects (to 5×10^7 RAD) – Good outgassing characteristics – Service temp.: -65 °C to 150 °C [-85 °F to 302 °F] 	<u>DISADVANTAGES</u> <ul style="list-style-type: none"> – Some ETFE insulations fail flammability tests in a 30% oxygen environment – Less flexible and more difficult to strip than extruded ETFE – Sensitive to degradation from ultraviolet (UV) – Some ETFE insulations (primarily white) are known to outgas fluorine (F) over time, which can cause corrosion of unprotected metals in sealed or confined environments



What Are The Options When Replacing Kapton Insulated Wire?

Lead paint is a hazard. In fact, most places in the US have regulations on how exactly lead paint is to be removed. If you live in a home with lead paint, then you live knowing a lethal time bomb sits idle on your walls. Old wiring is much the same in the aircraft world. It has been the subject of more than a few articles from InterConnect and regardless of the advantages discussed, one disadvantage is glaringly apparent. There are some wire types, when hit with an arcing current, which can catch fire possibly leading to a catastrophic failure. So, what are the options when one decides to replace aged aircraft wiring?

With the revelation of Kapton's potential explosive nature, the wire manufacturing world moved to produce wiring that could safely replace the old wire. Wire, such as TKT (Teflon/Kapton/Teflon) was introduced in the early 1990s. Other types of wire exist; however, many are variations of this TKT format. The options for replacing Kapton wiring are straightforward with the only true solution to completely replace the old wiring in your aircraft. Typically, this is done with a wiring overhaul program where the harnesses are remade with other types of wire. So what are the options available? We have experience with various rewire options and some are noted below.

When InterConnect helped the Army National Guard replace the wiring on their UH-60s, AED (Aviation Engineering Directorate) had us rewire the black hawks using cross-linked tefzel. When the Air Force contracted us to provide all of the wiring harnesses for their F-15C/D fleet, they had us use TKT. When the Coast Guard asked us to help rewire their MH-60s, we used Spec 55 wire. And currently, as we assist in rewiring AH-1 Cobras, we are using the TKT wire option.

Just as lead paint can be removed from your vintage home safely, so can old wiring from your aircraft. The safety of your aircraft and the people who fly them may depend on it.



Chapter 2

Rewire Programs: The Whole Kit and Kaboodle



Why Should Aircraft Pylon Wiring Harnesses Be Replaced?

An aircraft pylon is used to mount external equipment such as a weapon, reconnaissance pod, or external fuel tank. Figure 1 shows a pylon attached to an F-15 fighter aircraft and Figure 2 shows a close up of an F-16 Centerline Pylon.

Figure 1
Pylon on an
F-15 Aircraft



Figure 2
Centerline Pylon on
an F-16 Aircraft



In order to have electrical signals between an aircraft, the pylon, and the piece of equipment mounted to the pylon, there must be wiring. In most cases there is a lot of wiring that takes the form of a wiring harness. Most of the wiring harnesses inside an aircraft are protected by the structure of the aircraft. Therefore these wiring harnesses are not exposed to the environment. The same cannot be said of the wiring harnesses inside a pylon. Below shows what a pylon looks like when it is not attached to an aircraft.

Figure 3
Sample Pylon



In many cases the connectors and wiring of pylon wiring harnesses are exposed to the environment. Additionally, many pylons are stored outside instead of inside an aircraft's hanger. Because they are stored outside, the pylon wiring harnesses are subjected to rain, snow, ice, heat, and dust. After a lot of exposure to these environmental issues, the connectors and wiring become old and can lead to intermittent problems include arcing and possible fires. Even if pylons are stored inside a hanger when they are not being used, they are still subjected to many of the same environmental factors while they are attached to an aircraft. For this reason, pylon wiring harnesses should periodically be replaced.

InterConnect Wiring has been making F-16 pylon wiring harnesses now for 25 years. In fact, besides the wing leading edge wiring harnesses, InterConnect produces more replacement F-16 pylon wiring harnesses than any other F-16 wiring harness. F-16 pylon wiring harness part numbers are in the "900s" series. Some typical F-16 pylon wiring harnesses are H16DW901-06, H16DW905-03, H16DW910-25, H16DW912-05, and H16DW916-01. For replacement pylon wiring harnesses please contact InterConnect at sales@interconnect-wiring.com.

When Is A Total Rewire Needed?

When is a total aircraft rewire needed? Let's take a step back and ask a more common question that military users and maintainers of aged aircraft ask: "When should any aircraft rewire program be considered?" Here are 5 Main Factors to contemplate when deciding to rewire a military or commercial aircraft. They are listed in the order of importance.

THE TYPE OF INSULATION OF THE WIRE

Surprisingly, the most important factor is the type of insulation of the wire in the aircraft. A wire that undergoes hydrolysis is more likely to become aged and brittle. Unfortunately, many of the older aircraft have polyimide insulation. Polyimide insulation is commonly known as Kapton™ and can tend to experience hydrolysis more than other aircraft insulation types.

ENVIRONMENT WHERE OPERATED

The environment is the second most important aspect when considering rewiring your fighter jet, fixed wing, or helicopter. An aircraft that has primarily operated in a wet, salty, and/or humid environment is more likely to need to be rewired much sooner than one that is operated in hot dry environment.

THE AGE OF THE AIRCRAFT

The third main factor is the age of the aircraft. Age is defined as the number of years since the aircraft has left the production line. Generally speaking (and depending on the type of insulation and the environment in which it operated) rewire should be considered once it is 20 years old. After 20 years, the cost benefit analysis shows it is more beneficial to rewire a fleet of aircraft than continue to fix wire-related problems.

NUMBER OF INTERMITTENT PROBLEMS EXPERIENCED OVER THE PAST YEAR

The fourth item to consider is the number of intermittent and wire-related problems that an aircraft experiences. Some aircraft seem to have more wire related problems than others. Typically, they either have a gremlin in them or were operated in a harsher environment than the other aircraft in the fleet. It is recommended that all intermittent problems be recorded and analyzed on a yearly basis. If this analysis is done over many years, trends will be apparent and justify a complete or partial rewire of the aircraft.

THE NUMBER OF FLIGHT HOURS

Finally, the last factor is the number of flight hours. Many people think the number of flight hours is the most important factor when in fact it is not. The other four factors above have more of an effect than flight hours on deciding when to rewire. Flight hours however is a factor and should be considered. An aircraft flown more than other aircraft tend to have more intermittent and wire-related problems than other aircraft.

InterConnect Wiring has done multiple studies analyzing older aircraft wiring. Contact us for a copy of one of the original studies that InterConnect performed.

Now back to the original question... when is a TOTAL rewire needed? If your aircraft has experienced three or more of the five factors listed above, a total aircraft rewire is recommended.

What is Falcon Wire?

Many people in the F-16 community have heard of two of the largest F-16 structural update programs, (1) Falcon Up and (2) Falcon Star. These programs were designed by Lockheed Martin to extend the service life of F-16s. Back in 2005, InterConnect Wiring asked about increasing the service life for F-16 wiring. There was no such program so InterConnect created one which is now called Falcon Wire.

Prior to 2003, the primary insulation used on F-16 wiring harnesses was Kapton insulation. F-16s are now made with TKT insulation. After many years of use, Kapton insulation becomes old and brittle and can lead to wet or dry arcing. Arcing can lead to intermittent or catastrophic failures. The only solution for this potential problem is to replace the wiring harnesses with new wiring harnesses. The Falcon Wire program was designed and implemented to solve this issue.

Falcon Wire was designed to replace the 35 most troublesome wiring harnesses in the F-16. Most of these wiring harnesses are installed in the landing gear area and the mid and aft fuselage section. The Falcon Wire Program has been installed on 3 squadrons of F-16s throughout the years. It has been successful each time and has helped reduce intermittent failures and increased the reliability of the F-16.

To see a laboratory report of wiring harnesses removed from two F-16s as part of the Falcon Wire program refer to our F-16 Harnesses Laboratory Report. This report shows photos of nicks found in the wiring harnesses of an F-16 as well as the condition of the Kapton insulation. For more information about Falcon Wire please contact us.



Why Replace Leading Edge Wing Wiring Harnesses?

A common question asked of InterConnect Wiring is, “In harsh environments, which wiring harnesses inside an F-16 are affected most?” By harsh, they mean what we call the Big Six:

- (1) Very hot or very cold temperatures.
- (2) Grease and other fluids in the area as well as other contaminants such as sand and dust.
- (3) Open to the environment at certain times.
- (4) Often accessed and/or flexed.
- (5) Lots of vibration.
- (6) Has potential problems with chaffing.

The answer in the order of criticality is:

- (1) Leading Edge of the Wings
- (2) Main Landing Gear
- (3) Nose Wheel Steering
- (4) Battery Area
- (5) Engine Bay
- (6) Refueling Bay

Please note that there are other areas in an aircraft that are affected by harsh conditions, but those listed above are the worst.

Along the wing of an F-16 there are many wiring harnesses installed inside the leading edge flap. Because of the location on the F-16, the wiring harnesses are replaced more often than any other area of the F-16. For this reason, InterConnect supplies many more leading edge wing wiring harnesses than any other harnesses on the F-16.

So what makes this area so difficult for wiring harnesses? Well the answer is that they experience ALL of the harsh environments listed above. (1) They are located in the leading edge thus they are subjected to huge temperature differences. (2) They are located near rotary actuators. When rotary actuators get old they can sling grease. (3) Although the leading edge flap seals are good, they can sometimes let in environmental conditions. (4) The leading edge flaps get removed fairly often. In fact, maintenance personnel walk on the wings thus the wiring harnesses get flexed (not to mention being flexed during flight). (5) The vibration of these wiring harnesses is not as bad as other areas (such as the engine bay) but there is still a great deal of vibration. And finally, (6) the leading edge area has such a tight fit (with a large number of wiring harnesses), that there is the potential for chaffing.

As you can see, being the leading edge on an F-16 is a tough life!! So the short answer to the original question “Why Replace F-16 Leading Edge Wing Wiring Harnesses?”; because that particular location on the F-16 experiences the Big Six... temperature fluctuation, grease and grime, opened to the elements, flexed, vibration, and subject to chafing.

Remember, the Big Six are bad but InterConnect has a good solution with our Leading Edge Wing Wiring Harness and Mux Panel Replacement Program.

What is a Station 5 Large Wiring Harness and Why Replace it?

On the F-16 aircraft there are nine wing weapon stations. A wing weapon station is an attachment point for an ordnance such as a bomb, missile, or rocket. Wing stations can also carry reconnaissance pods, cameras, fuel tanks, or storage containers. Station 1 is on the tip of the left wing. Station 2, 3, and 4 are all on the left wing. Stations 6, 7, 8, and 9 are on the right wing with Station 9 being the right wing tip. Station 5 is on centerline of the fuselage. The figure below shows the wing weapon stations.



So now that we know what a wing weapon station is, what is a Station 5 wiring harness? A Station 5 wiring harness is the wiring harness inside the F-16 fuselage that directly attaches to the pylon at Station 5. For Block 40 and earlier F-16's the Station 5 is the largest wiring harness in the F-16. Typically its part number is HI6DW2602. Besides attaching to the Station 5 pylon it also stretches across the fuselage and connects to the "attach areas" of both wings.

A HI6DW2602 wiring harness is a huge, complicated wiring harness. It is also difficult to remove and replace since (a) it sits in the middle of the fuselage and (b) there is lots of equipment around it. So why is it replaced so often? The answer lies in the two connectors that go to the Station 5 pylon. The connectors get pulled so often that after a period of time they are damaged. Likewise, the wires that are terminated to these connectors are damaged too.

So there you have it; that is the reason the HI6DW2602 F-16 wiring harness is replaced so often. If you want to purchase one, please contact our sales team at InterConnect Wiring.

What is the F-16 Fuel Cell Area and Why Replace Their Wiring Harnesses?

Jet fuel is stored in five locations in an F-16 including: (1) the wings, (2) a large fuel bladder located behind the cockpit, (3) gas tanks on the wings and/or center fuselage, (4) Conformal Fuel Tanks (CFT's) and (5) the aft fuselage that surrounds the engine. The aft fuselage that surrounds the engine is also called the fuel cell area. The purpose of this blog is to: (a) describe the wiring harnesses in this area and (b) provide reasons why these wiring harnesses should periodically be inspected and possibly be replaced.

For about the first 2,000 F-16's manufactured, the wiring harnesses in the fuel cell area were made with convoluted, protective tubing. Convoluted tubing was selected because these wiring harnesses were surrounded by jet fuel. Special transitions were designed to connect the interface from one leg of the wiring harness to another leg. Likewise, special backshells were designed to connect the convoluted tubing to the backshells and ultimately the connectors. Figure 1 shows what one of these fuel cell wiring harnesses looks like. Notice the plastic-like tubing that covers the wires.

FIGURE 1



FIGURE 2



Normally, F-16 wiring harnesses have a Nomex braid that protects the wires underneath. Figure 2 shows a typical F-16 wiring harness with Nomex braid. The engineers who first designed the F-16 did not want to submerge a Nomex braided wiring harness in jet fuel; therefore, instead, they designed convoluted tubing wiring harnesses.

The convoluted tubing wiring harness was a good design, but as stated earlier, after the first ~2,000 F-16s a design change was made. Instead of convoluted tubing wiring harnesses, the F-16 engineers changed the design to injection molded wiring harnesses. Later model F-16s, including the ones currently being manufactured, are all injection molded wiring harnesses for the fuel cell area.

Now you know what a fuel cell wiring harness is. The next question is “Why Replace Them?” The answer is the same for any component on the F-16. After many years' worth of flying, all parts start to wear out and need to be replaced. The same is true for convoluted tubing wiring harnesses. Most of the aircraft that have convoluted tubing wiring harnesses are Block 15 F-16's. Most of these jets are more than 25 years old. Just think about it; the convoluted tubing wiring harnesses in the fuel cell area have been sitting in jet fuel now for over 25 years! That a long time for anything to be sitting in jet fuel!

These wiring harnesses are difficult to access so most people who work on and maintain the F-16 do not get to see them. Additionally, there are many panels (that are sealed to make sure jet fuel does not leak) that have to be removed in order to inspect these wiring harnesses. It is not uncommon for these old wiring harnesses to have breeches in the convoluted tubing and thus the Kapton insulated wire underneath is now also soaking in jet fuel for many years! The only solution is to replace these old wiring harnesses with new ones. Thus, the reason to replace the fuel cell area wiring harnesses is because of: (1) age and (2) breeches in the convoluted tubing.

Chapter 3

Refurbishment Programs: Why Buy New When You Can Refurb?



Where are F-16 Multiplex Panels and When do you Refurbish Them?

Welcome to F-16 Fighter Jet Design Class 101. In this class we will discuss: (1) the main components of an F-16, (2) what multiplex is, and (3) what is refurbishment in regards to F-16 electrical panels. Here we go!

An airplane is typically made up of four main structural components: (1) the fuselage, (2) the wings, (3) the horizontal tail, and (4) the vertical tail. The word fuselage is derived from the French word fuselé which means “spindle-shaped”. The fuselage is the largest structure in the F-16 as well as most other aircraft. It contains the crew, passengers, cargo, equipment (such as multiplex or mux panels), bulkheads, and my favorite ‘wiring’. The figure to the right (colored brown) displays the fuselage for a Boeing 737 aircraft.



The next portion of our F-16 Fighter Jet Design Class 101 is, “What is multiplex?” Multiplex is a way of sending multiple signals or streams of information over a communications system at the same time in the form of a single, complex signal. The signal is composed of either highs or lows (also called 1’s or 0’s). The F-16 uses multiplex signals in four primary systems: (1) navigation, (2) flight control, (3) communication, and (4) weapons. Multiplex signals are sent throughout the F-16 using a special type of wire called a ‘mux wire’. If there is a long length of mux wire, the multiplex signal starts to lose its strength. To fix this problem, mux transformers are used throughout the F-16 to enhance the signal strength. The mux transformers are contained in metal boxes called Mux Panels. In the F-16, Mux Panels are located in two structures: (1) the wings and (2) the fuselage. Thus, fuselage Mux Panels are boxes that contain mux transformers spread throughout the fuselage. Typically for an F-16 there are 18 fuselage Mux Panels and 6 wing Mux Panels. A typical fuselage Mux Panel is shown above. The mux transformers are located inside the metal box.

Our final topic in our F-16 Fighter Jet Design Class 101 is, “What is refurbishment in regards to F-16 electrical panels?” Refurbishment is the servicing and/or renovation of older or damaged equipment to bring it to a workable or better-looking condition. When InterConnect refurbishes F-16 fuselage Mux Panels we typically replace all mux transformers as well as wire and connectors where necessary. Besides F-16 Cockpit Panels, F-16 Mux Panels are the second most common F-16 panel that InterConnect refurbishes. In case you are wondering “Why refurbish an F-16 panel as opposed to replacing it?” the answer is simple, it is far less expensive. Refurbishing a panel is typically one-half the price of replacing it with a new one.

Why and When Should You Refurbish F-16 Cockpit Panels?

The purpose of this blog is to describe what F-16 cockpit panels are and answer the following questions: (1) “Why refurbish them?” and (2) “When should they be refurbished?” Before answering these two questions, let me explain what a cockpit panel is.

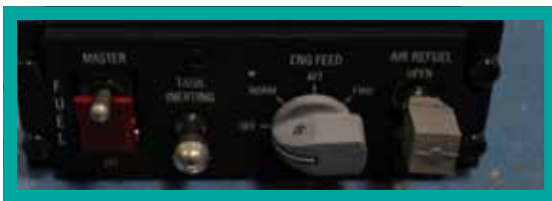
F-16 cockpit panels are electric, switch boxes located in front of and around the pilot in an F-16 cockpit. They are composed of: (1) a sheet metal box, (2) one or more switches, (3) knobs, (4) wire and connectors, and (5) an edge lit panel overlay. (InterConnect calls these “edgelights”.) Figure 1 shows some edgelights.

FIGURE 1



F-16 cockpit panels are usually about 3 inches wide, 4 inches long, and 6 inches in depth. They typically weigh less than 5 pounds. F-16 cockpit panels control many operations of the F-16 including: (1) landing gear, (2) radios, (3) interior lights, (4) exterior lights, (5) fuel control and (6) air conditioning. Figure 2 shows an F-16 cockpit panel while Figure 3 displays a typical F-16 cockpit layout.

FIGURE 2

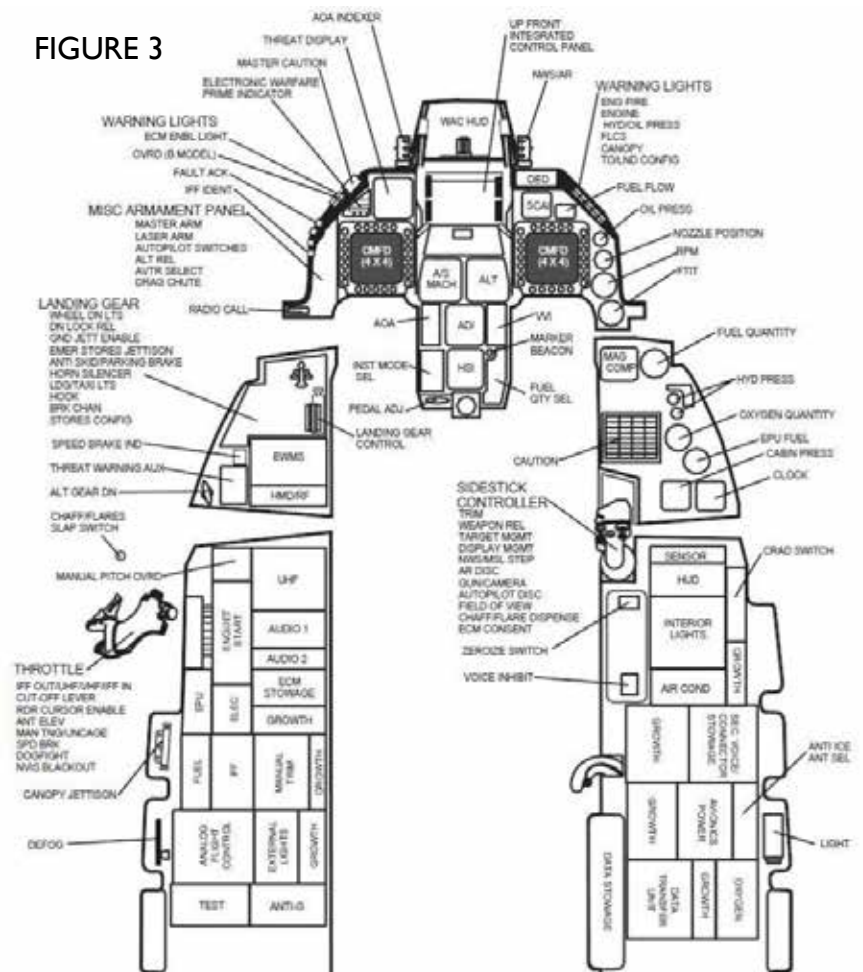


Now back to the first question at hand: “Why should F-16 cockpit panels be refurbished?” As with any piece of equipment, with age, components within the equipment become old and can cause problems. Typical issues include: (1) switches malfunctioning, (2) knobs and edge lights getting scratched causing light to bleed through them, and (3) connectors and wires needing replacement. Figure 4 shows actual old, worn cockpit panels needing refurbishment.

FIGURE 4



FIGURE 3



Why and When Should You Refurbish F-16 Cockpit Panels? (CONTINUED)

Now for the second question, “When should cockpit panels be refurbished?” To answer to this question, you don’t need to look farther than the car that you drive. When you buy a new car everything works perfectly. It all looks, feels, and smells new. Your new car is something to be proud of. Unfortunately after a few years it no longer looks or feels the same. It has “wear and tear” on many of its components especially in the interior of the car. F-16’s have this same type of problem, especially in the cockpit. After many years of flipping cockpit panel switches or turning cockpit panel knobs, they start to be worn to the point that the switches may start to fail or allow light to bleed through the knobs. Just like the interior of a five-year-old car shows signs of wear, so too, does an F-16 cockpit. Granted the material used to make an F-16 is a much higher grade than a car, but still, cockpit panels show signs of wear.

Rise of the “Glass Cockpits”



Although this was a longer blog than usual (mostly due to photos), we are offering a special, free of charge Bonus Blog. Read on to learn what a “Glass Cockpit” is.

The death of cockpit panels is rapidly approaching for almost all aircraft. Why are they dying? The answer lies in new technology. Instead of having lots of switches that will in-time fail, the new technology is to use displays made of “glass”. Switches are mechanical devices. Glass is not a mechanical device. So what does glass mean? This is an easy question to answer. When someone says a glass cockpit, think of your cell phone or your touch screen tablet. Instead of rotary or manual switches, your cell phone or tablet operates by touching the piece of glass on top of your device. You change screens, operations, or programs simply with the press of your finger.

A glass cockpit works similarly to your cell phone or tablet. A pilot changes screens as needed during flight using his finger. The glass cockpit replaces cockpit panels. So now you know what a “Glass Cockpit” is. Above is a photo of an Airbus A380 glass cockpit. As you can see, it has multiple large screens that do the same operations that cockpit panels used to do. □

If this statement is true, “The death of cockpit panels is rapidly approaching for almost all aircraft.” why should F-16 Users refurbish their F-16 cockpit panels? As far as we know, there are no current plans to modify or upgrade the F-16 Fighting Falcon to a Glass Cockpit, therefore, refurbishment or replacement with new cockpit panels may be necessary for your fleet.

Can a Wiring Harness be Repaired or Overhauled?

A common question asked of InterConnect Wiring is, “Can InterConnect repair or overhaul a wiring harnesses?” The short answer to this question is “Yes we can!” The long answer is that in many cases it is less expensive to produce a new wiring harness instead of repairing or overhauling an old one.

Typical wiring harnesses are made up of the following component parts: (1) connectors, (2) backshells, (3) wire, (4) splices, (5) terminals, (6) contacts, (7) shrink tubing, and (8) braid or string tie to hold the bundle of wires together.

The question of whether to repair or overhaul a wiring harness can be determined by answering the following six questions.

Is the wiring harness an injection molded wiring harness?

- a. Yes – Do not repair or overall. In most cases it is less expensive to purchase a new one.
- b. No – Go to question 2.

Are the connectors damaged or corroded?

- a. Yes – Damaged or corroded connectors need to be replaced. Go to question 3.
- b. No – Go to question 3.

Are the backshells damaged or corroded?

- a. Yes – Damaged or corroded backshells need to be replaced. Go to question 4.
- b. No – Go to question 4.

Are the wires damaged or need to be replaced?

- a. Yes – Damaged wires need to be replaced. Go to question 5.
- b. No – Go to question 5.

Are other component parts (such as contacts, splices, and terminals) damaged or need to be replaced?

- a. Yes – Damaged component parts need to be replaced. Go to question 6.
- b. No – Go to question 6.

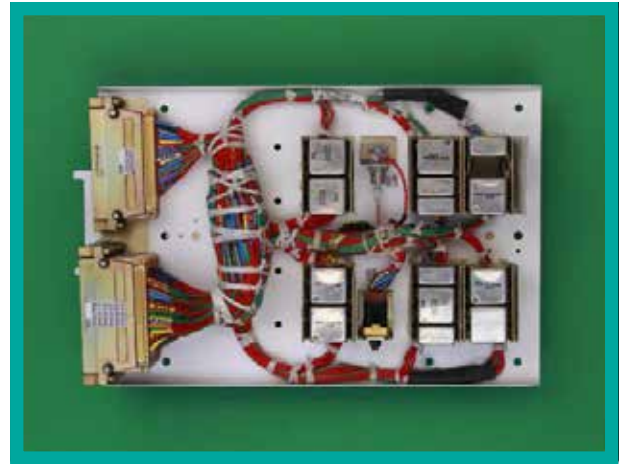
How many of Questions 2 to 5 was answered “Yes”?

- a. 1 or 2 – Repair or overhaul the wiring harness by replacing the damaged components and testing the wiring harness afterwards.
- b. 3 or 4 – Replace the wiring harness with a new one. In most cases it is less expensive to produce a new one instead of repairing or overhauling on old one. The reason is that it typically takes more time to remove damaged components and replace them with new ones instead of simply building a new wiring harness. The common term for this is BER which stand for “Beyond Economical Repair”.

As you found out, it is a fairly easy evaluation to decide to repair or overhaul a wiring harness or simply replace it.

How Often Should Relay Panels Be Refurbished or Replaced?

There are 4 main types of electrical panels in an F-16: (1) Cockpit, (2) Power or Circuit Breaker, (3) Multiplex (Mux), and (4) Relay. InterConnect refurbishes each of these types of electrical panels. We have been doing this now for over 25 years. Almost every day an F-16 electrical panel arrives for repair or refurbishment. InterConnect receives F-16 electrical panels from all over the world. Currently there are 25 countries who fly the F-16. Each one of these countries has one thing in common: "At some point they will all need to get their F-16 electrical panels refurbished". Of electrical panels, the most complex one is the relay panel. The figure shows a typical F-16 relay panel.



The reason F-16 relay panels are so complex is that they have so many electrical circuits inside them. A relay panel is made up of: (1) relays (of course), (2) wire, (3) tons of splices, (4) sheet metal, and (5) connectors. A typical F-16 relay panel may have 10 to 20 relays as well as over 50 splices. When energized, each relay opens many new electrical circuits.

Besides the fact that F-16 relay panels are difficult to manufacture, they are also the most complex to test. A test programmer must determine each the possible circuits in a relay panel. In some cases, there are over 70 circuits. Thus, the test program must conduct 70 separate continuity tests. Wow, that's a lot of tests!

So back to the main point of this blog "How often should an F-16 user get their relay panels refurbished?" InterConnect recommends that F-16 relay panels should be refurbished at least every 25 years. After 25 years, relays, wires, and connectors tend to get old and start to show signs of problems, such as relays sticking. InterConnect's F-16 Relay Refurbishment Program fixes any problems inside a relay panel. During our Refurbishment Program, we replace each relay, all wiring, connectors, and splices. Typically, the sheet metal enclosure is in acceptable condition so that major cost driver need not be included in our refurbishment price.

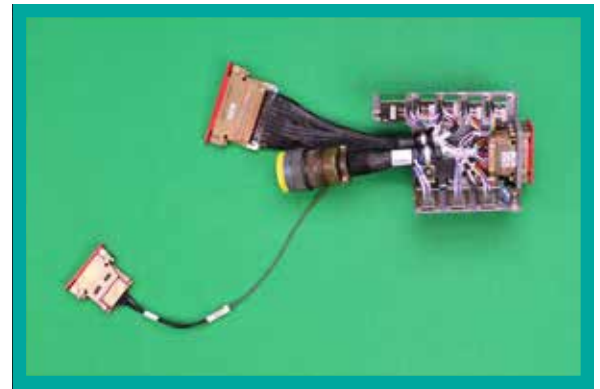
InterConnect is happy to provide price estimates to refurbish your F-16 relay panels. One of our approved F-16 distributors can quickly provide you a quote. InterConnect's refurbishment programs will make your F-16 Fleet mission ready!

How do you Refurbish Leading Edge Wing Multiplex Panels?

InterConnect Wiring is in the F-16 refurbishment business. We refurbish many F-16 electrical products including: (1) Cockpit Panels, (2) Circuit Breaker or Power Panels, (3) Relay Panels, (4) Fuselage Multiplex (Mux) Panels, and (5) Wing Mux Panels.

The most common type of F-16 mux panels that InterConnect refurbish are the ones found in the leading edge of the wing. In each F-16 wing there are three small but important mux panels. Like the wiring harnesses found in the leading-edge wing area, the wing mux panels are located in a difficult environment. In fact, the environment is so harsh that InterConnect routinely makes spare wing mux panels for F-16 Air Forces all over the world.

The basic components of a wing mux panel are: (1) sheet metal which serves as the enclosure, (2) mux transformers, (3) connectors, (4) wires, and (5) splices. See the two figures below for sample mux panels. Although InterConnect is happy to make spare mux panels, it is less expensive to refurbish them instead of making new ones. The main cost drivers for wing mux panels are the mux transformers and the sheet metal. InterConnect has found, over our 25-year history, that there have been only a few times that the mux panel needed new sheet metal. Thus, when InterConnect refurbishes wing mux panels the main costs are the mux transformers instead of the expensive sheet metal.



Refurbishing F-16 wing mux panels is a fairly simple process. InterConnect's process is: (1) remove and discard the old mux transformers, connectors, wire, and splices, (2) install the new component parts, and (3) electrically test the refurbished mux panel.

Some good news for F-16 customers throughout the world is that InterConnect refurbishes so many F-16 mux panels that we now stock all mux panel component parts. Our lead time to refurbish an F-16 mux panel used to be over 26 weeks. We are happy to announce that we can refurbish any F-16 mux panel in less than 4 weeks! That's right, less than 4 weeks!! One of InterConnect's Core Values is a "Can Do Attitude". Refurbishment of F-16 mux panels in less than 4 weeks is a good example of InterConnect living up to our "Can Do" Core Value.

Where are Circuit Breaker Panels and Why Refurbish Them?

The purpose of this blog is to explain where circuit breaker panels are located inside of an aircraft and why you may want to refurbish them.

If this blog was written by the president of InterConnect Wiring, John Ashour, he would say that the circuit breaker panels inside an F-16 are in Station 5, Station X, Station Blah, etc., but for me, I am not that smart! I am a very visual person who didn't write the Lockheed Martin specification 16PR8817, like John did, so find below a basic picture of where the circuit breakers are located inside of this fighter jet.



Now that you know where circuit breaker panels are located, let's answer this question, "Why would one want to refurbish their aircraft circuit breaker panels?" When a company or country decides to rewire their aircraft, the circuit breaker panel wiring is often forgotten. At InterConnect we remind the customer that the wiring inside of the circuit breaker box is just as old as the trunk wiring harnesses; therefore, they need to be rewired as well. This is especially the case when there is old Kapton wiring inside of the circuit breaker panels. So why rewire these circuit breaker panels? This is a very simple answer; it's less expensive than replacing them altogether and faster.

In the past InterConnect has rewired UH-60 Black Hawk circuit breaker panels for the US Army National Guard, F-15 circuit breaker panels for the USAF, and F-16 circuit breaker panels for various countries that fly the F-16. When we rewire the panels, we do the following:

- Remove the old wiring from the sheet metal box.
- Remove the circuit breakers and inspect them to see if they can be reused.
- Clean, touch up and repaint the sheet metal box to look like new.
- Repopulate the circuit breaker panel with new wiring and components.

Again, the decision to refurbish a circuit breaker panel will save not only money (the cost to purchase a brand-new panel is much higher than refurb) but saves a significant amount of time. The sheet metal box has a long lead time so if you can reuse the old one, and make it "like new", the delivery time is reduced significantly.

If you have the need, consider InterConnect for refurbishing your aircraft circuit breaker panels.



John Ashour

**President and Founder
of InterConnect Wiring**

