ABB CONTACT

Parts and Service News For the Power Transformer and Circuit Breaker Maintenance Community

March 1998 Special No. 1

"The Clock is Ticking"

Up-to-the-Minute News About Type "U" Transformer Bushings

Type "U" Bushings... So What's the Concern About?

Let's start at the beginning.

General Electric, a major player in the electrical world since the early 1900s, has been engaged in the development and manufacture of apparatus bushings as early as 1920. In the quest to develop the best bushing in the world, GE created many different types and styles of bushings such as Types A, F, L, LC, OF, T and U for both transformer and circuit breaker applications.

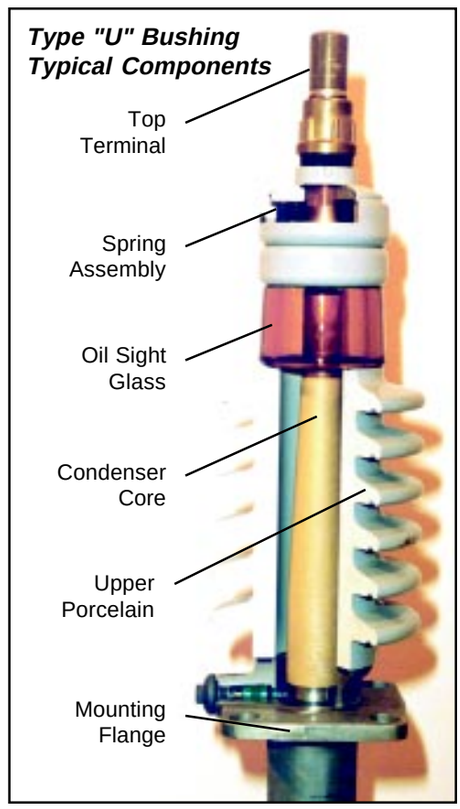
Let's concentrate on the Type U bushing history and technology first. Type U bushings were manufactured with voltage ratings from 15 kV through 800 kV. A Type U bushing is a condenser design with oil impregnated paper inside an oil filled shell. The shell consists of a cap, an upper porcelain weather casing, a metal mounting flange, a lower porcelain and a lower porcelain support. For sealing purposes, all parts are held together under a centrally clamped spring tension method. The principal behind a condenser bushing is to incorporate equal capacitance layers to provide equal voltage steps, resulting in a uniform voltage gradient throughout the bushing body and over the bushing surface.

The type of design and the materials within a condenser core may differ between manufacturers, but the design intention is the same. The type of construction used in some Type U designs was a herringbone pattern surface printed ink that formed the capacitive layers. A plain kraft paper was wound into the condenser between the active ink lined paper layers. For most of the production, both the lined paper and the plain paper were .008 inches in thickness. (**See figure 1**)

In 1979, American Electric Power Service Corporation reported increasing power factors in Type U bushings at the Doble Client Conference. *Since 1979 the concern for the Type U bushing rising power factor has increased dramatically due to documented accounts of bushing failures.*

Do you have Type U bushings on your system?

Most likely you do. From 1954 to 1986, the time period that GE was manufacturing Type U bushings, GE was the leader with 65 to 70 percent of the U.S. market. They were supplying bushings to their own transformer manufacturing facilities and to other transformer manufacturers as well as supplying replacement bushings directly to end users.



In this time frame the Type U bushing was known as the best product on the market, utilizing standardization of parts with a proven field record.

Now, are you a little more certain you have Type U bushings on your system?

So, what is the cause or causes related to the increase in power factor in Type U bushings?

Through Doble Client Conferences, utility feedback, Insurance Company reports, General Electric documents and our own investigations; ABB has accumulated data and we have the following concern for Type U bushings:

The condenser design with ink lined paper with plain kraft paper allowed a gap at the ends of the active layers in the condenser core. A heavily loaded transformer will generate heat internal to the bushing, subject the bushing to a higher immersion-oil temperature, and consequently increase internal temperature in the bushing. The heated bushing oil expands and intensifies the pressure in the confined gas space which causes an increased quantity of gas to become dissolved in the oil. Cyclic reduction

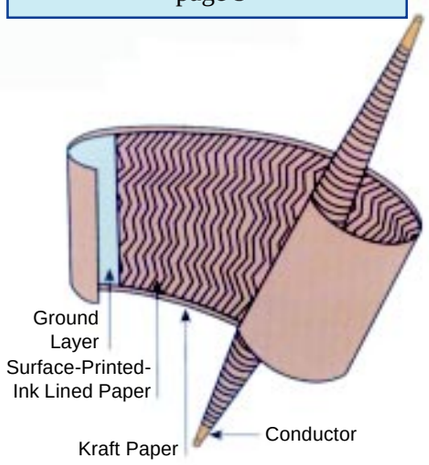


Figure 1 *- Surface-printed-ink condenser.*

in transformer load and/or reduction of ambient temperature allows cooling of the bushing oil. As the oil cools, it contracts, reducing the pressure of its gas blanket. If the pressure reduction occurs rapidly enough, the gas saturated oil will develop a tendency to evolve bubbles of gas. This evolution will first occur in the highest electrical stress regions of the bushings, normally between the lined paper and the plain paper layers of the bushing core. A critical combination of gas bubbles and dielectric stress causes partial discharges to occur within the insulation system.

The long term effect of the discharges is an increase in the dielectric-losses in the insulation system, resulting in an increased power factor.

Have you heard of migrating ink?

This is a process that could also be a contributing factor to Type U bushing rising power factors. Although GE designed and specified the herringbone ink process, they did not manufacture the paper, nor did they apply the Rescon conductive ink. The paper/ink process was completed by outside contractors. Reports as early as 1979 show that portions of the Rescon ink "herringbone pattern" had transferred from the printed-paper layers to the plain kraft paper layers. Investigations have revealed where Rescon-printed paper made contact with the overlapping plain paper, evidence of corona action or evidence of slight burning was found. (**See figure 1A**)

Ink/particulates aggravated GE's manufacturing system. During the cutting of lined and plain Kraft paper while winding the condensers, ink/paper particulates were generated, further complicating the rising power factor phenomenon. By 1985 GE had made many internal quality improvements to the design and processing of bushings. GE implemented an oil flushing procedure for all bushings in order to reduce the particles that may have originated with the bushing core insulation. Also, GE commissioned a new closed-loop continuous filtration oil system intended to improve bushing oil quality.

What kv ratings of Type U bushings used herringbone ink processing?

15 kV through 345 kV. Some Type U bushings have metal foil designed condensers. Most bushings 345 kV and above have foil designed condensers, but many have herringbone lined paper.

Should you be concerned <u>only</u> with Type U condenser bushings rated 15 kV through 345 kV?

No! Type U bushings were manufactured using a flex seal design. The flex seal is a copper diaphragm located in the top cap of bushings 161 kV and above. The flex seal (**see figure 2A**) was designed to allow for the expansion/contraction or movement of parts during thermal cycling of the bushing.

The flex seal diaphragm in many cases, depending on catalog number and application, carries the current from the main conductor to the cap cover to the upper terminal connection. As the diaphragm experienced movement, acting as an accordion, the diaphragm could experience mechanical stresses which would crack and result in a leak. Since the diaphragm is internal to the bushing, and is placed above normal oil level, where could the bushing leak?

During processing of the oil in the transformer, the oil could be evacuated from the bushing by vacuum if the bushing was inclined, or the bushing could become filled with oil during the transformer vacuum/fill process. If the bushing is full of oil (with no expansion space) and if the bushing is applied at higher temperatures, the oil will expand and compromise the gasketing system.

The flex seal system is connected to the main conductor with a swell seal gasket and a seal nut. This connection is also under oil and under spring tension of the bushing. The upper connection at the cover relies totally on the cover bolt tightness to adequately carry the current from the flex seal through the cover to the customer terminal connection. If the cover bolts have become loose over time, hot spots will develop which will compromise the cover gaskets. This situation is best revealed in the field by utilizing thermal scans with infrared apparatus.

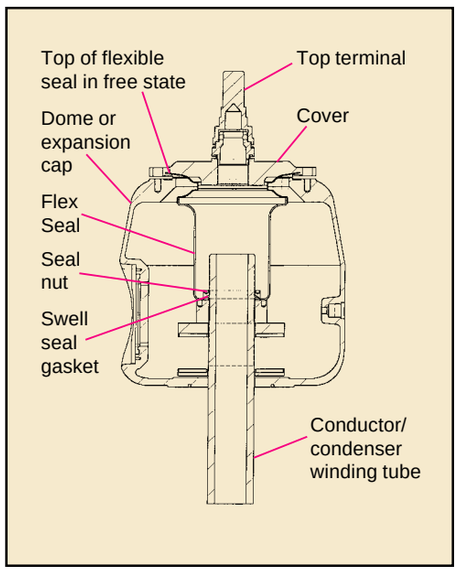


Figure 2A - *Flex seal design.*

Hot spots such as this can lead to catastrophic failure if not resolved immediately. GE recognized that the flex seal design could be improved upon, so they introduced the slip seal design in 1976 (s**ee figure 3A**). The slip seal design totally eliminates the flex seal and still allows the bushing to expand/contract during thermal cycling.

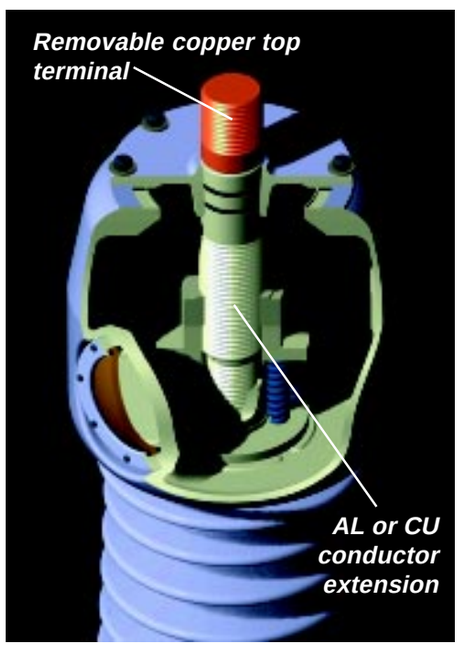
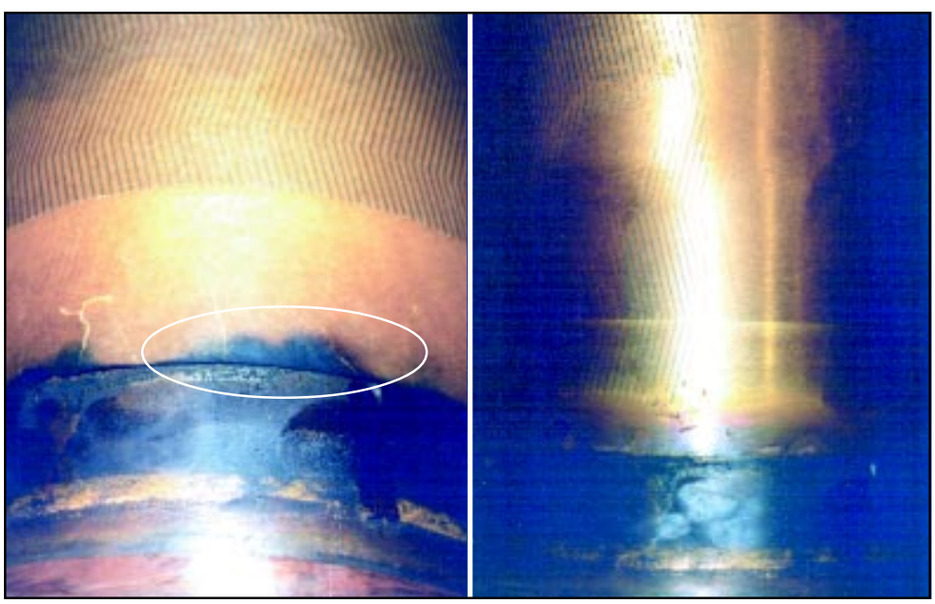


Figure 3A *- Slip seal design.*

Figure 1A - *Rescon conductive ink transfers from the printed paper layers (left) to the plain kraft paper layers or conductor (right) resulting in corona action and slight burning (circled).*



What about top terminal overheating issues?

Many Type U bushings were designed and manufactured to have the ability to change top terminals in the field. For instance, if a customer damaged the external threading of a top terminal, they could replace the top terminal without removing the bushing from the transformer. Also, draw lead bushings have a removable top terminal to allow disconnection from the transformer winding lead without requiring entry to or removal of oil from the transformer.

Type U bushings, if designed to have removable top terminals, require routine maintenance to ensure top terminal tightness. If the top terminal becomes loose, a hot spot may occur. Overheating of the top terminal may deteriorate the bushing's gasketing system, which could compromise the integrity of the insulating system resulting in failure. Slip seal bushings, 161 kV and above rated 1600 ampere and above, are perfect candidates for top terminal overheating if adequate maintenance is not performed.

How do you know if your Type U bushings have herringbone ink condensers or foil condensers, flex seal systems, slip seal designs or removable top terminals?

Contact ABB! ABB Alamo has the documentation for all GE bushings. We have all of the original design, test and manufacturing data for Type U bushings. If you have the *catalog number and the group number* from the nameplate of your bushings, ABB can help identify the type of bushing design to evaluate your critical needs, such as bushing maintenance, repair, refurbishment, or replacement.

Can a Type U bushing be refurbished?

Yes! Depending on the age, voltage class, current rating, design, and the condition of the existing bushing. Certain Type U bushings are excellent candidates for refurbishment. If the bushing external parts are in good condition and the concern centers on the herringbone ink condenser or flex seal system, it is very economical to refurbish Type U bushings rated 115 kV and above, or bushings below 69 kV that have a high current rating (such as 4000 amp and above).

The key to refurbishing Type U bushings is access to the original design documents and having trained, experienced people. All bushings refurbished by ABB will be updated with the latest ABB design enhancements, and will carry a new nameplate and warranty.

Were Type U bushings manufactured and supplied to the field with oil contaminated with PCB?

Yes! We cannot determine the content of PCB in a bushing by the serial number, catalog number nor the group number off of the nameplate. The only way to determine the PCB level is to have the oil tested. We can give some guidelines. Bushings manufactured by GE Pittsfield from 1954 to 1973 can have PCB levels that range from 50 to 500 ppm. From 1973 to 1980 we have test reports reporting levels from 2 to 50 ppm PCB. From 1981 to 1986 the levels are normally non-detectable or less than 1 ppm PCB.

What criteria should be used to evaluate bushings on your system?

If you have bushings with herringbone lined ink paper condensers:

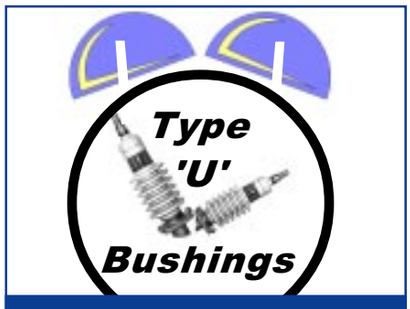
GE's recommendations-"Criteria for Concern" for Type U bushings in 1979 were:

- If the capacitance has increased by 10% or more, remove the bushing from service.
- If the P.F. is below 1.5%, there is no cause for concern.
- If the P.F. exceeds 1.5%, but is less than 3%, the bushing is in the region for concern
- If the capacitance change is below 5%, there is little risk of failure
- If the P.F. exceeds 3%, remove the bushing from service.

In 1985, ***Doble Company*** published recommended limits for Type U bushings.

- Power Factor of 1.0% questionable rather than 1.5% questionable

Today ***ABB***, has approximately a 65% market share of new bushings sold into the U.S. and is the leading supplier of replacement bushings for Type U bushings to the Utility and Industrials in the United States. ABB has the following recommendations:



"The Clock is Ticking"

ABB Updates the Criteria for Concern for Type U Bushings

If the bushing power factor doubles original nameplate value the bushing is questionable and should be replaced or refurbished.

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If the capacitance increases to 110% of the original installation value the bushing is questionable and should be replaced or refurbished.

How can ABB make these recommendations and on what basis can these statements be made?

Being the sounding board for 170 major utilities and many industrials across the U.S. we have seen the electrical industry increase awareness of Type U bushings due to high power factors and failures of Type U bushings.

At the same time, we have noticed maintenance periods have been extended beyond recommended levels. In today's competitive marketplace, companies have downsized maintenance programs and extended periodic maintenance from 1 year intervals up to 3 years and as high as 5 years or more.

Through field surveys and field experience we have noted that if a Type U bushing is exhibiting a rise in power factor, the rise accelerates very quickly once the action has started. Therefore, many utilities know that if they are on a 3 or 4 year maintenance interval and a bushing exhibits rising power factor, the bushing will not perform for the next 3 or 4 year period without failure.

The normal practice is to remove the bushings from the transformer immediately. Once the corona (partial discharge) activity has started, the remaining service life of the bushing can be very short and it could fail catastrophically.

Recommendation-If possible, measure power factor and capacitance on a yearly basis. If power factor is on the rise, replace or refurbish bushings.

If you have flex seal design bushings, thermal scan the units for hot spots, check for low or high oil levels, and complete power factor and capacitance testing on a yearly basis. If bushings exhibit any of the above mentioned scenarios, the bushing should be replaced or refurbished.

If you have bushings with removable top terminals, proper maintenance must be applied on a yearly basis either by thermal scan or manual inspection methods. For manual inspection of top terminals, check to see if terminal can be loosened first. If the terminal cannot be removed the terminal may have seen overheating and/or corrosion build up and should be removed from service.

If the terminal can be removed, inspect the top terminal gasket and look to see if there are signs of corrosion. If the terminal gasket appears to be brittle or have a permanent set, replace the gasket. When replacing the gasket, be sure to lubricate the gasket with petroleum jelly to prevent twisting of the gasket as the terminal is tightened. Tighten the top terminal to the correct torque values with the proper tools or fixtures.

Top Terminal Size	**Torque**
Inch - Threads	**ft-lb (N-m)**
1.125 - 12	**35 (48)**
1.500 - 12	**100 (136)**

If bushing top terminals show signs of corrosion or the top terminal cannot be removed we recommend replacement or refurbishment of the bushing. Top terminal overheating can compromise the bushing gasketing system or create loss of life of the bushing insulating system. This could result in a catastrophic failure if the proper action is not taken.

Bottom connected bushings 161 kV and above rated 1600 amp and above can be refurbished to the new ABB Unified top terminal design per **figure 4A**. The ABB Unified top terminal design eliminates top terminal maintenance and overheating, corrosion or deteriorating gasketing systems.

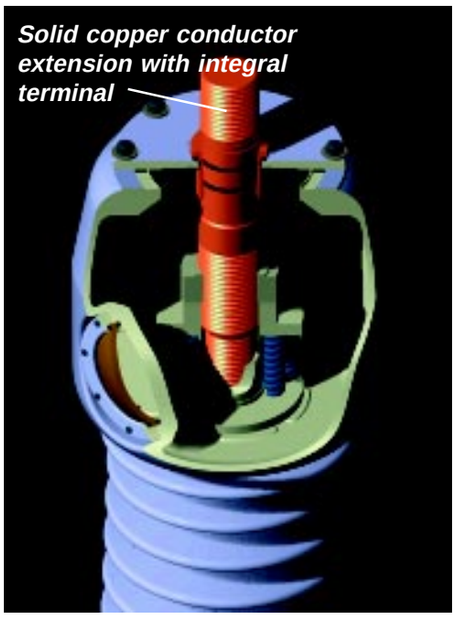


Figure 4A - *Unified top terminal.*

Who can rebuild or refurbish Type U bushings to be as new?

Some major utilities have tried to rebuild their own bushings, a few small business service shops have tried and other bushing manufacturers have tried to rebuild Type U bushings. Most rebuilds by people other than ABB rely on guess work or reverse engineering to determine the makeup and design of the original bushing.

GE went through many design changes through the years. GE designed and manufactured over 5000 different catalog or styles of bushings, and within each catalog or style there are an average of 7 design and manufacturing changes. That means there are over 35,000 different Type U bushing designs in the field today.

The key to rebuilding Type U bushings is to have all the documentation such as the drawings, design changes, manufacturing processes, and test data. ABB has this design and original manufacturing information, and design engineers and technicians experienced with GE technology.

ABB will not rebuild bushings without the original design information. If applicable or economical for the customer, ABB rebuilds Type U bushings to the latest technology.

Can ABB Alamo, Tennessee manufacturing facility accept bushings contaminated with PCB to be refurbished?

No, but read on! Bushings must be tested and a certificate (with results stating less than 1 ppm) must be presented to ABB prior to shipment of bushings to be accepted in the Alamo facility. ABB manufactures over 17,000 bushings per year in Alamo, Tennessee, which is more than any other manufacturer in the world. The Alamo plant is PCB free and we take all precautions to keep PCBs from entering into our system.

Then how can bushings with PCB contamination be refurbished by ABB Alamo?

A good question deserves a good answer. ABB Alamo has just announced the opening of their new decontamination facility in the ABB St. Louis Transformer Manufacturing Facility. Starting January 1st, 1998, ABB can decontaminate bushings up to 50 ppm and rebuild bushings to be “as new” condition at competitive price levels. This translates to good lead times and a quality product for a price considerably less than the price of a new bushing.

Are there other reasons why a customer should refurbish bushings?

Depending on state and government regulations, the economical benefit in refurbishment can vary. If a customer buys new product, what happens to the old product? Most likely, the customer must scrap or dispose of porcelain materials, metals materials, bushing oil and deal with the PCB issues. Sometimes the disposal fees are very expensive. Do you know the regulations and laws of disposal in your state? They are changing daily. Be careful. Refurbish bushings!!!!! An economic and viable solution to your problems.

ABB announces January 1, 1998 the opening of a bushing decontamination facility in St. Louis, Mo.

Type "U" Bushing Guidelines

Bushing kV	Current Rating	Herringbone Ink Condenser	Foil Condenser Design	Removable Top Terminal	Flex Seal Design	Slip Seal Design	50-500 ppm PCB Content	2-50 ppm PCB Content	< 1 ppm PCB Content	Economical to Refurbish
15 kv - 69 kV	400	yes		yes			1954-1973	1973-1980	1981-1986	
	400/1200	yes		yes			1954-1973	1973-1980	1981-1986	
	2000 to 3500	yes					1954-1973	1973-1980	1981-1986	
	4000 & Above	yes					1954-1973	1973-1980	1981-1996	
115 kv - 138 kV	800	yes		yes			1954-1973	1973-1980	1981-1986	yes
	800/1200	yes		yes			1954-1973	1973-1980	1981-1986	yes
	1600 & Above	yes					1954-1973	1973-1980	1981-1986	yes
161 kv - 230 kV	800	yes		yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	800/1200	yes		yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	1600 & Above	yes		yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
345 kV	800	See Note 1	See Note 1	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	800/1200	See Note 1	See Note 1	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	1600 & Above	See Note 1	See Note 1	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
550 kV	800		yes	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	800/1200		yes	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	1600 & Above		yes	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
800 kV	800		yes	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	800/1200		yes	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes
	1600 & Above		yes	yes	See Note 2	See Note 3	1954-1973	1973-1980	1981-1986	yes

Note 1: To verify herringbone ink or foil design condensers the bushing catalog # and group # from the bushing nameplate must be supplied.

Note 2: To verify if bushing utilizes flex seal design the bushing catalog # and group # from the bushing nameplate must be supplied

Note 3: To verify if bushing utilizes slip seal design the bushing catalog # and group # from the bushing nameplate must be supplied

ABB's St. Louis facility can decontaminate bushings up to 50 ppm allowing ABB to rebuild these bushings to "as new" condition at competitive prices with fast turnaround.

Type "T" Bushings

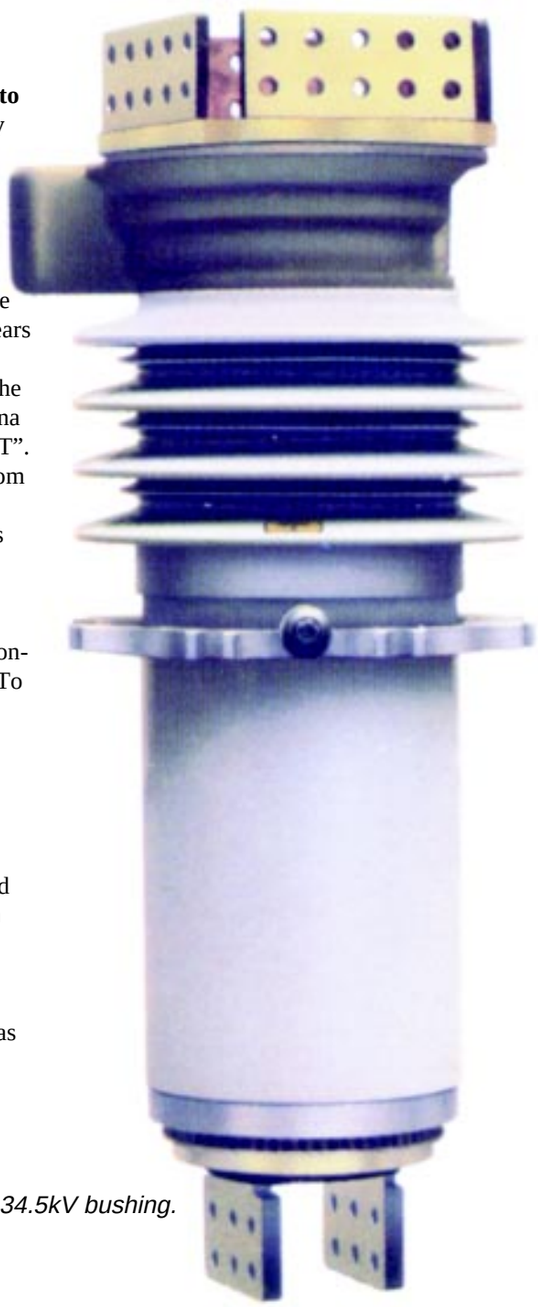
Is the Type "T" Bushing a predecessor to the Type "U" bushing manufactured by General Electric? No!

Type "T" bushings were designed and manufactured by General Electric for low voltage, high current, low corona, transformer applications. GE supplied low voltage, high current stud type or bulk type bushings (Type "A" bushings) for many years and then the market demanded a bushing with low corona values. GE's answer to the market demand was the ultimate low corona condenser bushing technology, the Type "T".

GE manufactured Type "T" bushings from 1971 to 1985. Type "T" bushings range from 25 kV to 34.5 kV and current ratings 600 ampere draw lead to 18,000 ampere bottom connected. These bushings were designed for low voltage application; therefore, GE designed bushings for horizontal applications and vertical applications. To achieve maximum low corona values, not obtainable by bulk type bushings, GE incorporated a condenser into the design.

Why is there a concern with Type "T" bushings?

Type "T" bushings are basically designed and manufactured in the same manner as a Type "U" bushing. Outside shell and mechanical parts are very similar. ***What about the condenser core process?*** The condenser design and process is the same as the Type "U" using herringbone ink lined printed paper.



Type "T" 25kV through 34.5kV bushing.

Should you be concerned about <u>all</u> Type "T" bushings?

No. Some Type "T" bushings are designed for high temperature (125 degree C) applications. Units designed for high temperature applications used Nomex winding paper with foil inserts for gradients. The ink process could not be applied to the Nomex winding paper.

Is the concern for Type "T" bushings as valid as the concern for Type "U" bushings even though they are a low voltage bushing?

Yes! Even more so. The normal application of these bushings is on the low voltage side of a transformer with higher current ratings, higher temperatures and sometimes being applied in bus duct. When these bushings are subjected to thermal cycling, gas bubbles trapped in high stress areas of the lined ink printed paper condenser can create partial discharge leading to a high power factor or failure of the bushing.

How do you know if you have herringbone ink lined paper or foil gradients in your Type "T" bushings?

Contact ABB. If you know the General Electric *<u>catalog number and the group number</u>* from the nameplate of the bushing, ABB can research the General Electric drawings in our archives and verify the type of design. If you wish to discuss application, such as high temperature, ABB can also verify if the units are suitable for 105 degree C or 125 degree C application. Many transformer manufacturers, utilities and contractors tend to mis-apply bushings in high temperature applications assuming that higher current rated bushings can be applied at higher temperature ratings. Overload conditions described in **IEEE Standard C57.19.100 section 4** are normally abused more with Type "T" and Bulk Type bushings than other types of bushings.

The updated ABB ***"Criteria for Concern"*** (power factor and capacitance values) and recommended maintenance applies to Type "T" bushings as well as Type "U" bushings.

Can you buy new bushings to replace Type "T" bushings or can Type "T" bushings be refurbished?

Yes & Yes! ABB offers direct replacement bushings for Type "T" bushings. ABB manufactures Type "T" bushings today with the same dimensional and electrical characteristics as the General Electric bushing for ease of installation, proper fit and application, but ABB has incorporated into today's Type "T" the advanced technology and superior condenser design of the ABB Type O Plus C bushing.

Although Type "T" bushings are low voltage, they are typically high current and the economics of refurbishment is well worth the effort. Normally, a refurbished bushing is approximately 65% of the cost of a new bushing. Please be aware that GE went through many gasketing system design changes in the early stages of the Type "T" design. ABB utilizes the original GE design data and drawings to update bushings to the best design and latest technology when refurbishing bushings to "as new" condition.

The Good, The Bad and The Ugly of Type "U" Bushings.

The problem of increasing power factor in Type "U" bushings has been well documented over the years. In this special issue of *Contact* we explore the latest findings about these controversial bushings and recommended methods for continued operation.

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