Longevity of Key Components in Uninterruptible Power Systems

A White Paper by Liebert

SUMMARY
Liebert has a huge installed base of 3-phase UPS systems rated 65 kVA and above. Approximately 2,500 of the Series 600 UPS systems have been shipped from 1989 to the present. Approximately 3,000 Emerson Series 500 UPS systems were built from 1979 to 1989. This paper describes the useful life and replacement schedule of key components to enable these systems to achieve their full rated design life.

The rated design life of our UPS products is 20 years. In response to customer inquiries, we have studied the components used in these products to see which should be replaced according to a predetermined schedule. The following paragraphs explain our findings.

Magnetics: Transformers, Inductors, DC Chokes
The design value of most magnetic components is 20 years of operation. Key factors here are the insulation used in the winding process and the temperature rise while in service. Our magnetics use Class H insulation rated at 220°C, and are never operated at higher than 150°C.

Some commutation inductors may exhibit deterioration after ten to fifteen years of service due to load variations and the constant cycling of the current through the inductor. Before it fails, the inductor starts to vibrate and becomes very noisy. This condition will be obvious during preventive maintenance, and the Customer Engineer can schedule a return visit to replace the inductor. Experience has shown that with proper preventive maintenance, no definitive replacement interval is needed to preclude inadvertent UPS shutdown.

Power Semiconductors
The power semiconductors used in the Series 500 and Series 600 UPS do not have a rated end of life in the normal mode of operation of the UPS. The only way to tell if a power semiconductor is about to fail is to test leakage current. If it is above the maximum rated value for the device being tested, then the device should be changed. During the annual preventive maintenance cycle, the devices should also be inspected for corrosion and for damage to the hermetic seal. If corrosion or seal damage is found, the device should be replaced. Otherwise, we would *not* recommend changing the power semiconductors in the large UPS.

Electrolytic DC Capacitors
The expected life of electrolytic capacitors can be calculated as a function of manufacturer's rating and the expected operating temperature of the device. For particulars, see Appendix A: Design Life Calculations for Electrolytic Capacitors. Based on these calculations, the average service life is eight years for capacitors manufactured and purchased before 1988. Due to improvements in the capacitors manufactured and purchased after 1988, the rated service life was extended to fifteen 15 years. These service life ratings assume an average room ambient temperature of 30°C (86°F).

The table below shows expected life at various different ambient temperatures. The Appendix shows how we calculated these numbers, using the later capacitors and 30°C room ambient as sample values.

		Pre-1988 Caps		**Post-1988 Caps**	
DC Bus	**Ambient**	**Expected Life**		**Expected Life**	
Voltage	**Temp °C**	**Hours**	**Years**	**Hours**	**Years**
405	20	139,675	15.9	279,351	31.9
405	25	98,765	11.3	197,531	22.5
405	30	69,838	8.0	139,675	15.9

405	35	49,383	5.6	98,765	11.3
405	40	34,919	4.0	69,838	8.0
540	20	146,659	16.7	293,318	33.5
540	25	103,704	11.8	207,407	23.7
540	30	73,330	8.4	146,659	16.7
540	35	51,852	5.9	103,703	11.8
540	40	36,665	4.2	73,329	8.4

Oil-Filled Ac Capacitors
The oil-filled capacitors have an operating life of ten (10) years. They should be changed at that time due to the internal breakdown of the soggy foils and possible loss of capacitance. We recommend that all oil-filled capacitors be inspected and those within six (6) months of their service life can be changed out during the annual preventive maintenance (PM) cycle. The oil-filled capacitors should also be inspected during the annual PM for deformation, which indicates that the capacitor needs replacing. Changing the AC oil-filled capacitors based on service life is generally not part of most maintenance contracts, but can be included.

Circuit Boards
There is no rated service life on the components specified for use on the circuit boards. Circuit boards with problems are removed and returned to the manufacturing plant for repair and test. Before they are returned, they will have all outstanding revisions incorporated, and will then be system tested. If a circuit board returns a second time for the same problem, it is scrapped. All calibrations are verified during annual PM to ensure that the circuit boards don’t exhibit any signs of failure. If any weakness is seen during the PM, the circuit board will be replaced.

The most serious limitation to circuit board longevity is availability of replacement components for some boards. Certain parts are no longer available from their manufacturers. Liebert has safety stock on some key components, but it’s difficult to foresee all contingencies. Please note that this parts-availability issue affects all vendors of both static and rotary UPS products.

Summary
With proper maintenance, the Series 500 and Series 600 UPS products should meet or exceed their service-life goals of 20 years.

Appendix A: Design Life Calculations for Electrolytic Capacitors
The expected life of these capacitors has been confirmed to follow Aprhenius’ equation -- a formula describing chemical reactions due to dielectric molecules activated by thermal energy. We can calculate L, expected device life in hours, according to the following:

$L = L_{BASE} \times 2\text{^}((T_{BASE} - T_{CORE})/10) \times \text{Voltage Multiplier}$

Where:

L_{BASE} = 5,000 hours at 85°C core temperature and rated voltage

T_{BASE} = 85°C

T_{AMB} = 30°C

$T_{CORE} = T_{AMB} + T_{RISE}$ = 30°C + 10°C = 40°C

V_R = Rated Voltage

V_A = Actual Voltage

Voltage Multiplier = $(2.50 - 1.5)\ V_R/V_A$

= 700/540 = 1.2963 for 540 volts DC bus

= 500/405 = 1.23 for 405 volts DC bus

Solving this we get:

L = 5,000 x 2^((85-40)/10) x 1.2963

= 5,000 x $2^{4.5}$ x 1.2963

= **146,659 hours** (about 16.7 years) for a 540 volts DC bus

$L = 5{,}000 \times 2^{((85-40)/10)} \times 1.23$

$= 5{,}000 \times 2^{4.5} \times 1.23$

= **139,158 hours** (about 15.9 years) for a 405 volts DC bus