

dr. Gaál-Szabó Zsuzsanna

Magas hőállóságú szigetelőpapírok használata nagyfeszültségű transzformátorokban

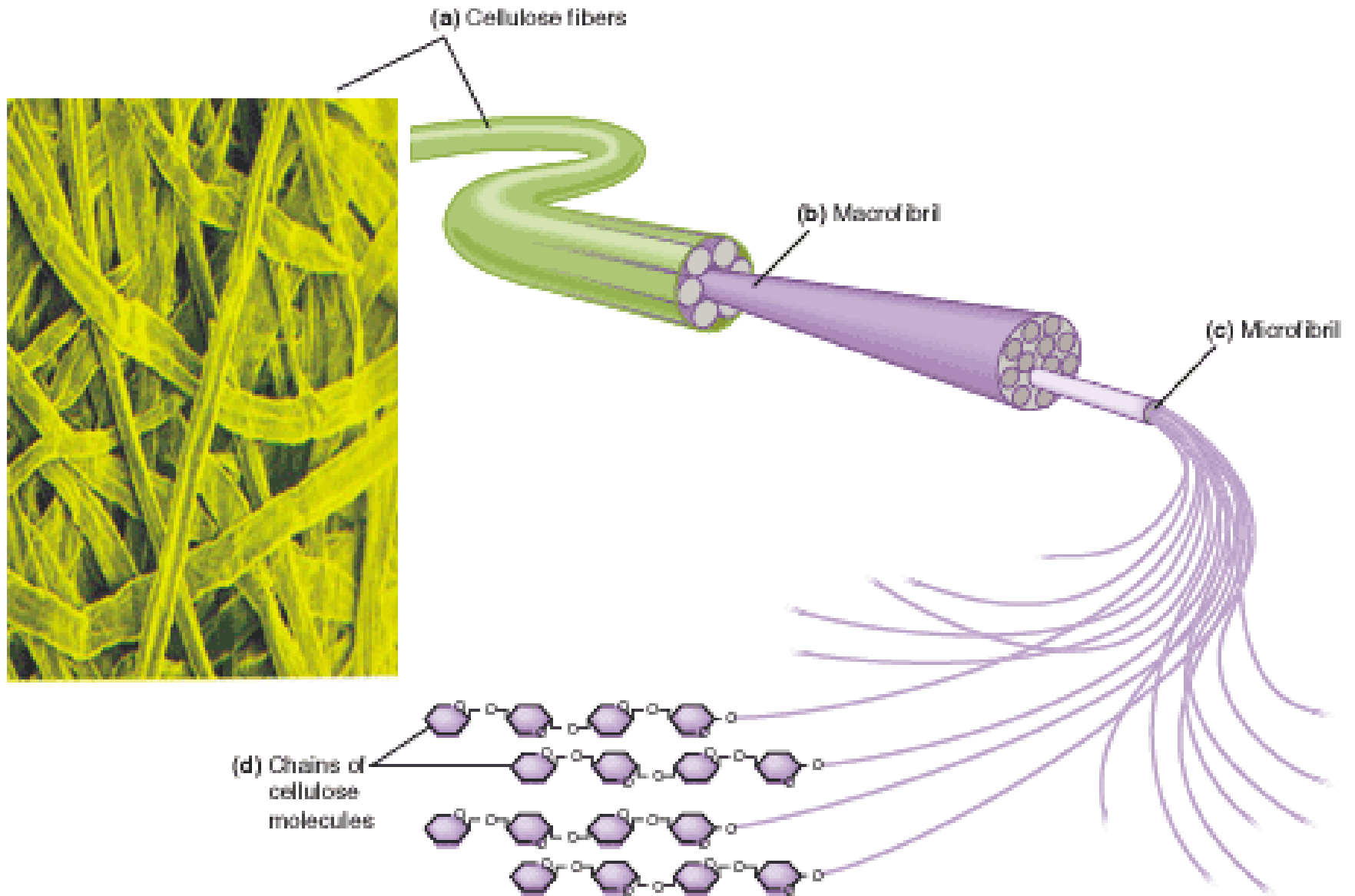
Szigetelésdiagnosztikai Konferencia, 2015

zsuzsagsz@gmail.com

**A transzformátor élettartama =
szigetelőpapír élettartama**







Normal insulation life of a well dried, oxygen free, thermally upgraded insulation system, at the reference temperature 110°C (IEC 60076-7:2005)

Basis	Normal insulation life	
	Hours	Years
50 % retained tensile strength of insulation	65 000	7,42
25 % retained tensile strength of insulation	135 000	15,41
200 retained degree of polymerization in insulation	150 000	17,12
Interpretation of distribution transformer functional life test data	180 000	20,55

The relative ageing rate $V = 1,0$ corresponds to a temperature of 98 °C for non-thermally upgraded paper and to 110 °C for thermally upgraded paper.

UNITED STATES PATENT OFFICE

2,665,733

CELLULOSE FIBER TIRE CASING PRO-
TECTED AGAINST HEAT AGING

Howard M. Buckwalter, Detroit, Mich., assignor
to United States Rubber Company, New York,
N. Y., a corporation of New Jersey

Application September 20, 1949, Serial No. 116,857

5 Claims. (Cl. 152-359)

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This invention relates to the protection of cellulose fibers against deterioration of heat aging.

Deterioration of cellulose fiber upon subjection to elevated temperatures for prolonged periods of time is a very serious problem in the art. This problem is encountered particularly in the case of rubber articles which are reinforced with cellulose fiber, almost invariably stranded and in the form of cords of fabric, which may be a woven fabric having warp and woof threads or a so-called "weftless fabric" or "web fabric" composed of parallel cords joined together by a dry deposit of rubber latex, as described for example in the patent to Hopkinson, No. 1,424,020. Such cellulose fiber reinforced articles include pneumatic tires, steam hose, power transmission belts, conveyor belts, etc. These articles are subjected to elevated temperatures in normal use, either because they are subjected to external heating, or because they generate heat within themselves by reason of repeated rapid flexing, as in the case of pneumatic tires. The deterioration of the reinforcing cellulose fiber under the action of heat is particularly evidenced by progressive reduction in tensile strength of the fiber, leading to eventual breakage. This deteriorating action

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In carrying out the invention, the melamine may be applied to the cellulose fiber in any suitable manner, conveniently by immersing the fiber to be treated in a solution or dispersion of the melamine for a time sufficient for the fiber to become substantially impregnated with the melamine solution. The cellulose fiber employed is usually ordinary grey cotton fiber, although the process of the invention may also be employed advantageously with the various regenerated cellulose fibers, such as viscose rayon. The invention is applicable to native cellulose fibers in general, such as flax, hemp, etc., as well as to scoured, bleached and mercerized cotton, etc. In place of immersing the fiber to be treated in the melamine solution, I may incorporate the melamine in the fiber in any other suitable manner, such as by spraying or brushing.

For convenience, I usually employ the melamine in the form of an aqueous solution, typically at a concentration of 5% by weight (this being the concentration of a saturated aqueous solution at the boiling point), although marked improvement in heat age resistance is also obtainable with surprisingly dilute solutions, e. g., solutions containing 0.2% of melamine.

Szigetelőpapírok

„Normál” papír

- Cellulóz

Magas hőállóságú papír (1950-es évektől)

- Cellulóz
- + hőstabilizálás N-donorral: diciándiamid, akrilnitril, dimetil-formamid, melamin, piperazin
N-tartalom: 0,5-4% /száraz papír

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- **Nő a hőállóképesség**

TECHNICAL CHARACTERISTICS OF STANDARD INSULATING PAPERS

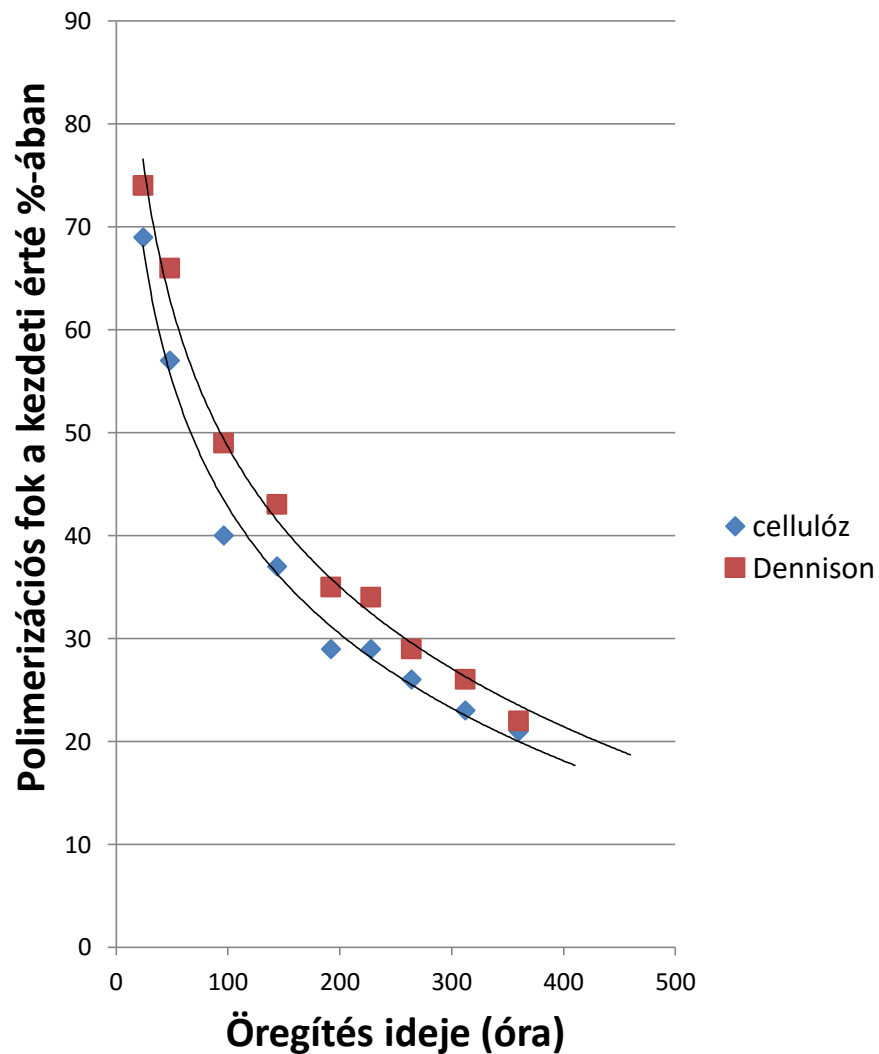
REQUIREMENT	UNIT														
manufacturer		Tervakosky	Tervakosky	Tullis Russel	Tullis Russel	Tullis Russel	Tullis Russel	Tullis Russel	Tullis Russel	Munkajö	Munkajö	Dennison	Dennison	Cottrell	Masterwright
type of manufacturer		Tertrans N	Tertrans N	HIHD	HIHD	HIHD	ROTHERM	ROTHERM	ROTHERM	Thermo Trans	Thermo Trans	Densiflex 22HCC	4,5/2HCC	Kraft TU 125	CINDUS 42 HCF
type according to IEC 554		5A2-1M3	5A2-1M3	5B4-2L4	5B4-2L4	5B4-2L4	5B4-2L4	5B4-2L4	5B4-2L4	5B1-2M3	5B1-2M3	3;1	3;1	d.n.a	d.n.a
color		natural brown	natural brown	natural brown	natural brown	natural brown	green tint	green tint	green tint	natural brown	natural brown	natural brown	natural brown	natural brown	natural brown
thermally upgraded		no	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes
calendered		no	no	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes
microcreped		no	no	no	no	no	no	no	no	no	no	yes	yes	no	yes
nominal thickness	mm	0,06	0,08	0,065	0,08	0,105	0,065	0,065	0,105	0,06	0,075	0,076	0,114	0,125	0,076
tolerance of thickness	mm	±0,005	±0,005	±0,005	±0,005	±0,005	±0,005	±0,005	±0,005	±0,003	±0,005	±0,01	±0,005	±0,025	±0,010-0,003
density	g/cm³	0,76-0,85	0,76-0,85	0,96-1,05	0,96-1,05	0,96-1,05	0,96-1,05	0,96-1,05	0,96-1,05	0,7-0,8	0,7-0,8	0,95-1,15	0,85-1,00	1,10-1,20	0,85-1,30
mass per unit area	g/m²	48	64	62-68	77-83	101-109	62-68	62-68	101-109	42-47	52,5-57,5	72-87	97-114	145-170	75 - 94
air resistance gurley	s	500-1000	500-1000	1000-4000	1000-4000	1000-4000	1000-4000	1000-4000	1000-4000	260-500	300-600	1000-4000	1000-4000	d.n.a	min 800
air resistance	µm/Pa.s	0,2-0,5	0,2-0,5	0,03-0,12	0,03-0,12	0,03-0,12	0,03-0,12	0,03-0,12	0,03-0,12	0,008-0,02	0,009-0,02	0,03-0,12	0,03-0,12	d.n.a	d.n.a
tensile strength MD	kN/m	>3,8	>5,1	>5,2	>6,4	>8,3	>5,2	>6,7	>8,3	>4,5	>6,6	>8	>8	>10	>5
tensile strength CD	kN/m	>1,7	>2,2	>2,3	>2,8	>3,6	>2,3	>2,9	>3,6	>1,5	>2,2	d.n.a	d.n.a	>7	>2
elongation MD	%	>2	>2	>2	>2	>2	>2	>2	>2	>1,4	>1,5	>15	>15	>10	>15
elongation CD	%	>4	>4	>4	>4	>4	>4	>4	>4	>4,5	>4,5	d.n.a	d.n.a	>4	>5
el.conductivity	mS/m	<4	<4	<10	<10	<10	<10	<10	<10	<7,5	<5	<10	<10	<4	<8,2
PH-value		6,9-7,7	6,9-7,7	6,5-8,0	6,5-8,0	6,5-8,0	6,5-8,0	6,5-8,0	6,5-8,0	7,5-9,5	7,5-9,5	6,0-8,0	6,0-8,0	6,5-8,5	6,8
ash content	%	<0,6	<0,6	<1	<1	<1	<1	<1	<1	<0,7	<0,7	<1	<1	<0,35	<1
el.breakdown voltage dry	kV/mm	>9,5	>8,8	>8,0	>9,0	>9,0	>9,0	>9,0	>9,0	>8	>8	>9,8	>10	>10	>10
el.breakdown voltage in oil	kV/mm	>60	>58	>90	>90	>90	>90	>90	>99	d.n.a.	d.n.a.	>74	>83	d.n.a	>99,5
nitrogen content	%	not applicable	not applicable	not applicable	not applicable	not applicable	d.n.a	d.n.a	d.n.a	1,50-3,00	1,50-3,00	2,0-4,0	2,0-4,0	1,35-4,0	2,0-4,0

d.n.a.= data not available

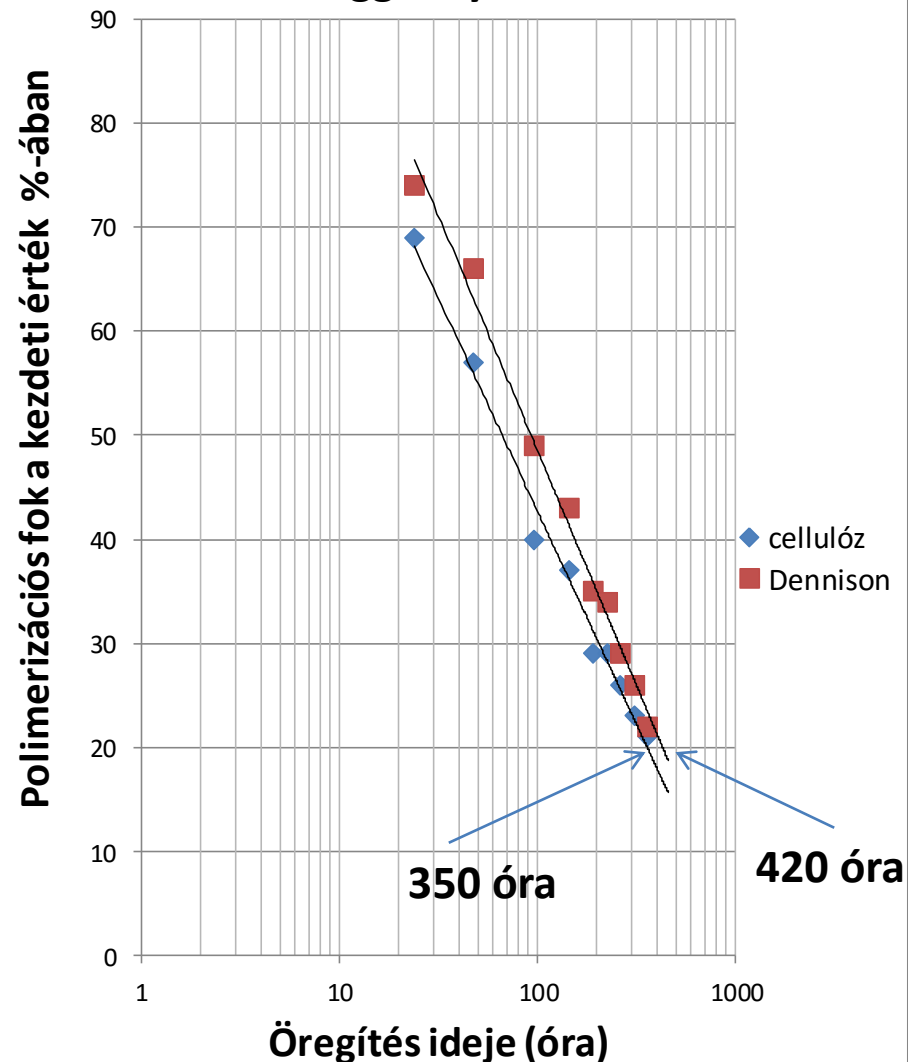
REQUIREMENT	UNIT	
manufacturer		Dennison
type of manufacturer		Densiflex 22HCC
type according to IEC 554		3;1
color		natural brown
thermally upgraded		yes
calandered		yes
microcreped		yes
nominal thickness	mm	0,076
tolerance of thickness	mm	0,01
density	g/cm ³	0,95-1,15
mass per unit area	g/cm ²	72-87
air resistance	s	1000-4000
air resistance	µm/Pas	0,02-0,12
tensile strength MD	kN/m	>8
tensile strength CD	kN/m	n.a.
elongation MD	%	>15
elongation CD	%	n.a.
el. conductivity	mS/m	<10
pH value		6,0-8,0
ash content	%	<1
el. breakdown voltage dry	kV/mm	>9,8
el. breakdown voltage in oil	kV/mm	>74
nitrogen content	%	2,0-4,0

Papír öregítés **szárazon** 155° -on

Polimerizációs fok (%) az idő függvényében

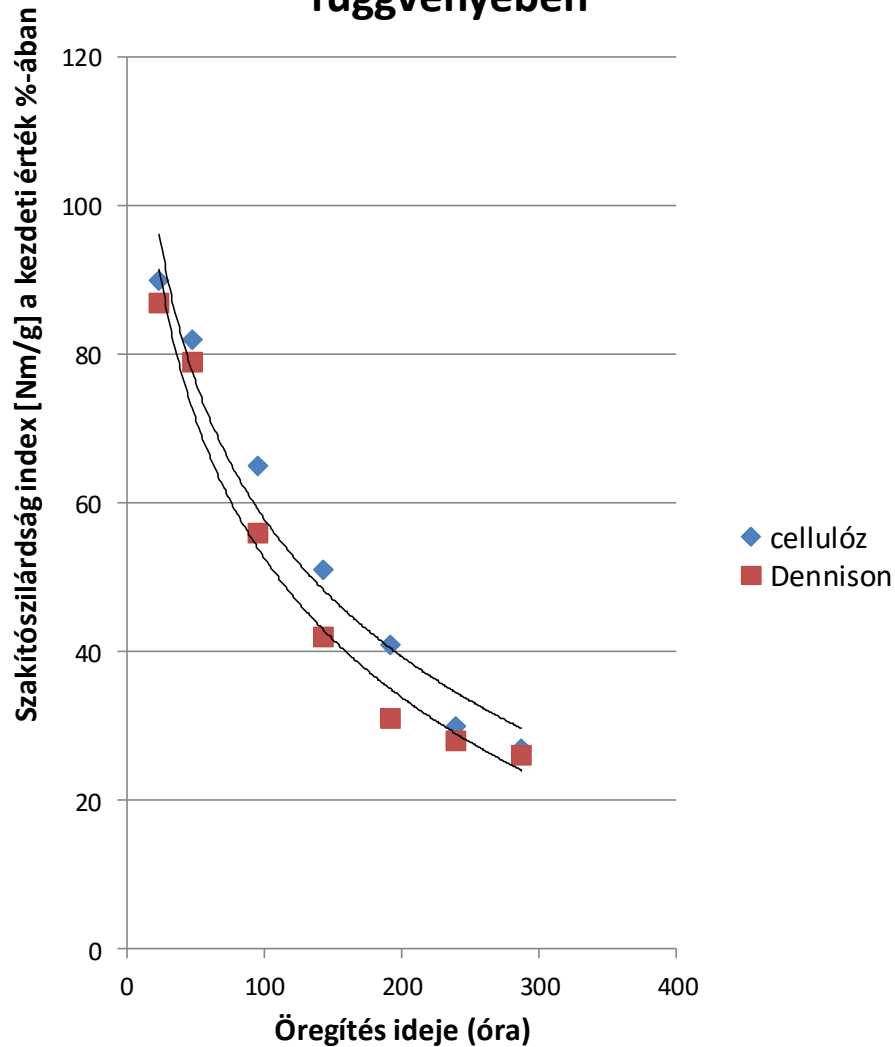


Polimerizációs fok (%) az idő függvényében

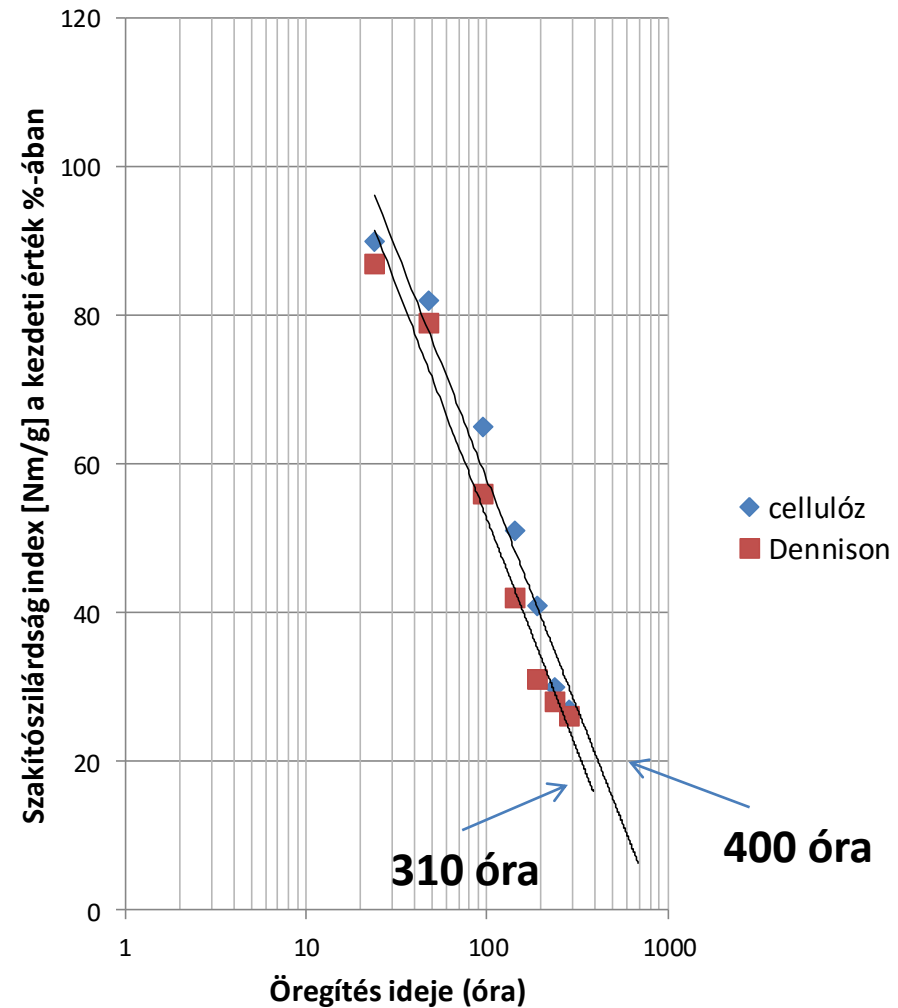


Papír öregítés **szárazon** 155°-on

Szakítószilárdsági index % az idő függvényében



Szakítószilárdság index % az idő függvényében



Life of paper under various conditions (IEC 60076-7:2005)

Paper type/ageing temperature		Life years	
		Dry and free from air	With air and 2 % moisture
Wood pulp at	80 °C	118	5,7
	90 °C	38	1,9
	98 °C	15	0,8
Upgraded wood pulp at	80 °C	72	76
	90 °C	34	27
	98 °C	18	12



Papír öregítés **szárazon** 155°-on

Cellulóz papír élettartama

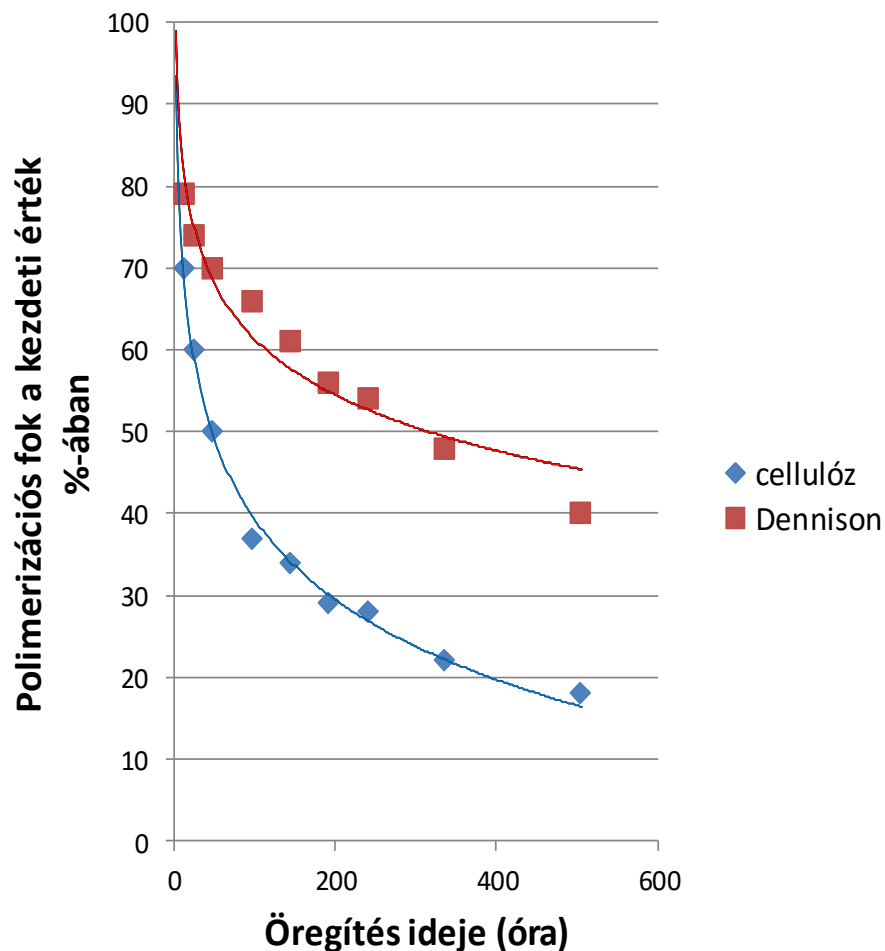


**Gyártás-
technológiai
megfontolás**

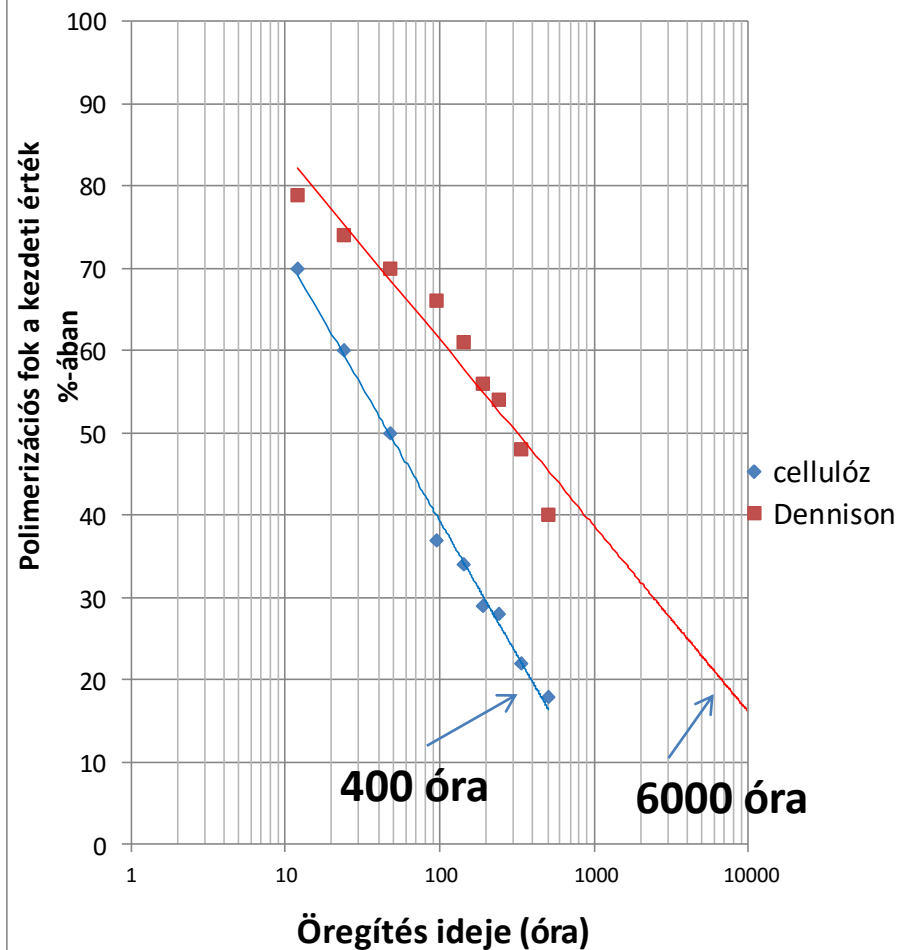
Dennison papír élettartama

Papír öregítés **olajban** 155°-on

Polimerizációs fok az idő függvényében

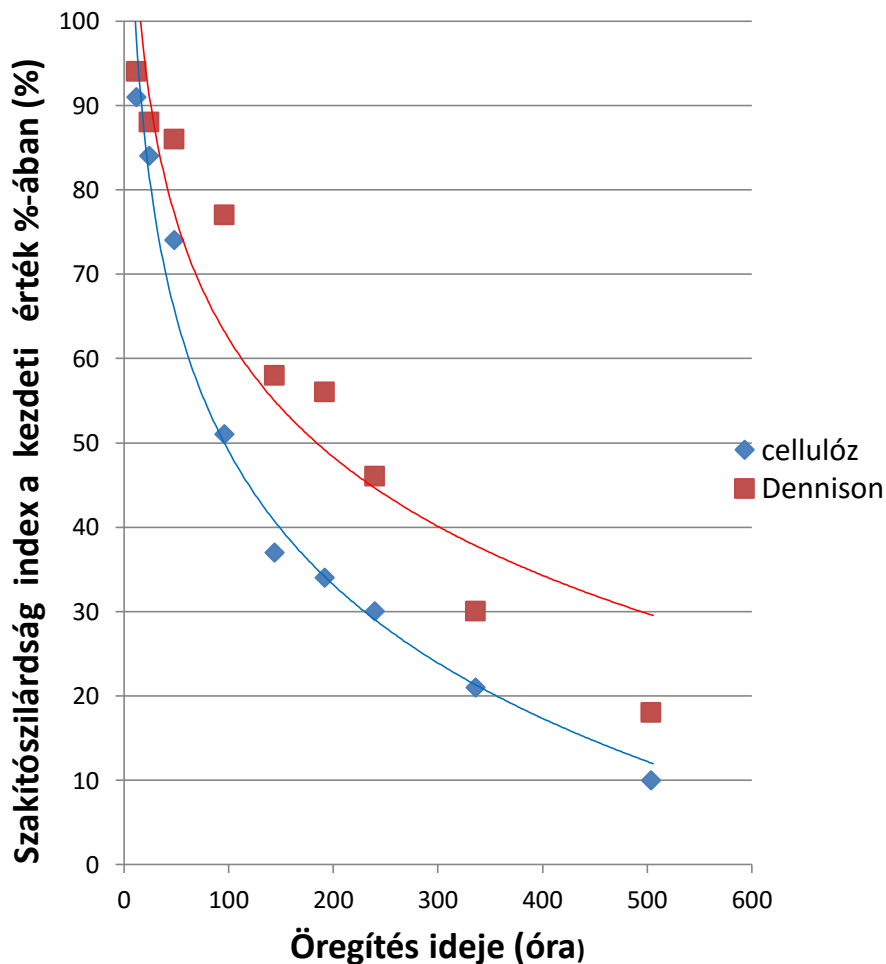


Polimerizációs fok az idő függvényében

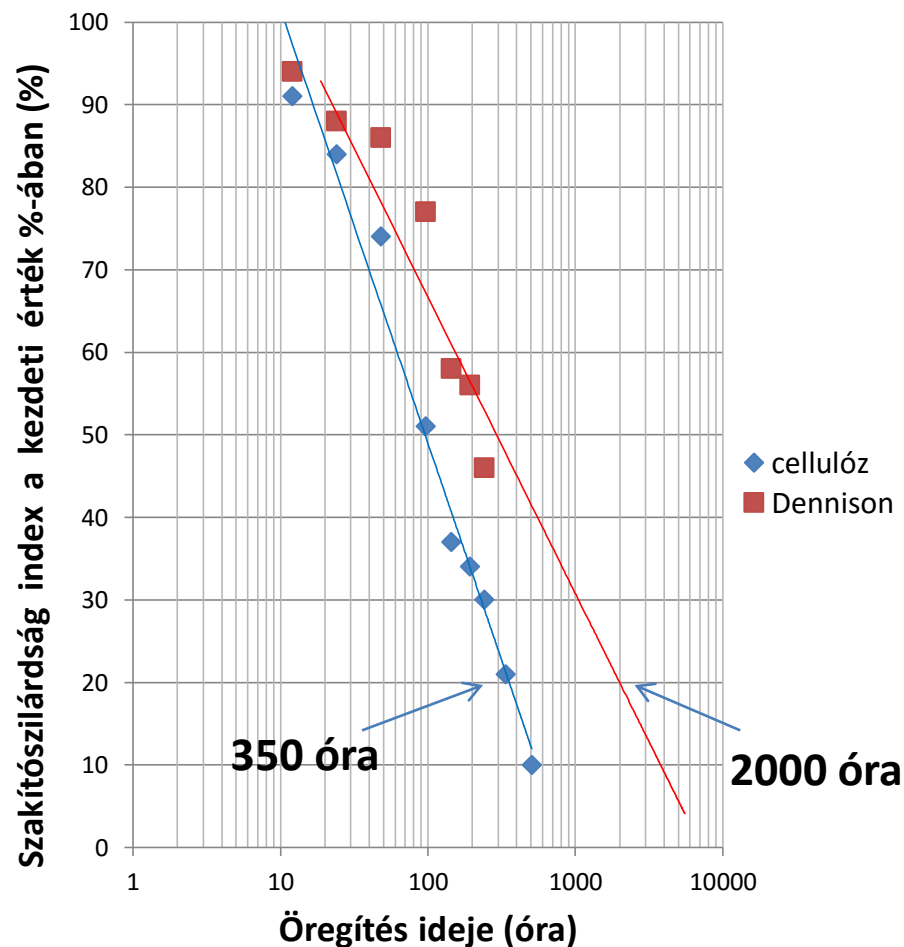


Papír öregítés **olajban** 155°-on

Szakítószilárdság index %-a az idő függvényében



Szakítószilárdság index %-a az idő függvényében



Papír öregítés **olajban** 155°-on



Cellulóz papír élettartama

Hogyan, mire
használható mindez a
teljesítménytransz-
formátorokban



Dennison papír élettartama

Öregítési kísérletek tanulsága

„Normál” cellulóz papír élettartama ugyanannyi volt szárazon és olajban öregítve is.

Szárazon öregítés során a normál és az emelt hőállóképességű Dennison papír között különbséget az élettartamban nem találtunk. Szárazon a kétféle papír hő hatására ugyanúgy viselkedik. Számolni kell azzal, hogy a transzformátor vákuumszárítása alkalmával a magas hőállóságú papír ugyanúgy öregszik, mint a sima cellulóz papír .

Olajban öregítés során a kétféle papír élettartamában jelentős különbség mutatkozott a magas hőállóságú papír javára. A valós körülmények közt, a transzformátorban tehát a magas hőállóságú papír sokkal kedvezőbb, hosszabb (a cellulóz papír életének többszöröse) működést biztosít.

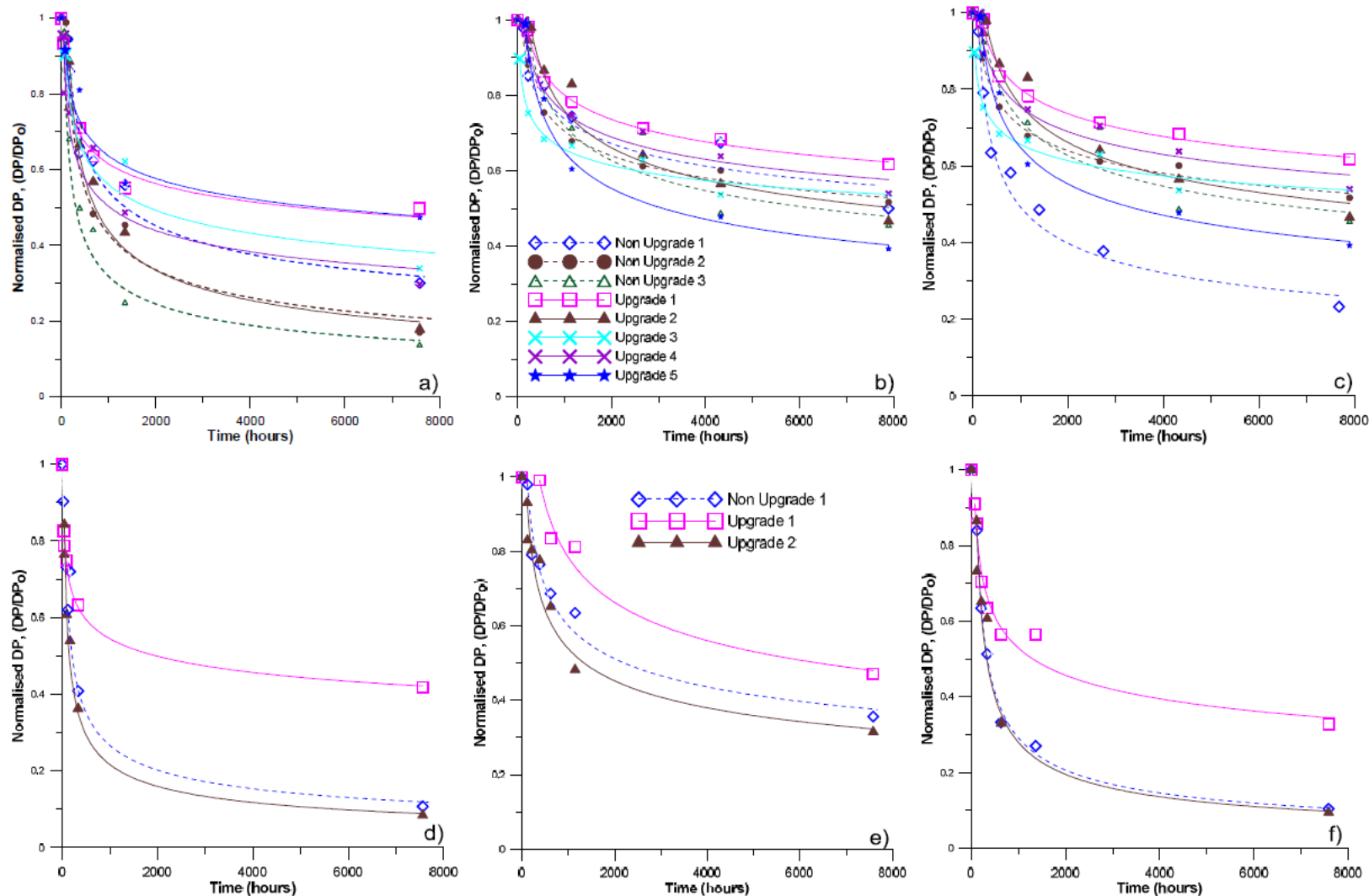
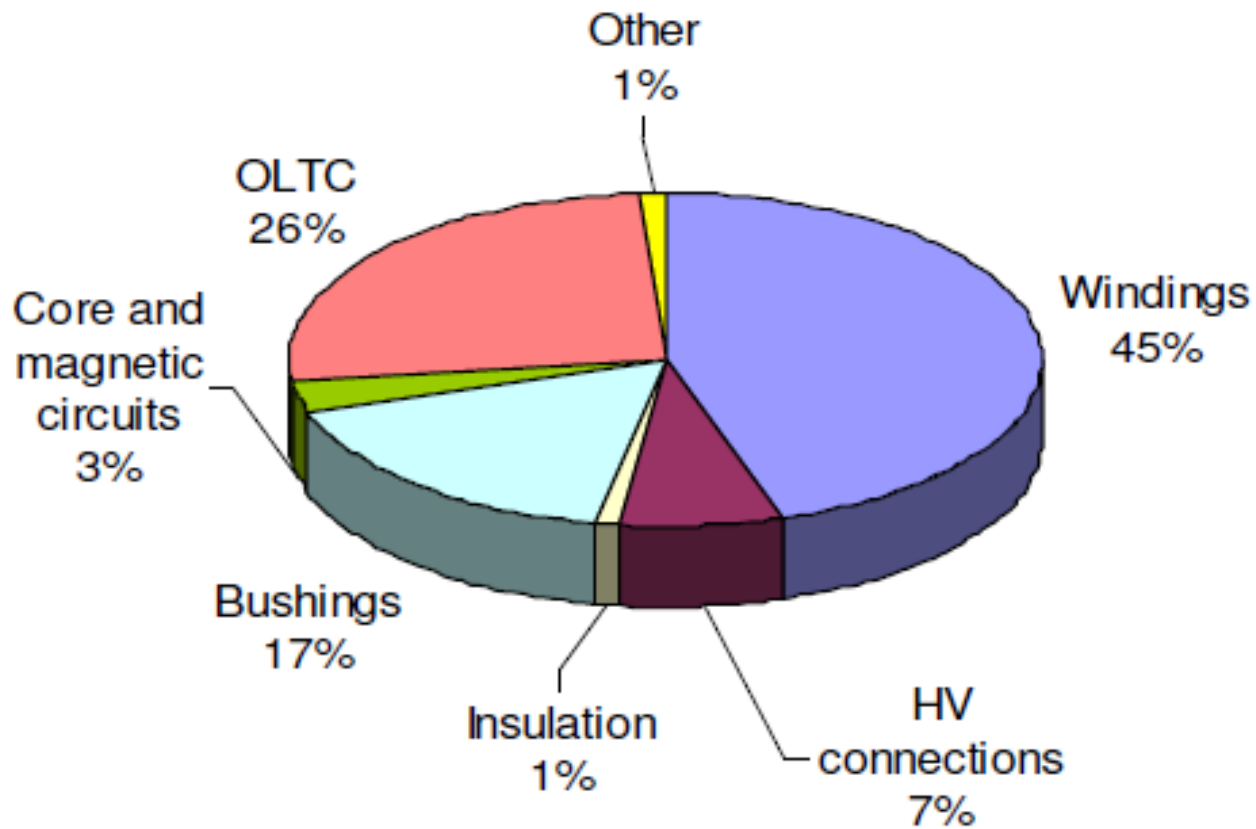


Figure 1: Normalised DP for non upgraded and thermally upgraded oil impregnated papers aged under different conditions, a) wet paper, Argon atmosphere, T=110°C, b) dry paper, Argon atmosphere, T=110°C, c) dry paper, Air atmosphere, T=110°C, d) wet paper, Argon atmosphere, T=130°C, e) dry paper, Argon atmosphere, T=130°C, f) dry paper, Air atmosphere, T=130°C

Table 1: Nitrogen level in paper, before and after 4 months of ageing in air, dry and 110 °C.

Paper	Nitrogen (%) Start	Nitrogen (%) 4 months Air, dry, 110 °C
Upgrade 1	2.7	2.9
Upgrade 2	1.0	0
Upgrade 3	2.0	2.0
Upgrade 4	1.9	1.9
Upgrade 5	1.0	0.9
Non upgrade 1	0	0

(forrás: **Ageing of oil impregnated thermally upgraded papers** CONFERENCE PAPER · JANUARY 2011)



fault location grouping from CIGRE

(source: CIGRE A2-107,2014)

Köszönöm a figyelmet!

2015

zsuzsagsz@gmail.com