Based on ANSI C57. 117 (1986) we propose the following:

- **Failure**: "Termination of a transformer to perform its specified functions"
- **Failure with forced outage**: "Failure of a transformer that requires its immediate removal from the system"
- **Failure with scheduled outage**: "Failure for which a transformer must be deliberately taken out of service at a selected time"
- **Defect / Non-Conformity**: "Inspection or partial lack of performance that can be corrected without taking the transformer out of service"

**Failure Rate / Reliability Parameters**

- **Failure Rate (FR)**: The ratio of the number of failures with forced outage of a given population over a given period of time to the number of accumulated service years for all transformers in that period of time
- **Reliability Parameter**: Mean Time between failures (MTBF) = 1 / FR (years)

**Figure 1: Failure Definition**
Floating time period: 10 years

N: Number of units in service in that 10 year time period

SY: Number of service years accumulated with [N] units in service

nF : Number of failures or number of units from N units in service

Failure Rate FR
FR = (nF / SY) 100[%]

Reliability Indicator ” MEAN TIME BETWEEN FAILURES”

MTBF = (1 / FR) [years]

Figure 2: In-Service Failure Statistics or reliability parameters
Quality Assessment In-Service: PTD T - PT In-Service Failure Statistic 1994 - 2003
according to ANSI C 57.117 and [1]


<table>
<thead>
<tr>
<th>PTD T w.w. BUT</th>
<th>KPT</th>
<th>FS</th>
<th>SAT</th>
<th>STC *</th>
<th>PD</th>
<th>TUSA</th>
<th>PN + T</th>
</tr>
</thead>
<tbody>
<tr>
<td>N 6957</td>
<td>217</td>
<td>424</td>
<td>582</td>
<td>546</td>
<td>391</td>
<td>601</td>
<td>937</td>
</tr>
<tr>
<td>SY 31612</td>
<td>712</td>
<td>1793</td>
<td>2658</td>
<td>3148</td>
<td>1185</td>
<td>2660</td>
<td>4790</td>
</tr>
<tr>
<td>nF 80</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>FRe (%) 0,25</td>
<td>0,56</td>
<td>0,11</td>
<td>0</td>
<td>0,25</td>
<td>0,08</td>
<td>0,08</td>
<td>0,48</td>
</tr>
<tr>
<td>MTBF 395</td>
<td>178</td>
<td>897</td>
<td>∞</td>
<td>394</td>
<td>1185</td>
<td>1330</td>
<td>208</td>
</tr>
</tbody>
</table>

N = No of delivered units
SY = No of Service years
nF = No of units failed
FRe = Failure rate = (nF/SY)100%
MTBF = Mean time between failure = (1/FR) yrs

FRe ≤ 0,5 % excellent
0,5 < FRe ≤ 1,0 % good
1,0 < FRe ≤ 1,5 % satisfactory
1,5 < FRe ≤ 2,0 % acceptable
FRe > 2,0 % not acceptable

1995-2003

Figure 3: Example of our Siemens In-Service Failure Statistic
Figure 4: Electromagnetic field calculation
Transformers

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Fig. 5 Progress on Loss and Noise [3]

http://webs.uvigo.es/arwtr04
Here are some Examples for Siemens

Figure 6: Core production

Improved overlapping results in lower no-load losses and lower noise
Fig. 7 Winding Production In-winding axial and radial compression. In winding length adjustments enables effective common pressing. Vapor phase drying under constant pressure provides improved short circuit capability.
Some examples Transport Damages

Figure 8: 240 MVA/220 kV – Transport damage due to excess speed
Figure 9: Development of a floating transformer required
A regular trend analysis over gas-in-oil analyses and oil analysis

- Reducing the moisture content in the insulating system through drying

- Degassing
- Oil reclaiming/oil change in case of high acidity and/or low interfacial tension. Use of inhibited oils
- Online monitoring of fault gases, especially hydrogen
- Monitoring of moisture
- Monitoring of the operating temperature

Figure 10: Required Actions against Ageing, Life Extension Measures

The purpose of maintenance and life prolongation should be:
- Recovery of the dielectric properties of the oil/paper insulation to the largest possible extent
- Reduction of the future ageing rate
PROJECT MANAGEMENT
Responsibility NN

BASED ON THE UNBIASED FINDINGS OF THE PROCESSES 1)…..5), THE MOST LIKELY ROOT CAUSE IS DETECTED IN > 95% OF THE CASES

THIS IS A PRECONDITION TO IMPROVE DESIGNS, PRODUCTION QUALITY, SYSTEM CONDITION.

Figure 11: Joint Root Cause Analysis of Field Failures
Conclusions

1. Assure high competence in Design (experiences, man power, tools, calculation and design programs).
2. Perform effective Design Review versus Specification / Standards and special site requirements, learn from failures (test floor and in service).
3. Assure top competence in production quality (tools, machines, maintenance, tolerances, processes, In-process inspection).
4. Material Quality - where ever possible use world supply management / supplier development for A-Materials (steel, copper, insulation, oil, etc.) Only qualified and by Materials laboratory released materials are allowed.

Figure 12: Responsibilities of Manufacturers high Reliability
Conclusions cont.


6. Consequent Maintenance, Service and Monitoring and competent diagnostics, condition Assessment in the form of Fingerprinting, trend analysis at regular intervals (DGA, all oil values, mechanical control, moisture and furane control)

7. On-Line Monitoring as early warning system


10. Consequent Root-Cause Analysis of failures / defects jointly with the manufacturers.

Figure 13: Essential User Responsibilities for high Reliability.
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