

Summary:

Seven identical 10 mva transformers.

Analysis – water reduction - cellulose to oil water migration rates.

A group of 10 Mva 3ph transmission transformers (66/22 Kv - 3phase) first commissioned around 1968, 12,000 litres of oil, free breathing, are being Analysed online to find the water in oil activity, and water in cellulose volume (%). The Trojan then filtered each transformer for a different period of time as a first stage water reduction. The Trojan has been returned to two transformers so far to re-analyse and record the improvement (see TT1 and TT3 Dry-Out examples). All operate at medium load range. The project started on 13.10.2005 (spring) and is ongoing. Using the same diagnostic methods, all seven have water in cellulose values of 4.0% to 4.5%. This level of contamination seems common across other utilities in close location, with transformers of similar age and a medium load profile.

A Trojan 1000 owned by the utility was used to Analyse for 48 hrs, Degas for 60 hrs, then Filter for 30 hrs between the automated Filter Re-Dry. These Trojan settings were used on all transformers to compare the water removal characteristics at different temperatures covering winter and summer. The Trojan will be returned to the transformers for a second round of Analysis and water removal within 12 months. This will form part of a larger study on water reduction strategy.

Objectives of the ongoing group study

1. Water in oil activity – dielectric profile reliability
2. Accuracy of Trojan water in cellulose diagnosis method %
3. Water from cellulose migration rates at different operating temperatures.
4. Daily water removal rate between the start and end of Filtering.
5. Time to achieve the target water reduction.

Update to 31st January 2007

| | T 1 | T 2 | T 3 | T 4 | T 5 | T 6 | T 7 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Water in Cellulose start | 4.40% | 4.10% | 4.30% | 4.30% | 4.30% | 4.30% | 4.25% |
| Days filtering | 26 | 32 | 35 | 42 | 38 | 46 | 52 |
| Water Removed (mils) | 3640 | 3795 | 3995 | 4570 | 3565 | 4250 | 5300 |
| Mils per day | 140 | 119 | 114 | 109 | 94 | 92 | 102 |
| Number of Filter Re-Dry's | 18 | 21 | 23 | 28 | 22 | 26 | 30 |
| Ave - each Re-Dry (mils) | 202 | 181 | 174 | 163 | 162 | 163 | 177 |
| Average's during filtering | | | | | | | |
| Bottom oil temperature 0°C | 29.1 | 31.1 | 33.0 | 19.8 | 18.5 | 22.5 | 25.1 |
| Water in oil - Inlet ppm | 9.69 | 9.61 | 10.64 | 7.60 | 6.55 | 7.20 | 9.03 |
| Water in oil - Outlet ppm | 5.04 | 4.99 | 6.34 | 2.70 | 2.88 | 3.12 | 4.09 |
| Water removed ppm | 4.65 | 4.62 | 4.30 | 4.90 | 3.67 | 4.08 | 4.94 |
| Removal percentage | 48% | 48% | 40% | 64% | 56% | 57% | 55% |

Fig. 1 – Summary of seven transformers

Cost of water removal

The Trojan has removed a total of 29.2 litres of water from the seven transformers over a total of 271 days of Filtering, an average of 110 mils per day. Over 40 litres of water per annum can be removed on medium load. Larger transformers will give more water in the same time. Based on the minimum expected life of the Filters of 18 months or 548 days, the proportional filter cost to remove the 29.2 litres of water is \$451.00, or \$15.50 per litre of water. The filters will easily last the 18 month minimum target.

Fig. 2 shows the water removed at each Filter Re-Dry of the seven transformers. All transformers started with similar water in cellulose %. The Trojan filtering on all transformers was set for 30

TROJAN water removal trends

hours before auto Re-Drying. Despite a 12°C difference in the average bottom oil temperature of the transformers during Filtering, there is a very strong consistency to the water removal trend.

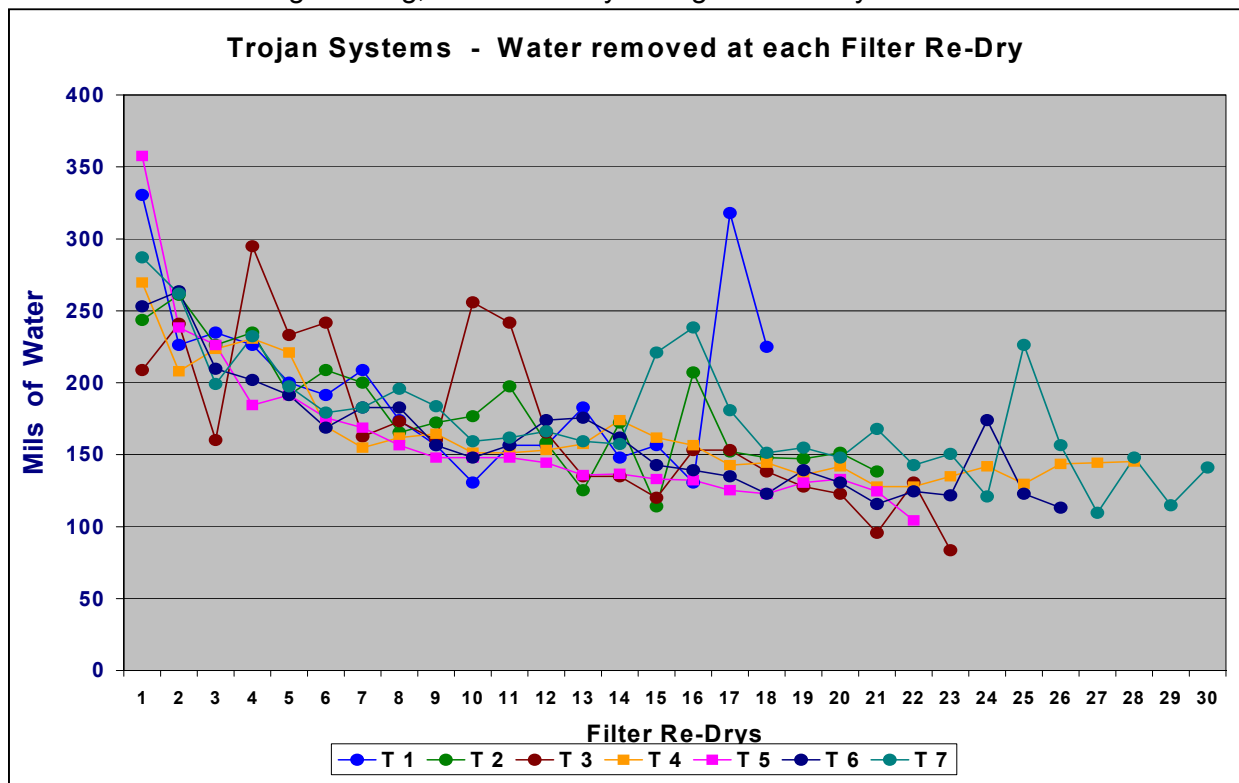


Fig. 2 – Water removal trends from 7 transformers

The individual high water removal points indicate the temperature peaks. T1 has been re-analysed and had two more filtering cycles. The increased water removal after the re-connection is obvious by the volume of water removed in the last two filter Re-Dry's.

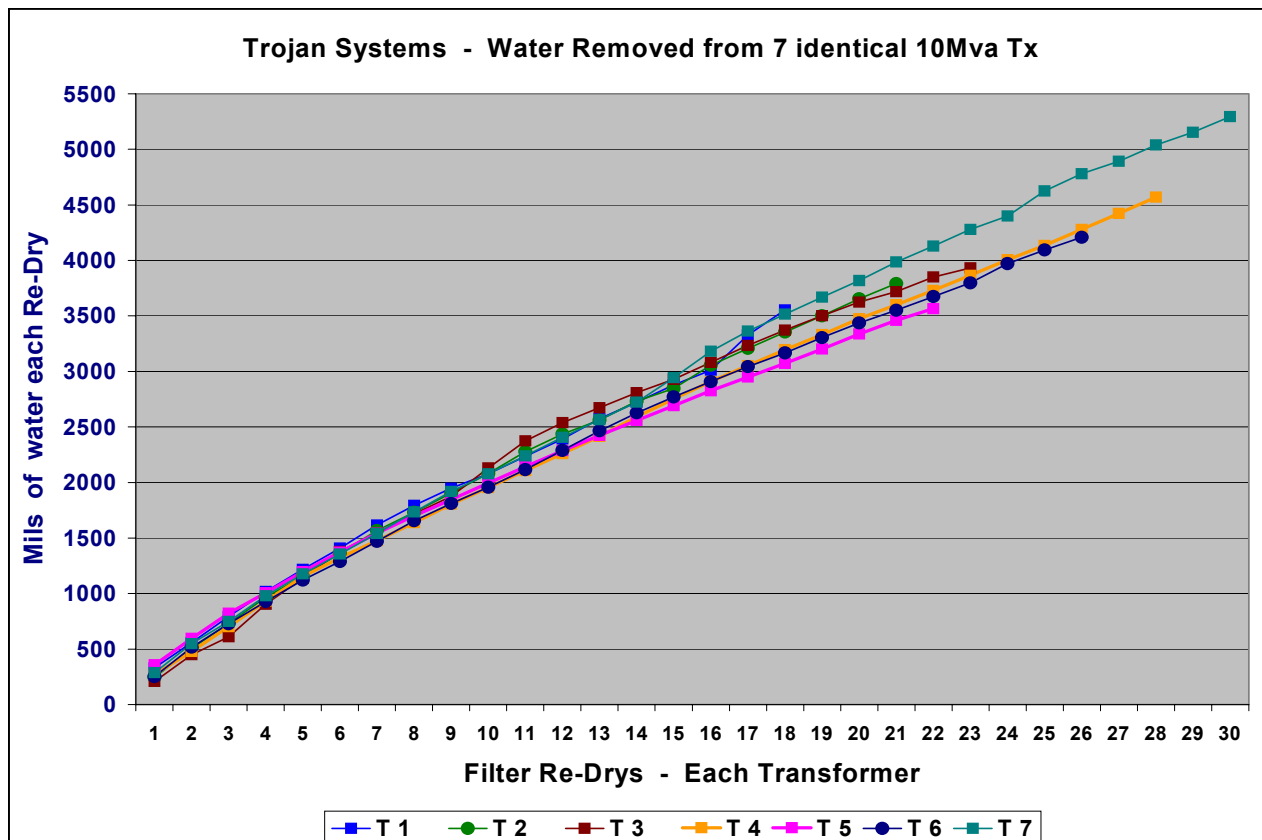


Fig. 3 – Accumulated water removal trends from 7 transformers

TROJAN water removal trends

T7 had a total of 30 Filter Re-Dry's. The average transformer bottom oil temperature during filtering for the first 15 was 23.9°C, and the last 15 it was 26.3°C, compared to **T4** which was 19.9°C for the first 14 Re-Dry's and 19.7°C for the second 14 Re-Dry's. The 5.3°C operating temperature increase that **T7** had over **T4** is evident at the 28th filter Re-Dry for both. The average increase in temperature of **T7** had released 500 mils of water from the cellulose insulation in exactly the same filtering time (28 Re-Dry's). **T5** had the slowest water migration rates release and the lowest average bottom oil temperature of 18.5°C.

Conclusions

The results from the seven transformers so far confirm the water migration rates of a group of similar transmission transformers, all with a very similar age, construction and water in cellulose levels. Even at low operating load temperatures the daily water removal rates are significant, and excellent long term dielectric improvements can be achieved with very little effort.

All seven will be re-Analysed to confirm the water in cellulose reduction. All seven started with similar volumes of water in the cellulose, and all had different volumes of water removed. This will provide an accurate profile of the water volume in cellulose levels. **T1** was filtered for the shortest initial period of 23 days, and was re-analysed after a 72 day equilibrium recovery period which provided a good indication of the improvement trend. The remaining transformers will be given 12 months with re-analysis of T2 and T3 in February 2007.

The (proportional cost) of Filter replacement to remove the 29.2 litres of water is \$451.00, or \$15.50 per litre of water. The filters will easily last the 18 month minimum target. The Trojan operated without incident during the program and is continuing with the fleet water reduction program.

More importantly the utility has a clear picture of the risk profile, and the oil dielectric is restored to high levels. The life of the cellulose insulation in all seven transformers has been extended by at least 10 years. Reducing the water level in the cellulose significantly reduces the paper degradation process.

The project will be updated regularly.

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