ADVANCES IN THE DECOMMISSIONING OF END-OF-LIFE OIL FILLED CABLES

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ABSTRACT

The oil removal process developed by EA Technology is now available as a service to network owners and contractors. The process delivers the major benefit of rendering end-of-life oil filled cables in a condition where they no longer pose a significant long-term threat to the environment. This paper describes the procedures taken to ensure a successful operation. It then goes on to consider the results of a successful oil removal from an undulating 1.5 km, 33 kV circuit.

INTRODUCTION

In the UK there are many thousands of kilometres of oil pressure cables. This is now an old network, many circuits having been being installed over 50 years ago. As the circuits continue to age more oil leaks develop and maintenance costs increase. Therefore there is an increasing trend to replace oil filled cables with polymeric cables. However, untreated redundant circuits contain a lot of oil. This constitutes a continued environmental threat.

At the CIRED 2003 conference the lead author of the present paper described the laboratory and field trial development of a process based on detergent flushing to remove oil from cables that have reached the ends of their lives [1].

Since that time the process has been introduced as a service, jointly operated by EA Technology and Aalto Technical Services Ltd, to the Distribution Network Operators in the UK and Ireland. Several major oil removal operations have now been carried out and there is now a steady increase in orders.

In this paper the process, as currently carried out, is outlined and a case study of oil removal from a 33 kV, 3-core circuit is described.

THE PROCESS

The oil removal process is carried out by specialist Aalto Technical Services Ltd. EA Technology provides the project management, supervision and technical consultancy.

In the first part of the paper the oil removal process is described, along with some of the important supporting issues such as preparation, health & safety and protection of the environment.

The Process Basics

The process developed and supervised by EA Technology consists of the following:

1) gas purging;
2) flushing with detergent;
3) removal of detergent by water flushing.

Gas purging frees space in the cable, thus easing the initial pumping of detergent into the cable. Nitrogen is invariably specified for purging; compressed air is not entertained, as there is a potential risk of explosion, i.e. via the "diesel effect", whereby there is a build-up of oil droplets in the air stream.

As demonstrated in the CIRED '03 paper [1], the heart of the EA Technology-Aalto process is the detergent flushing. For short lengths of cable, pumping is simply from one International Bulk Container (IBC) to another, as shown in Figure 1. Note, however, that often it simplifies and shortens the process to link parallel short circuits together by temporary pressure hoses; this is especially useful when there is good access only at one end.

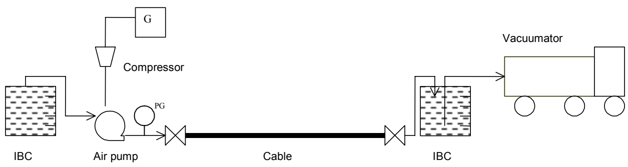

Fig. 1: Basic detergent cleaning process

The proprietary detergent was carefully selected, not only for effectiveness, but also has the following benign characteristics:

- complies with Detergents Regulation (2004/648/EC);
- no specifically named List 1 and List 2 substances (76/464/EEC);
- no priority list (2000/60/EC) substances;
- all components of AQ Plus show more than 90% biodegradability according to OECD test;
- the biodegradability of AQ Plus under German Law is greater than 95%;
- acute fish toxicity LC50 = 140 mg/L;
- contains no caustic soda;
- classed as an irritant to skin and eyes (as are virtually all detergents).

Notwithstanding the careful selection of the detergent, any spillage of detergent is itself a threat to flora and fauna, and many cable routes are close to watercourses, boreholes and other very environmentally sensitive areas. Therefore, aside from taking care not to cause spillage during the process, it is considered essential to remove as much as the detergent as possible from the cable. This is done in the final stage of the process by flushing with a large volume of water. The dilution is such that only tiny amounts of detergent remain in the cable.

An observation made during the application of the process is that the concentration of oil in the outlet stream drops in a near-step change after switching from detergent solution to water. This is a clear indication that water alone is much less effective than detergent in removing oil, presumably because water alone does not wet cable components nearly so well.

For audit trail requirements, inflow and outflow rates are continuously monitored and samples are taken periodically. Knowing both the concentration of oil and flow rates, the amount of oil removed is easily determined. Oil concentration is determined very simply by allowing a sample of mixture containing oil and detergent solution (or water) to settle for a few days. If the solution has been placed in a parallel sided glass vessel, the volumetric concentration can be determined simply by measuring layer heights. Although clarification of the layers may continue for many months or even a year or so, the relative layer heights remain virtually constant.

Preparation

Preparation is a very important part, in order to ensure that the process can go ahead smoothly.

Some of the more important aspects to be considered are:

- details of circuit and cable;
- site visit;
- careful planning of strategy;
- carrying out a risk assessment;
- preparing a method statement.

Commenting on the above list, it is essential to know the length of route, number of circuits, type of cable, size of cable and nature of the route itself. Taken together they determine exactly how the process is to be carried out and for how long. However, experience shows that it is necessary to be adaptable and some minor modifications are often required as the work unfolds. The site visit will highlight such mundane matters as obtaining a water supply and vehicular access, as well as indicating to clients necessary preparations required from their side, e.g. by-passing of oil tanks and fitting of appropriate connections.

Health and Safety

Among the essential requirements are:

- trained personnel;
- good working knowledge of the operation of the process;
- awareness of all hazards;
- certification to work in confined spaces (needed when access is via a joint pit);
- training in and provision of first aid;
- strict adherence to customers' site rules;
- traffic management and awareness;
- wearing of appropriate safety wear (protective boots, high visibility clothing, hard hat, goggles and gloves).

Environmental Considerations

Damage to the environment during the decommissioning of oil-filled cables is to be avoided at all costs. Therefore measures have to be taken to avoid and contain spillages, and to dispose of the waste in a compliant manner.

Spillage avoidance and containment

Among the most important considerations are:

- spillage of oil, oil/surfactant/water waste and surfactant solutions to be avoided;
- careful set up and monitoring of the process;
- action plan to deal with spillage – large or small;
- personnel to be trained in dealing effectively with a spillage;
- secure couplings;
- restriction of pressure on the cable;
- provision of spill kits;
- bunded IBCs;
- portable spill trays and buckets.

Even with good planning and provision of the right equipment, sometimes minor spills do occur. It is important that personnel are vigilant to deal with such incidents promptly.

Disposal of waste

The waste from the oil removal process is a mixture of water, surfactant and oil. Under UK law it is classed as "hazardous waste" under the Hazardous Waste (England and Wales) Regulations 2005, Annex 1A, No. 9: oil/water, hydrocarbon/ water mixtures, emulsions.

Typically there will be about 4 to 6 m^3 of waste per kilometre of cable, but this obviously depends on cable size and type.

Disposal of waste is to a licensed disposer complying with the aforementioned hazardous waste regulations, and is also governed in England and Wales by:

- The Environmental Protection (Duty of Care) Regulations 1991(and subsequent amendments).
- The Waste Management Licensing Regulations 1994 (and subsequent amendments).

Process Reporting

At the end of all oil removal projects EA Technology provides the client with a full report, describing the method and details of the process. Included in the report are tables and graphs of oil removed. An estimate of the percentage removal of oil from the circuit is also given. This is based on details of the circuit provided by the client and tables of oil content for specific cable types

CASE STUDY: 3-CORE CIRCUIT

The 33 kV circuit, which took an undulating route, had been taken out of service a few months before the oil removal process was carried out. It consisted of 1331.9 metres of 0.25 in^2 (161 mm^2) and 155.4 metres of 0.3 in^2 (193 mm^2) 3-core cable, 1487.3 metres in total. The cable had three oil ducts of 12 mm diameter. Along the length were 8 straight through joints. There were two sets of oil tanks at two positions, a 180 litre tank at a joint bay and a 135 litre tank at a stop joint. Both were disconnected from the cable and the piping was blanked off prior to the initial gas purge.

A 4 day strategy was devised to yield a good oil yield and to quantify the amount taken out:

Day 1: Travel to site and gas purge;
Day 2: Detergent flushing;
Day 3: Detergent Flushing;
Day 4: Water Flushing and travel from site.

During the nitrogen purge the pressure regulator was set to 2.4 Bar, a low value, because the circuit was known to be leaking. The purge was undertaken from the stop joint (alluded to earlier) at the edge of a highway and oil was collected out of a trifurcating joint at a substation. The end of the purge was signalled by the outflow of oil being reduced to a trickle.

The duct volume (duct ID) was estimated to be 505 litres. The total oil removed by gas purging, however, was only 240 litres, showing that this part of the process is not very efficient. The reason for this is that in three core cables the gas takes the path of least resistance; once about one-third of the duct space is cleared, this becomes the preferred path of the gas, so that the gas no longer effectively pushes forward a slug of oil. Another likely reason is that the oil in the ducts was cleared upstream of the leak. When this point was reached some of the gas would have escaped through the hole. Indeed in other cases we have found that if a leak position is close to the inlet, gas purging is almost wholly ineffective. In general, however, the gas purge is worthwhile. When there is a large volume of oil to be removed, it frees up space and allows the detergent solution to fill the duct space rapidly; otherwise the detergent solution process would start by working against a large head of fluid, which is hard to move.

As the length of the circuit was moderate rather than short, the process set up was slightly different to that shown in Fig. 1. Detergent solution in was pumped from a 1 m^3 International Bulk Container (IBC) through the cable as shown in the Fig. 2. For the purposes of outflow measurement and sampling, the oil/detergent mixture was collected in the bucket before being sucked into the vacuum tanker. The outflow rate was simply determined by measuring the time to collect a known volume of fluid.

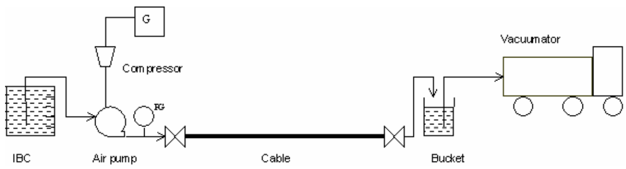

Fig. 2: Modified detergent cleaning process

Pumping on its own was found to result in slow inflow rates. As mentioned earlier, it is easier to induce flow into an empty or partially empty duct. Further, it is important to cycle the cable between the nearly-empty and nearly-full state in order to induce flow into and out of the insulation, fillers and spaces. Therefore to boost the flow through the system, the vacuumator was periodically connected to the cable, i.e. by-passing the bucket.

There were, of course, two overnight soak periods, which are needed to allow a long diffusion time.

Essentially the water purge was carried out in the same manner as the detergent purge. To the first batch of water a tracer dye was added. The second batch of water contained no tracer dye.

The results of the oil removal process are shown in Fig. 3. About 1340 litres of oil was flushed out of the system.

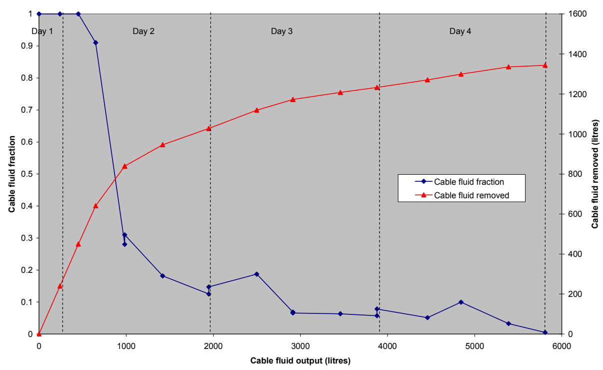

Fig. 3: Oil removed at various stages of the process

Figures 4 to 6 show the 17 samples of effluent taken on Days 2 to 4. Note that sample S1 is pure oil. Sample S2 was 91% oil, with the small aqueous layer just visible at the bottom of the jar.

Figure 4: Effluent samples taken on Day 2

Figure 5: Effluent samples taken on Day 3

Figure 6: Effluent samples taken on Day 4

The dye was observed in the effluent stream shortly after the taking of sample 14. At this point about 580 litres of fluid had come out of the cable following the start of the dyed water injection. This is slightly less than the estimated readily accessible free volume in the system (ducts and joints) of 670 litres. To a large degree the water being pumped into the cable pushes the column of water in front of it with relatively little axial mixing. However, it is not quite as simple as that, because at the end of the process dye was still observed in the effluent (although the colour was much less intense), and this was after the second dye-free water batch had been pumped in. We deduced that some of the dyed water had infiltrated recesses of the cable away from the ducts and is only slowly leached out by the clean water. This is, of course, what is required. Not only must the water (or detergent) push out oil in the ducts; it must also penetrate and wet the more inaccessible parts of the cable.

It can also be observed that the aqueous phase was initially very dark at the start of each day, but became lighter as the process progressed. This is almost certainly because of the known leak on the system. The gas from the purge on Day 1 probably leaked away quickly. When the pressure was equalised between the outside environment and the cable, dirty soil water would have been admitted overnight at the leak position. Internal cable pressure is more easily retained with liquid in the system, so that, during the subsequent injection of detergent, flow of soil water into the cable system at the leak point is less likely. Hence, with the replacement of the soiled water by fresh, there is a gradual reduction in colour intensity.

The total volume of oil in the system was estimated to have been about 1500 litres. The 1340 litres removed represents approximately a 90% recovery. It is possible to remove some of the remaining 10% of oil, but it is questionable whether the large expenditure required to remove the residue is justified. A balance is required between economic necessities on the one hand and total protection of the environment on the other. In the state the 33 kV circuit was rendered the subsequent leakage rates to the soil should be very small indeed.

It must be stressed that the process, as outlined in this case study, was devised for the particular cable type/size and circuit length. In general, the greater the volume of oil to be removed the greater is the time required to carry out the process. Furthermore, the higher the system voltage, the greater the thickness of the dielectric, so that diffusion times are lengthened; longer soak periods and more extended flushes are required for these cables.

Lengths of 3 km have been successfully flushed and a 3.5 km section of 0.4/0.6 in^2 (258/387 mm^2), 3-core, 33 kV cable is shortly to be treated.

CONCLUSION

The EA Technology process has been established as a viable method for removing oil from end-of-life cables. Clear procedures are in place to allow a smooth, safe and compliant operation. The case study described herein demonstrates that a high recovery of oil can be achieved.

ACKNOWLEDGEMENT

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REFERENCE

[1] G. J. Le Poidevin, 2003, "Approaches to the decommissioning of end-of-life oil filled cables", *CIRED 2003*