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HYDROGEN ELIMINATION FROM A 225 KV HPOF PIPE-TYPE LINE

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ABSTRACT

In RTE network, numerous oil-static lines show very high amounts of H_2 in oil, which makes operation not reliable. An oil-reprocessing method, using local bleeding at semi-stop joints, was elaborated.
The pipe is kept under nominal pressure for avoiding H_2 bubbles generation in the pipe. While collecting oil, continuous elimination of H_2 is made according specific security requirements.
2 exemples are related. Advantages of the method are discussed.

KEYWORDS

HPOF pipe-type, oil-static, hydrogen, security, oil reprocessing.

INTRODUCTION

Since 2002, systematic DGA (Dissolved Gas Analysis) were processed on RTE oil-static lines. Numerous lines showed hydrogen rates in oil much higher than solubility level at atmospheric pressure. In case of pressure fall in the line, free gas generation within oil can make operating hazardous and be prejudicial to dielectric strength, even when paper dielectric qualities are still very good. For operating these lines further in satisfactory conditions, excess hydrogen has to be eliminated. This article describes a method for bleeding locally the gas loaded oil. RTE choose this method preferably to complete draining and refilling of pipes.
Because of the wide range of explosivity for air-hydrogen mix, the process pays special attention to security. First experiences are described.

OIL-STATIC LINES SURVEYING AT RTE

RTE operates 254 km of 225 kV oil-static HPOF pipe-type lines (53 lines), from 30 to 50 years old.
In this technology, cables are insulated with paper layers, impregnated with viscous oil. The three phases are set in a steel-pipe, filled with semi-fluid oil, and kept under nominal pressure of 15 bars. Partial discharges (PD) easily occur between paper layers, and produce deterioration of the impregnation-compound, giving decomposition gases. These gases pass through papers, and are collected in compression oil.
Nature and amounts of decomposition gases mainly depends on PD energy level. PD energy level seems tightly related with operation temperature, and so, with thermal characteristics of surroundings. Other parameters certainly interact, such as quality fabrication, nature and ageing of impregnation-compound, thermal decomposition of oil and paper. Anyway, energy level is limited, as paper is destroyed over 350℃ (660℉).
At low energy levels, PD creates very preferentially H_2.

In opposition with many pipe-type cables (mainly in the USA), where oil is circulating, and can degas spontaneously at the pressurization station, RTE pipe-type cables were conceived without oil circulation (oil-static). The pipe is a closed volume, which collects all gases produced within insulation, from the beginning of the line.
Since 2002, systematic DGA, using EDOSS method, are processed on samples taken at semi-stop joints of all oil-static lines. Most lines have already been sampled, and about 30 lines have been interpreted. Results are varying, but, globally, H_2 amounts are by 100 to 1000 times higher than all other gas amounts. Very often, H_2 is the only sign of activity on the line.

GLOBAL ANALYSIS OF DGA RESULTS

Global analysis points out that H_2 moves very easily, and is accumulated at highest points of the line. This phenomenon is active even far below solubility level in oil, and must be taken into account for interpreting DGA results. Hydrocarbon gas are much more static.
H_2 is very easily produced, and is also much less soluble than hydrocarbon gas (70 000 ppmv at atmospheric pressure, vs 300 000 for CH_4, and 2 800 000 for C_2H_4 or C_2H_6). Solubility in oil is roughly proportional to pressure.
Usually, even the highest rates observed for H_2 (over saturation level of chromatograph : 500 000 to 700 000 ppmv) stay dissolved at operating pressure. All other decomposition gases rates are 10^2 to 10^5 times lower than solubility at atmospheric pressure.
Nevertheless, when the line is put out of pressure, H_2 bubbles will be generated within oil, come together and accumulate in higher points of the line. Big gas bubbles will form, which will not dissolve back when pressure returns.
This bubble generation was observed several times. In one case, a big bubble (trapped in the middle of a long flat section) led every morning to disruption through “low pressure” protection relay, when minimum electrical losses caused the bubble contraction. This problem could only be solved by bleeding gases.
In another case, a dielectric flashover happened in a place where free hydrogen was found. This was interpreted as ionisation in non-impregnated gas-filled bubbles between paper layers, which could not be compressed properly by external hydrogen pressure.

In any case where paper-ageing investigation could be processed, analysis revealed no significant ageing (Mean Polymerisation Degree (MPD) usually > 900. By exception, 600 was found ounce), even for lines where high amounts of gas was known.

That is why we think that elimination of excess gas (mainly H_2) would be sufficient for increasing significantly operating reliability and prospective life duration for oil-static lines.

CONCEPTION OF A SECURE PROCESS FOR LOCAL GAS-BLEEDING

Oil reprocessing in an oil-static line by complete draining and re-filling is long, difficult and expensive (oil content is 13 000 l/km), with special difficulties, according to the line profile (longitudinal section). Unavailability duration could not fall under 4 weeks, with no intermediate possibility for returning in operating condition Moreover, when line contains large H_2 amounts, pressure drop is sufficient for generating uncontrolled H_2 bubbles in the pipe, breaking oil continuity and creating explosion hazards when draining.

That is why a local gas-bleeding process was elaborated, where pressure is kept near operating pressure, for avoiding bubble generation in the pipe.
Because of the wide range of explosivity for H_2 mixed with air (about 4 - 75%), special attention was given to security in eliminating hydrogen, by adapting a technique coming from natural gas transmission.

Oil collecting

To be re-processed, oil must be collected in a clean receptacle, protected from moisture. Because of high H_2 contents in oil, and possible free H_2 bubbles, receptacle atmosphere must be oxygen-free.

Line is kept under nominal pressure. Oil is collected at a semi-stop joint, through an adjustable pressure-regulated valve, which stops oil-flow when pressure drops below 10 bars at the highest point of the line (profile of the line must be known). If such a valve is not available, oil-flow can be adjusted manually, using a manometer. As a matter of fact, pressure depends on oil-flow, but keeps steady as long as oil-tap is opening. When turning off the tap, pressure oscillations may occur , essentially depending on the mass of moving oil. In order to avoid opening of security-valves along the pipe, it may be necessary to stop oil-flow slowly, and by steps.
Oil flows to the collecting tank through a transparent flexible gas tight pipe, armoured with glass-fibre. This way, degassing of oil can be estimated visually.

Management of freed gases

The collecting tank is gas-tight. Inside the tank, a low-pressure (relative pressure of 0.05-0.10 bar) of dry Nitrogen is maintained an regulated. The tank is protected against over-pressure by a security-valve, rated at 0.2 bar (relative). To prevent H_2.accumulation and growing pressure in the tank, we use a process created by natural gas transmission operators : H_2-N_2 mix is continuously extracted from the tank, using a Venturi-effect extractor, fed by an air-compressor. By hydraulic effect only, without motor nor rotating parts or hot points, the mix is extracted, diluted with air from the compressor far below H_2 explosivity level, and blown out through a rigid pipe 2 m above the working area.

Figure 1: Oil collecting device

Oil reprocessing

Compression oil is a stable paraffinic oil. It is not submitted to dielectric constraints, kept away from oxygen by the pipe, and stay below 65℃ (149℉). There is no reasons wh y oil dielectric characteristics should be modified, excepting decomposition gases of impregnation compound. Putting

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apart CO, CO_2, and water, paper decomposition products may be neglected in this range of temperature.
As long as oil is collected properly, it can be re-processed and put back in the line. Reprocessing is limited : oil is filtrated, warmed up to 75℃ (167℉), then gases an d moisture are extracted through vacuum-pumps. No DGA are made on reprocessed oil, but reprocessing is considered complete when vacuum drops down to 0.1 Torr. By 200 litre batch, this is usually obtained in 30 to 60 minutes , according to gases dissolved in oil. Continuous extraction of gases, while collecting oil, makes re-processing easier, as most part of gases over solubility at atmospheric pressure are extracted.

Each operational team is equipped with an oil processing unit which can reprocess 2 000 litres / day.

Reprocessed oil is put in the compensation-tank of the pressurizing station, then re-injected in the pipe. This way, new oil quantities to buy, and old oil quantities to eliminate, are minimized.

Works organisation

Usually, oil-collecting points are set in public property area (footpath or roadway). In order to minimize constraints on public circulation and increase the works mobility, all parts of the oil-collecting works are set on a truck platform (12 to 15 m² are enough). Every morning and night, connection or disconnection to the pipe are quick (about 1/2 h).
For bleeding efficiently gas-loaded oil, oil must be pushed towards the collecting point. Moreover, it is better when oil go upwards, not to oppose natural move of hydrogen. According to the line profile, it may be necessary to push oil from the line end opposite to the pressurization station. In this case, a mobile station must be used, instead of the permanent one. When line profile goes up and down, it may be useful to change several times injecting and collecting points.
Anyway, when line is long, the best way to cut down pressure oscillations when stopping oil-flow is to minimize moving oil quantities by pushing oil from one semi-stop joint to the next.
If required by the network operator, the line can return to operating conditions in about 4 hours, as nominal pressure was kept all the time. Earthing devices just have to be removed at both ends of the line.

PROCESS USE EXEMPLES

Cretaine-Tolbiac line

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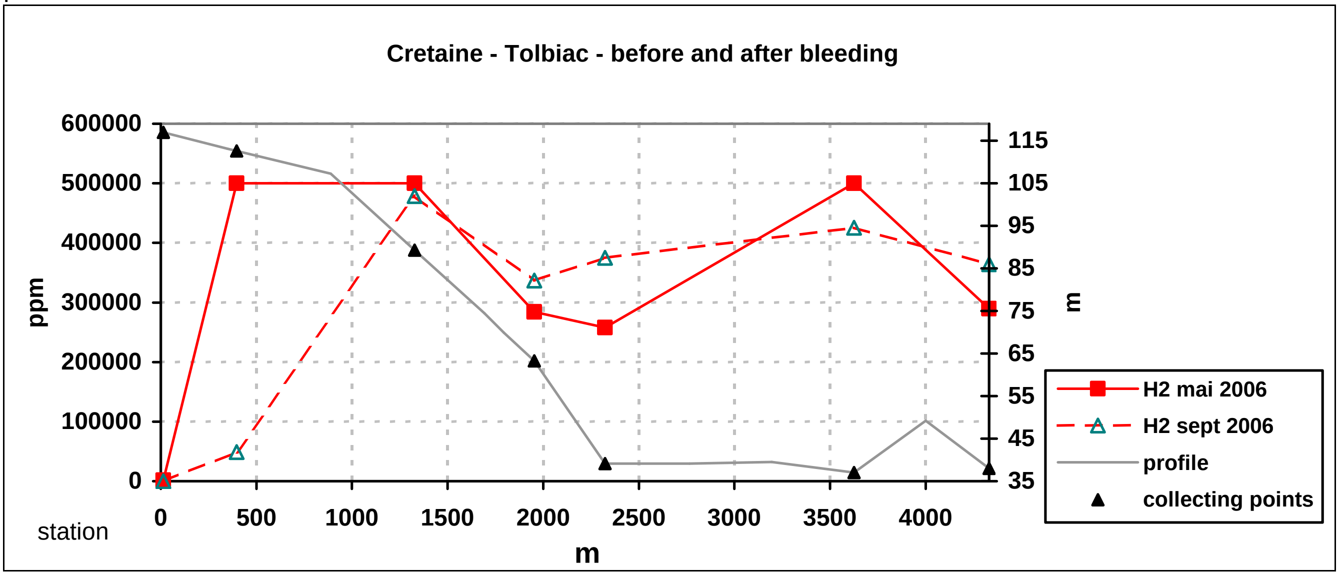

Figure 2: Profile and H2 amounts along Cretaine-Tolbiac line

DGA results showed that the line contained large amounts of H_2 (7 times over solubility at atmospheric pressure), at any sampling point. Total H_2 content was estimated at 1/3 of oil volume. If pressurization would fail, free gas generated within oil would increase oil volume far over the expansion volume available in the station tank. Free H_2 in terminations would probably drive to further internal flashover. The terminations of this particular line are set in GIS compartments, where gas-bleeding is specially difficult.
Lowering global gas amounts was essential.
For network operating reasons, line unavailability could not exceed 1 week. Gas-bleeding was only partial.
In the figure above, pressurizing station is on the left. Gas

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bleeding was complete at the first semi-stop joint (400 m from the station), and only partial at the second one (1 300 m from the station). Total oil bleeding volume was 4 500 l (corresponding to 350 m pipe length). Eliminated H_2 was estimated to 2 m^3.

Ampere- St Ouen 2 line

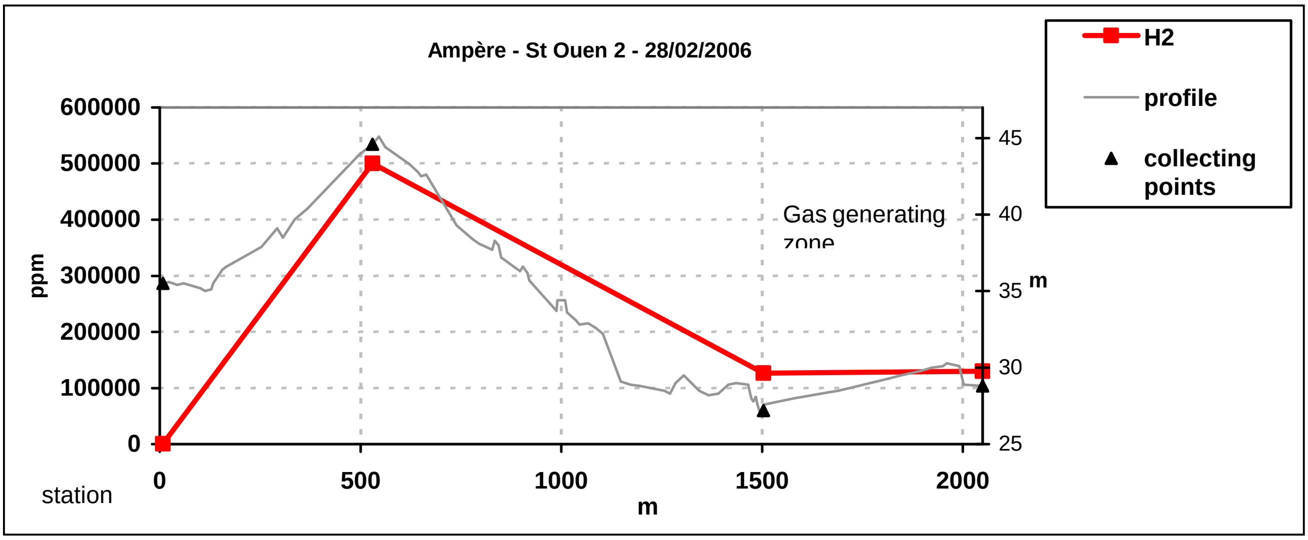

Figure 3: Profile and H2 amounts along Ampere-St Ouen 2 line

DGA interpretation showed a gas-generating zone, due to proximity with a steam duct. Generated H_2 is collected at the highest point of the line, where H_2 rates are 7 times over solubility at atmospheric pressure. As the gas generating zone is at the opposite end of the pressurizing station, bleeding efficiency made necessary to use a mobile pressurizing station. All gases over solubility at atmospheric pressure were eliminated in the line. For better efficiency, bleeding and injecting points were changed several times.

Line was restored into service after 3 weeks . Total oil bleeding volume was 15 000 l (to be compared with the total oil content of the line, which is 26 000 l)

CONCLUSION

More and more oil-static lines prove to contain excess H_2, and should be reprocessed soon. The method presented in this article is an alternative solution to one-shot reprocessing, by draining and refilling all the pipe. It proved to be efficient and secure.

Security apart, main advantages of the method are :

- Reprocessing can be partial, when only a section contains excess gas. Process can be stopped as soon as no excess gas appears when bleeding
- Unavailability of the line is reduced, and line can be restored into service in less than a day, if necessary
- The process can be operated by normal cable maintenance teams, without special heavy equipment.

GLOSSARY

DGA : Dissolved Gas Analysis
EDOSS : EPRI Disposable Oil Sampling System. This sampling method uses vacuum vials, with rubber seal. Samples are collected through a syringe needle piercing the rubber seal, without gas losses and air contact. Vials can be put directly in chromatograph device.
HPOF pipe-type : High Pressure Oil Filled cable. The 3 phases, insulated with Impregnated Paper, are set in a steel pipe, which is filled with pressurized semi-fluid oil.
PD : Partial Discharge.
ppmv : parts per million in volume, i.e. µl of gas at atmospheric pressure , 20℃, per litre of oil