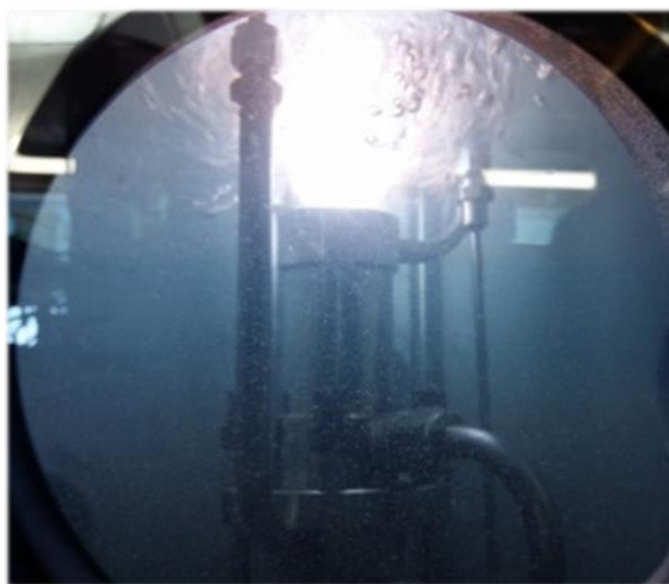


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**ELIPSE : An innovative process for plasma
mineralization of liquid radioactive organic waste**

Introduction

The operation of nuclear industry facilities and the clean-up and dismantling of end-of-life facilities generate significant quantities of radioactive waste, the management of which poses a major challenge in economic, regulatory, environmental, societal, and industrial terms.

The French industrial process for treating radioactive organic liquids (ROL) is incineration at Cyclife's CENTRACO facility, located at the Marcoule nuclear site. However, a significant portion of this waste does not meet the acceptance specifications for this process, given certain radiological and/or physico-chemical characteristics. As such, it constitutes radioactive waste with no immediate disposal option, which is stored at various sites throughout France.

This is the case for oils and various organic liquids held by Andra and producers of radioactive waste such as CEA, Orano, EDF, and Framatome, as well as various research centers and hospitals. For these, treatment processes still need to be defined in order to make them compatible with existing or future channels.

The ELIPSE process is specifically designed to address the issue of treating contaminated organic liquids with two main objectives. On the one hand, it aims to develop a process capable of mineralizing a wide range of liquids, which have the particular characteristics of being both exothermic and corrosive, and on the other hand, it aims to develop a capacitive and compact process.

The ELIPSE process

The ELIPSE process is based on an innovative concept and a major technological breakthrough: the use of thermal plasma fully immersed in a reactor chamber filled with water. The principle of the process is therefore based on the injection and combustion of an organic liquid at the heart of a high-energy plasma, leading to the complete mineralization of organic molecules. The resulting degradation products (gases, liquids) are instantly drowned in the aqueous solution that immerses the plasma source. This design gives the process multiple advantages:

- It is a generally cold process since the combustion gases are instantly quenched by the solution.
- The gas treatment system is reduced to the water column, which provides cooling, filtration, and gas scrubbing.
- The process is compact, with the plasma torch enabling high power density to be achieved in a small volume.
- It is a versatile process designed to treat several types of mineral-laden effluents (phosphorus, chlorine, fluorine, etc.).

The process is covered by two patents and is the result of some 20 years of development, initially in academic collaboration with the Limoges Plasma Chemistry Laboratory (2002-2012), then through own CEA financing (2013-2016) and through the BPI's future investment programs via the MILOR project (2017-2022) and currently the ECCLOR project (2023-2027).

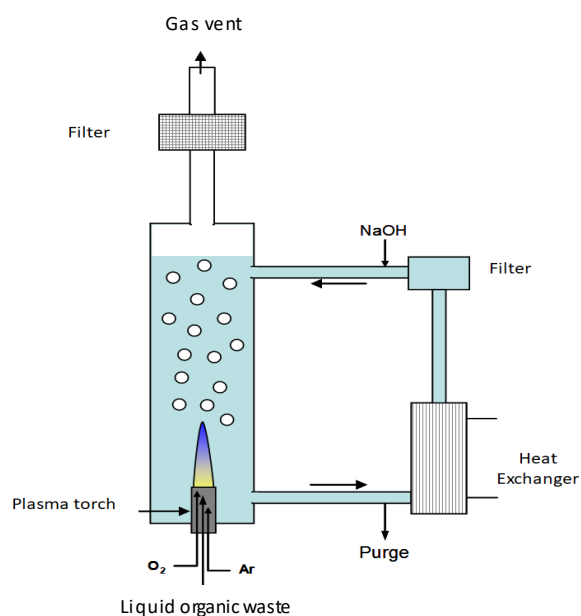


Figure 1 : Schematic diagram of operation



Photo 1 : ELIPSE test platform

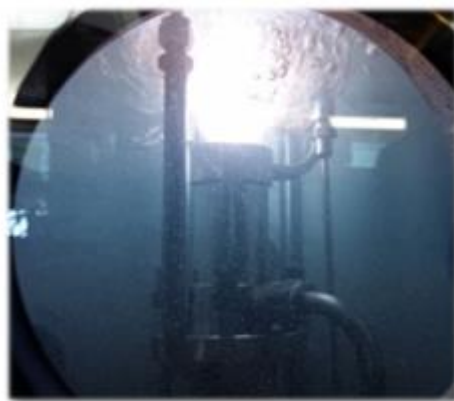


Photo 2 : Immersed plasma

Major results

From a process performance perspective, the mineralization efficiency of the ELIPSE process for a wide variety of LOR families has been demonstrated, and this at significant flow rates considering the size of the reactor skid. The main results are presented in the table below:

Waste type	Treatment capacity	Chemical limits
Organics CHON	4kg/h max	
Organophosphoride compounds	4kg/h max	7%wt. P
Organochloride compounds	2kg/h max	20%wt. Cl
Organofluoride compounds	2kg/h max	6000 ppm F
Organosulfur compounds	4kg/h max	35%wt. S
Organic oils	1kg/h tested	
Mineral oils	1kg/h tested	

In these cases, the destruction rates of ROLs are almost quantitative, since the combustion efficiency balance is greater than 99.9% and the organic carbon destruction rate is greater than 99%. For heteroatoms, the trapping balances are greater than 95%.

In terms of endurance testing, it is worth noting the mineralization test of 100 L of a TBP/dodecane mixture (30/70% vol) at a constant flow rate of 3.2 L/h was successful. For this test, there were a total of 32 hours of feeding, and the test was conducted in two 8-hour shifts. The other major results of this test are:

- The volume balance is very attractive, since the volume of aqueous effluent at the end of the campaign for the mineralization of 100 L of mixture is 145 L (factor ~ 1.5).
- that the process is remarkably stable,
- that the ELIPSE process is advantageous and safe during the start-up and shutdown phases of the process, due to the rapid ignition and shutdown of the torch and the absence of residual heat once the plasma is extinguished.

This demonstration brings the ELIPSE process to a level of maturity that positions it as a relevant and effective technological solution for addressing the issue of managing LORs without immediate processing.

From a technological development perspective, the core of the process focuses on the design of the torch and plasma nozzle and on controlling its operation underwater. The operational experience and knowledge acquired over 20 years of research have enabled the development of robust technology and proven materials.