THE EDDITh THERMOLYSIS PROCESS

A GROUND-BREAKING SOLUTION FOR CLEAN TREATMENT OF WASTES

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LE PROCÉDÉ DE THERMOLYSE EDDITh

UNE SOLUTION INNOVANTE POUR UN TRAITEMENT PROPRE DES DÉCHETS

Les réglementations en vigueur relatives aux rejets atmosphériques des incinérateurs et la volonté des pouvoirs publics de supprimer les décharges dès le début de la prochaine décennie conduisent à une forte demande en installations neuves. Les régions qui pratiquent encore la mise en décharge devront s'équiper d'usines de traitement ad hoc et les incinérateurs construits il y a plus d'une vingtaine d'années devront souvent céder la place à des unités plus performantes répondant aux exigences du législateur. Au total, plus de 200 installations nouvelles devraient voir le jour d'ici dix ans rien qu'en France. Les perspectives de marché sont encore plus grandes en Europe, puisque le problème de l'élimination des déchets se pose sensiblement dans les mêmes termes dans les pays voisins.

THE EDDITh THERMOLYSIS PROCESS

A GROUND-BREAKING SOLUTION FORCLEAN TREATMENT OF WASTES

The current regulations concerning atmospheric pollutant discharge by incinerators, and the determination of public authorities to do away with waste dumps as of the beginning of the next decade are leading to a heavy demand for new installations. Areas which still use the dump method will have to equip themselves with purpose-built plants, and incinerators built more than twenty years ago will in many cases have to make way for more efficient units which meet the requirements of the legislators. In all, more than 200 new installations should be erected within the next ten years in France alone. The market prospects are even greater in Europe as a whole, since the problem of waste disposal exists under very much the same conditions in neighbouring countries.

EL PROCEDIMIENTO DE TERMÓLISIS EDDITh

SOLUCIÓN INNOVADORA PARA UN TRATAMIENTO LIMPIO DE LOS RESIDUOS

Las normativas vigentes, relativas a las evacuaciones atmosféricas de los incineradores y la voluntad de los poderes públicos consistentes en suprimir los vertederos desde principios de la próxima década conducen a una intensa demanda en cuanto a nuevas instalaciones. Las regiones en que aún se sigue procediendo a las descargas en vertederos, deberán equiparse con plantas adecuadas para el tratamiento de residuos y desechos y los incineradores construidos hace ya más de unos veinte años

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deberán ser sustituidos por unidades de características superiores y que respondan a los requerimientos de la normativa. En total, más de 200 nuevas instalaciones se deberán implantar de aquí a diez años, nada menos que en Francia. Las perspectivas de mercado son aún mayores en Europa, ya que el problema de la eliminación de los residuos se plantea de forma acuciante en los mismos términos al tratarse de los países vecinos.

INTRODUCTION

Although incineration is today the only means of satisfactorily meeting the needs of large conurbations, the situation is much more flexible where refuse treatment in rural or moderately urbanized areas is concerned, or in the case of ordinary industrial waste disposal. In these areas, the social and economic context is different from that in the big cities, as are the possibilities of energy recovery. This is the analysis which led to the EDDITh process for thermolysis of refuse, developed jointly by *THIDE Environnement* company and *IFP*, with the financial assistance of *ADEME* and of *ANVAR*, and the technical assistance of *CEA*.

1 BRIEF REVIEW OF TERMINOLOGY RELATING TO THERMOLYSIS

Thermolysis[1] is an operation which consists in heating a hydrocarbon-containing feedstock in the total absence of oxygen, with the objective of obtaining coke, oil and dry gases. By appropriate regulation of the operating conditions, it is possible to maximize the production of one or other of the phases, or to modify the quality of the products obtained. Gasification clearly differs from thermolysis, since it uses a certain amount of air (sub-stoichiometric) to ensure the complete conversion of the hydrocarbon-containing feed into combustible gases. As to incineration, this is carried out with considerable excess air.

Thermolysis is thus a process based on a very simple principle and it has been used on a large scale by mankind since time immemorial, first on biomass, then on fossil fuels like coal and oil, and, soon, on refuse which now represents a far-from-negligible source of hydrocarbon-containing material [1]. Obviously, the constantly increasing demand for product quality and energy efficiency implies that thermolysis no longer means simply heating in a retort, which is the way it was practised in very ancient times. Processes such as the EDDITh process are very technical, and physical and chemical treatment of the feeds and products is associated with the actual thermal treatment.

2 OBJECTIVES

In developing the EDDITh process, *THIDE Environnement* company and *IFP* aimed at finding the

(1) The term pyrolisis may also be used since it is identical from the chemical point of view.

best solution to the economic and environmental constraints of local authorities and industrialists faced with the problem of waste disposal. Consequently, the goals of the two partners were:
– to reduce treatment costs, despite increasingly stringent specifications and regulations;
– to avoid the production of flue gas treatment residue, which has become extremely expensive to stabilize and store;
– to avoid the production of bottom ash, for which there is less and less use;
– to produce a multi-purpose tool capable of treating a very wide range of waste materials, both domestic and industrial;
– to produce a tool which is sufficiently flexible to cope with severer legislation on pollutant emissions into the atmosphere;
– to make the best possible use of the energy content of refuse, both in time and in space;
– to develop a product which is easy to export because it can be adapted to waste upgrading schemes other than those used in France.

3 PROCESS DESCRIPTION

The outline of the process for the treatment of municipal wastes is shown in Figure 1. It comprises three main stages:
– waste pretreatment,
– thermolysis stage,
– treatment and storage of the fuel obtained.

3.1 Waste pretreatment

The waste is first of all roughly shredded to prevent objects larger than 15-20 cm from entering the thermolyser. Then, ferrous metal is removed and the waste is dried. These steps are carried out with the facilities conventionally used in the waste treatment sector.

3.2 Thermolysis

The dried waste is fed into a rotary kiln indirectly heated by flue gases. Thermolysis is performed at a temperature between 400 and 600°C, in the complete absence of oxygen and at atmospheric pressure. The residence time of the waste in the kiln is 45 min. While in the kiln, the waste is thermally cracked, resulting in the formation of solid residue and gas.

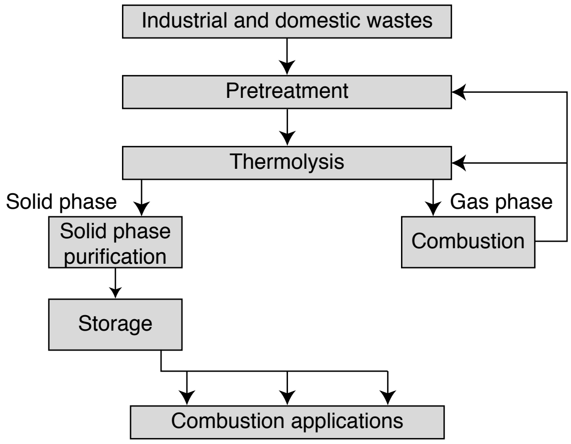

Figure 1

General outline of the process.

The gaseous phase, which contains both dry gases and substances condensable at ambient temperature, is extracted from rotary kiln and burned without further treatment in a combustion chamber adjacent to the thermolyser.

The flue gases formed are used both to heat the kiln and to dry the damp refuse. The solid phase is withdrawn from the thermolyser through an air lock.

The combination of kiln + combustion chamber, which is fundamental to the process, was studied in detail by *IFP* and *THIDE Environnement*. Seals were the subject of particular attention in order to avoid either release of combustible gas or penetration of air into the rotary kiln.

It should be noted that, unlike other processes, the fact of operating at around atmospheric pressure prevents from risks of explosion, while still allowing the required quality of product to be obtained and faster heating of the feed.

3.3 Solid phase treatment

The solid phase, which is similar to coke, is first fed into a stirred container filled with water for removing the majority of the chlorine compounds, and for cooling.

The cooling stage also separates some of the inert mineral material such as gravel, glass, non-ferrous metals, etc., which are recovered and washed for possible recycling. The coke, in suspension in the water, is then re-treated by crushing and washing, to reduce the chlorine content still further. The final operation consists in filtering and drying, producing a fuel with around 20% moisture content, known commercially as CARBOR. The water used for the treatment of the solid phase comes mostly from the drying of the refuse, and can be recycled after appropriate treatment.

This is the basic process scheme. It can be readily modified if required by the proposed use of the CARBOR, or if importance is placed on recycling certain mineral fractions. For example, aluminum, which has not been oxidized during residence time in the thermolyser, can be easily recovered by methods commonly used in some types of waste treatment.

About ten patent applications for the EDDITh process and a number of its possible variations have been registered in France and abroad.

4 PROCESS DEVELOPMENT

After the promising tests carried out in the laboratories of *IFP* and *CEA*, *THIDE Environnement* and *IFP* decided to build a pilot unit which could treat up to 500 kg/h of municipal wastes. The pilot unit was built at Vernouillet (Eure-et-Loir) in 1992 and operated for more than 16 months. In all, several hundred tons of municipal wastes from the town of Laval (Mayenne) were treated.

While working on the pilot unit, the *IFP* also developed a computer model to simulate the thermolyser. The model describes all the thermal and chemical processes that take place in the rotary kiln and was validated by the results of the pilot unit (Fig. 2). It is now used for designing and optimizing future industrial units.

IFP has also prepared a process book for a municipal waste treatment plant with a capacity of 40 000 t/year. The process book includes complete material and energy balances. All the equipment has been selected and the unit control strategy has been decided. The process book includes the cost estimation of municipal waste treatment by the EDDITh process.

THIDE Environnement started marketing the process in 1995 and has been successful in having the new technique recognized by several regional authorities in Europe as the best way for processing municipal solid wastes.

5 PROCESS PERFORMANCE

An extensive parametric study was carried out on the Vernouillet pilot unit. The study made it possible to determine, on an industrial scale, the optimum operating conditions for the process in terms of temperature, residence time, heat supply management, gas removal, waste flow rate, feed quality etc. A simplified material and energy balance is shown in Figure 3 and Table 1, for a feed with 15% moisture content. It can be seen that the process is thermally self-sustaining. The energy released by the thermolysis gas

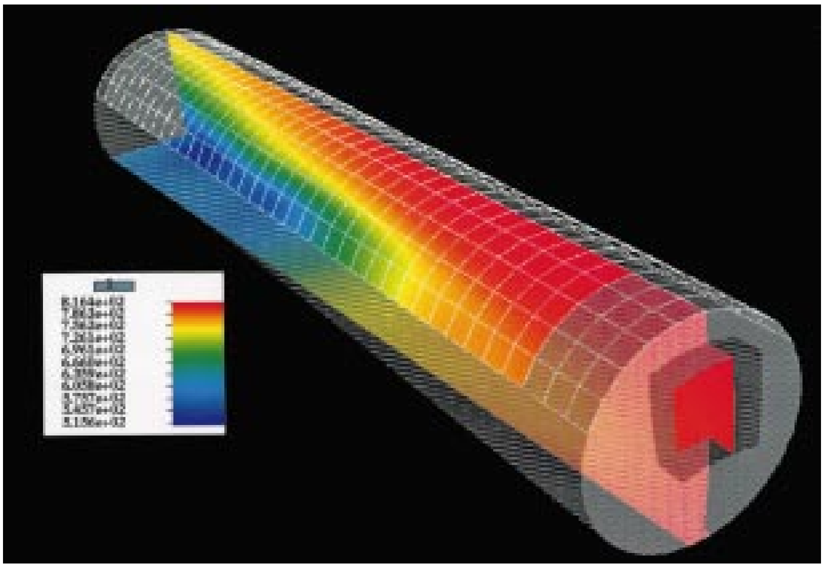

Figure 2

Temperatures (K) in the rotary kiln at the surface of the solid phase and in the gas phase.

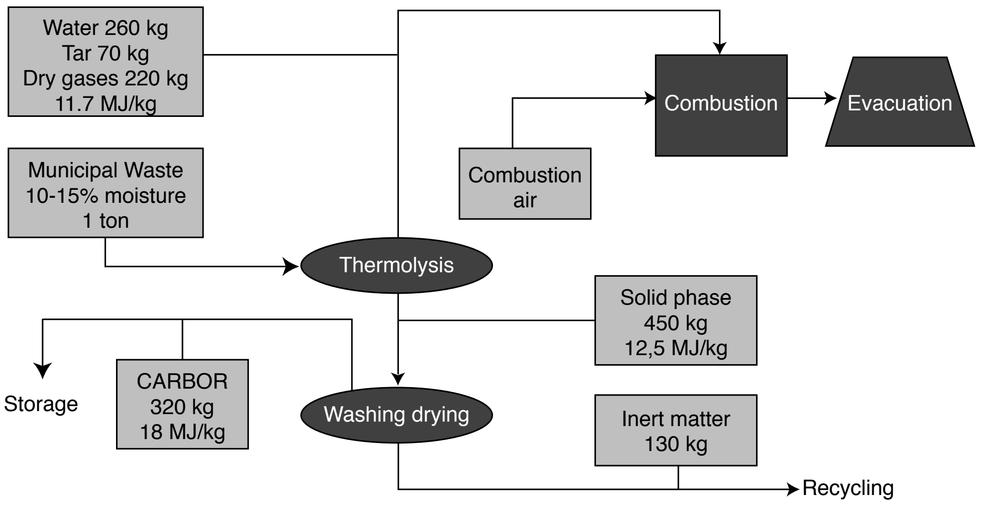

Figure 3

EDDITh process-material and energy balance.

TABLE 1

Material balance

Gas			55%
of which:	water	26%	
	tar	7%	
	dry gases	22%	
Solid phase			45%
of which:	inert matter	13%	
	CARBOR	32%	

TABLE 2

Characteristics of CARBOR

	Proximate analysis	Ultimate analysis
Ashes	38%	
Volatile matter	15%	
Calorific value	18 MJ/kg	
Carbon		50.0%
Hydrogen		1.6%
Nitrogen		1.6%
Sulphur		0.6%
Chlorine		0.5%

is sufficient to supply the needs of the dryer and the rotary kiln. For a ton of municipal wastes, around 240 kg of CARBOR are recovered. The main characteristics of CARBOR are given in Table 2. This fuel has a calorific value of 18 MJ/kg (7 750 Btu/lb) and an ash content of less than 40%. It is homogeneous, with a grain size ranging from a few tens of microns to a few millimetres. It has a low sulphur content and the chlorine content is never higher than 0.5%, a common figure for a number of coals available on the French and European markets.

The mineral matter extracted during the treatment of the solid phase does not contain any carbon-bearing substances. Nor, as analyses have shown, does it contain any pollutant substances, which means that it can be recycled, or failing that, it can be stored in ordinary landfills.

Table 3 shows the pollutant content of the flue gases resulting from the combustion of the thermolysis gases.

TABLE 3

Pollutant content of flue gases produced by the combustion of thermolysis gases

Legislation of 25/01/1991*	Values measured on pilot**
	NO_x^2: 470 mg/Nm^3
	N_2O: 1.6 mg/Nm^3
CO: 100 mg/Nm^3	CO < 50 mg/Nm^3
SO_2: 300 mg/Nm^3	SO_2 < 200 mg/Nm^3
HCl: 50 mg/Nm^3	HCl: 30 mg/Nm^3
HF: 2 mg/Nm^3	HF < 1 mg/Nm^3
Organic compounds 20 mg/Nm^3	Organic compounds < 15 mg/Nm^3
Pb + Cr + Cu + Mn: 5 mg/Nm^3	Pb + Cr + Cu + Mn: 1.6 mg/Nm^3
Ni + As: 1 mg/Nm^3	Ni + As < 0.5 mg/Nm^3
Hg + Cd: 0.2 mg/Nm^3	Hg + Cd: 0.2 mg/Nm^3

* mg/Nm^3 of dry flue gases with 11% O_2.

** 250 mg/Nm^3 expected with suitable low NO_x burner.

The observed levels of pollutant emissions are lower than the limits fixed by the regulations of January 25, 1991, relating to waste treatment installations with a capacity of more than 3 t/h (the most restrictive regulations in France to date). The hydrochloric acid content is particularly low without the addition of any sorbent to the feed. This performance is explained by the self-neutralization of acid components by basic materials present in the waste. The desired effect was achieved by optimizing the thermal profiles in the rotary kiln and by using the appropriate reactor technology. Chlorine retention by the solid phase can reach levels of 97%, which is considerably higher than the results obtained by the conventional dry or semi-dry flue gas treatment units which still equip many plants today. By increasing the basicity of the feed, it is possible to reduce the flue gas HCl content to 5 mg/Nm^3. This result is the highest that can be achieved today by the most efficient flue gas treatment methods, i.e. wet treatment. Since treatment temperatures are low, and thermolysis is performed without oxygen, heavy metals are neither oxidized nor volatilized, except for mercury [2]. However, the cadmium and mercury contents observed at the combustion chamber outlet of the pilot unit do not exceed the legal values. Generally speaking, the heavy metals in the flue gases are essentially deposited on the dust entrained by the gases leaving the thermolyser.

The combustion of the thermolysis gas is carried out in a refractory chamber, under carefully controlled conditions of temperature, residence time and excess air, which guarantees the destruction of all the toxic organic compounds such as dioxins, furans, or polycyclic aromatic hydrocarbons. It should be noted that the unburned content of the flue gases is low compared with that of conventional incinerators.

In short, the flue gases produced by the combustion of the thermolysis gases do not require any special treatment in order to meet legal requirements, except a classic deduster.

6 POSSIBLE USES OF CARBOR

CARBOR has physico-chemical characteristics which make it very similar to certain coals. It has the advantage of having a low sulphur content, compared with many fuels used in industry, such as heavy fuel oils or petroleum residues. CARBOR as it stands can replace fossil fuels in cement kilns, lime kilns, brick kilns, blast furnaces, etc. In all these applications, the use of CARBOR requires no special capital expenditure for storage and handling.

However, these uses do not exactly correspond to the primary objective of *THIDE Environnement* and *IFP*, which is to promote the EDDITh process in low urbanized areas where energy-intensive industries are often lacking. This is why the partners are attempting to develop a more localized use of CARBOR. Work is in progress with COMPTE Company that manufactures small and medium-capacity boilers and with the financial assistance of *ADEME*, to develop a new slagging furnace. The heavy metals present in CARBOR are thus trapped in a vitreous layer which is totally inert with respect to the environment. There is then no longer any need to store the ashes in landfills and they may even be recycled as road building materials. This new furnace has been tested successfully on a 100 kW pilot unit.

The first tests on fluidized bed combustion of CARBOR have also been carried out. The results obtained are very good, with very low emissions of atmospheric pollutants. Analyses performed on the ashes produced by this other type of furnace have shown better lixiviation behaviour than the bottom ash produced by traditional incineration.

Other possibilities for upgrading CARBOR are being explored but are not discussed here. The common goal of *IFP* and *THIDE Environnement* is either to offer users of the EDDITh process adapted solutions for the use of CARBOR.

7 PROCESS APPLICATIONS

The EDDITh process can be integrated into very different waste treatment schemes and thus satisfactorily meet the needs of local authorities.

One possible scheme concerns a plant in which the treatment is limited to the thermolysis stage and the CARBOR is sold to an energy producer. This first scheme can therefore be summed up as conversion of the waste into fuel at low cost. The application of this concept in industry, when there are wastes with a high energy content to be treated, means that thermolysis gases can be used in place of other existing fuels. For the manufacturer, the operation offers two advantages: it entirely solves his problem of waste disposal, and it enables him to substantially reduce his energy costs.

Figure 4
CARBOR: solid fuel produced from waste.

When coal or heavy fuel oil is replaced by CARBOR, there is also very often an environmental benefit, due to the reduction in atmospheric pollutant emissions, especially of SO_2.

A second possible scheme is that of a thermolysis unit associated with a boiler equipped with a molten ash firebox to burn the CARBOR. This approach is very efficient from the environmental point of view. Atmospheric emissions (and aqueous effluents when they exist) are very low in pollutants since they are well within the requirements of regulations. The mineral substances from the refuse are contained in two streams —a stream of inert material and a stream of vitrified material— and the two streams can, when appropriate, be recycled. This is virtually a “zero emission” solution.

Although it is more expensive than the first approach mentioned, it is nevertheless attractive by comparison with incineration.

A third feasible scheme involves a number of thermolysis units located within a given geographical area. The CARBOR produced by each unit is subsequently centralized and burned on a single site, alone or mixed with other fuels and in a medium or high capacity thermal generator. Obviously, this scheme is suitable for a relatively large geographical area, and the end product could be electricity, for example. The first advantage is economic, with a scale effect, since a single thermal generator is used in place of a number of small combustion units.

Another advantage is the fact that the thermolysis units are far less obtrusive than the high-capacity incineration plants, fit into the countryside much better and do not give rise to intensive road traffic. Such units are thus more readily accepted by the population.

The EDDITh process can also be directly integrated into an energy-intensive industrial plant, and can be run by the owner or by an outside company. The CARBOR produced then partly replaces the other energy sources.

8 PROCESS COST

The cost of treating municipal wastes by the EDDITh process is between FF365 (≅ 60 $/t) and FF490 per ton (≅ 82 $/t), for units with a capacity of 20 000 to 50 000 t/year. The cost includes operating costs, unit depreciation and maintenance costs. They are lower than those mentioned for conventional incineration plants in this range of capacities.

This economic performance is explained, firstly, by the relative simplicity of the EDDITh process, although this does not exclude the use of sophisticated equipment that has been intensively optimized. Further, flue gas treatment is reduced to its simplest form, and the pretreatment of the waste before it enters the thermolyser is reduced to a minimum. Lastly, operating costs are reduced because no sorbent is required and the products do not need to be sent to a landfill.

CONCLUSIONS

Today, it would be an aberration to burn crude oil directly in a boiler or an engine. In the course of the 150 years during which this source of energy has existed, refiners have continually improved the quality of fuels by more and more sophisticated crude oil conversion processes in order to facilitate and optimize all types of combustion, from the standpoint of both energy efficiency and pollutant emissions.

This rule has applied to all energy sources and waste will be no exception. Today, waste is incinerated unprocessed and the result, from the combustion standpoint, is mediocre, requiring more and more expensive flue gas and ash treatment in order to comply with regulatory standards.

The EDDITh process fits naturally into this process which tends to favour the combustion stage, since it enables the waste to be converted into a homogeneous, storable fuel with a low pollutant content, similar to existing coals. It also promotes the self-neutralization of pollutant elements present in the refuse, and this potential is ignored by incineration.

From the economic point of view, the EDDITh process confirms a fact observed many times in the past in different contexts, which shows that the best approach is to find the solution to the problems of pollutant emissions directly during the combustion stage, rather than make do with a low-performance combustion stage followed by effluent treatment.

In short, the EDDITh process constitutes a new approach to the treatment of municipal and industrial wastes. It is aimed at all local authorities and all industrials who are particularly interested in cost control, savings in energy and raw materials, the impact on the environment, the flexibility of the equipment and its acceptance by the local population.

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