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INTEGRATED APPROACH OF ENVIRONMENTAL ISSUES IN INDUSTRIAL COMPLEX TREATED AS COMPLICATED OPERATED MACHINE

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Abstract

Refining, petrochemical and energy industry are examples of influence on all environment components. Uncontrolled imposing new stricter burdens and legal requirements may cause the lack of expected results in reducing their impact on the environment. Moreover, effects may be counterproductive. Simultaneously, companies have to balance between legislative challenges, social expectations and technical possibilities, paying special attention on Corporate Social Responsibility (CSR), sustainability and biodiversity. During the Fifth Refinery Forum in Brussels, representatives of the European Commission admitted that legislation laid down within the European Union in the years 2000-2012 lowered the competitiveness of European refining industry. This status is proven by the analysis of refining industry prepared by The Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, and Joint Research Centre [1]. Weakening demand for fuels, lack of opportunities for increasing the capacity of European refineries (permanent shutdowns) and shale revolution cause a number of challenges including environmental. Therefore, it is necessary to take into account all factors mentioned above, and an integrated approach to environmental and climate protection in the face of changing legal regulations becomes crucial. This article proposes a new integrated, model approach to all issues connected with environmental protection in refining, petrochemical and energy complexes. In simple words, such complexes require maintenance shutdowns, repairs, overhauls. In addition, in the process various forms of energy is used and converted, so we can talk about the "exploitation of high thermodynamic machine".

Keywords: *integrated environmental approach, the thermodynamic machine*

1. Introduction

Any activity, especially industrial one, is strongly linked to the environment within it operates, regardless of its scale and sort of production. Direct and indirect impact on the environment can be easily noticed on many levels. These aspects interact each other and they must be considered during decision-making process, especially regarding the expansion and development of the industrial sector. Thus, it is important to use an integrated approach to matters connected with environmental impact of industry complexes. Production of electricity and heat, hydrocarbon processing, production of chemicals results in release of pollutants. Refining processes, e.g. distillation, reforming, cracking, hydrotreatment require a lot energy. Due to the fact that the demand is high and constant, the most reasonable solution is to produce energy based on a conventional (solid, liquid or gaseous) fuels and using own fuels from the distillation and conversions processes of crude oil. Refining and petrochemical industry is characterised by extensive network of interconnections. Some refining products may be used as a feedstock for chemical plants, and by-products may be utilised in energy system in integrated complex. It allows generating savings in transport followed by minimising environmental impact.

In recent years due to technical development, education, and increasing public awareness, this impact is becoming lower and lower. Concepts such as Corporate Social Responsibility (CSR), sustainable development and biodiversity, which have appeared in the strategies of many companies, are combination of social expectations, technological possibilities and legal requirements (especially in the field of environmental law).

Imposition of new stricter burdens and legal requirements may cause the lack of expected results in reducing their impact on the environment. Therefore, it is necessary to take into account all factors mentioned above, and an integrated approach to environmental and climate protection in the face of changing legal regulations becomes crucial.

2. Industry's current situation against a background of environmental law and requirements

During the Fifth Refinery Forum in Brussels, representatives of the European Commission admitted that legislation laid down within the European Union in the years 2000-2012 lowered the competitiveness of European refining industry. This status is proven by the analysis of refining industry prepared by The Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, and Joint Research Centre [1]. Environmental issues arising from continuous, variable and strict policy of the European Union, which wants to be a leader in the fight against climate change. Energy-saving engines in automotive industry, new energy sources, popularity of unconventional fuels contribute to reducing demand for refinery fuels. It is worth mentioning that we also observe no possibility of increasing the capacity of European refineries as a result of permanent shutdown (between 2008 and 2013 fifteen refineries in Europe were closed). Some plants were transformed into fuel terminals, shale revolution (gas and crude oil) is in full swing in the USA, Russian refineries are retrofitted to produce vacuum gas oil (VGO), new investments are postponed due to unstable law, economical crisis and changing macroeconomic conditions. All factors mentioned above are slowly 'killing' European refining industry. It requires operators to take a number of challenges, including environmental. This is widely commented within the reports released by the International Energy Agency (IEA), CONCAWE and FuelsEurope [2-6].

In the coming years, decreasing fuel demand in Europe can mean stronger competition in the market of crude oil processing and fuel distribution where companies with direct access to natural sources seem to be leaders. On the other hand, the increasing competitive pressure on local markets combined with the level of global margins will have a negative impact on margins generated by refining sector. European refineries' strategies assume focusing on increasing flexibility and efficiency by eliminating of bottlenecks, reducing losses, creating possibility of processing many types of crude oil, and maximizing the yield of the most valuable products. It is also important to reduce energy costs (energy costs in Europe equal 60% of OPEX versus 20% in the USA), CO2 emissions, and to optimise energy intensity. Therefore, environmental investments are necessary in building competitive advantage. It has been estimated that EU environmental policy might raise the cost of crude oil processing by $1 per bbl [2-6].

Strict legal requirements and increasing environmental awareness cause that it is very important to look at environmental impact of production units in integrated way. Despite the fact that in Europe attempts are made to treat environmental protection comprehensively (Industrial Emission Directive (IED) combined the previous Integrated Pollution Prevention and Control Directive (IPPC) and six other environmental directives), legislation in this the field tends to be focused on individual components separately (soil directive, Water Framework Directive). Large volume industrial production, in particular, power generation, crude oil refining and production of chemicals are sources of flue- and off-gases. Combustion of different kinds of fuels which may contain, among others, sulphur and nitrogen compounds, metals and other mineral substances result in sulphur oxides, nitrogen oxides and dust emissions. For decades, in Poland, there are legal acts and regulations that establish emission limit values for SO_2, NO_x and dust from combustion plants in which heat and/or electricity are produced. Meanwhile, to be able to actually and honestly assess the impact of industrial production in terms of emissions to air, soil and water protection, and energy input (noise, electromagnetic fields), individual approach (according to regulations mentioned above) seems to be insufficient.

3. An attempt to integrated approach to air emission – bubble concept in REF BREF Reference Document

Recognising the complexity and interdependence of individual (environmental and production) factors, and the need to minimise industry's impact on the environment, maintaining the proper process parameters, integrated approach to air emission was proposed. In 2003, long before IED Directive, Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries [7] was published. The section on integrated refinery management contained a chapter describing the bubble concept. It is a regulatory tool adopted in several EU Member States for common expressing and comparing the level of performance achieved or expected at refinery site level, from a clearly identified set of combustion and process units, and for a given substance or parameter. The idea behind this approach is to replace particular stacks by virtual one stack and establish one emission limit value for each pollutant. According to the provisions of BREF [7], bubble concept concerns mainly SO_2 emission. However, it can also be extended to calculate NO_x, dust, CO and even metals (nickel, vanadium) emissions. As a rule, this approach is an analogy to wastewater treatment plants where only 'end-of-pipe' emission is important. Intermediate emission parameters for particular production processes are irrelevant.

The specificity of refining production leads to the conclusion that bubble concept is justified because of integrated technology and processes. Single units within the refinery complex are rarely operated alone, rather they are combined together in branched technological sequence and they use the distillation and conversion residues, optionally supplemented by natural gas. In practice, coal and lignite may be combusted only in power plants functioning on the refinery site. Such complexes are characterised by technical and economic interdependence between raw materials, kind of processes and changes in various operating conditions in conjunction with the requirements of final product quality. In the face of above-mentioned facts, inclusion of bubble concept in REF BREF document has opened a possibility to create Europe-wide, unified tool for flexible management of emissions on the refinery site by:

- reducing air emissions where it is the most effective and economically viable,
- adequate reaction to changes in the market of crude oil and petroleum products through the optimal selection of energy sources and conducted processes,
- the need to meet one emission limit value, instead of even dozens.

Chapter containing a proposal of Best Available Techniques Conclusions appeared in REF BREF Draft 2, published in March 2012. However, contrary to the industry expectations, it did not include the bubble concept as one of BAT. Nevertheless, bubble was included in the general part of this Reference Document, thus further discussion on the status of the bubble, its assumptions and specific provisions was not closed. During Article 13th IED Forum in September 2013, the European Commission confirmed that the bubble approach can be considered as an integrated emissions management technique in the context of the IED and would be eligible as BAT when certain conditions are fulfilled. Principally to ensure the approach delivers at least an equivalent environmental outcome as the application of the individual unit-based BAT-AELs [7-9].

Finally, bubble concept for SO_2 and NO_x was legally allowed by Commission Implementing Decision of 9 October 2014 establishing best available techniques (BAT) conclusions [8]. In addition, Commission Implementing Decision of 30 October 2014 establishing the type, format and frequency of information to be made available by the Member States on integrated emission management techniques applied in mineral oil and gas refineries [9] was published. Type of information to be made available to the Commission is, among others, as follows:

- general information on installation and its operator,
- list and description of combustion and process units covered by the integrated emission management techniques for SO_2 and NO_x,
- applicable emission limit values for SO_2 and NO_x under the integrated emission management techniques,

– information on the monitoring system and monitoring results.

The information shall be made available to the Commission by 30 September 2020 and it shall cover the years 2017, 2018 and 2019.

General principle of the bubble concept is that emission from installation as a whole must be at least equal or even lower than total emission from individual sources within installations concerned. Furthermore, emission limit values still must be based on application of BAT. In this way in cost effective manner the same or even better environmental effect can be achieved as by applying BAT AELs for single emission sources. Monitoring associated with the bubble should include at least (in addition to the general provisions monitoring requirements for individual pollutants and processes):

– monitoring plan including a description of the processes monitored, a list of the emission sources and source streams (products, waste gases) monitored for each process and a description of the methodology (calculations, measurements) used and the underlying assumptions and associated level of confidence,
– continuous monitoring of the flue-gas flow rates of the units concerned, either through direct measurement or by an equivalent method,
– data management system for collecting, processing and reporting all monitoring data needed to determine the emissions.

Operators can encounter problems, which may arise from the fact that the emissions from major individual units have been determined based on periodic measurements (e.g. 2 times per year) so far. Usage of bubble concept requires at least continuous monitoring of flue-gas flow rate. Other issue is to determine the monthly average emissions of particular substances. For SO_2, an alternative calculation method may be used (based on the sulphur content in the fuel or feed), but in the case of NO_x such methods are much more complicated and require monitoring of other surrogate and complementary parameters [7-9].

4. Integrated model approach to environmental protection exemplified by refining, petrochemical and energy complex

In view of the significant issues mentioned above, and taking into account different attempts to integrated approach to emissions to air, for the refining and petrochemical complex with its own source of energy an integrated approach to environmental management is proposed. It is based on the network of products, raw materials and energy sources, which is schematically shown in Fig. 1. The model assumes that the industrial complex works as a homogeneous thermodynamic machine that converts one form of energy into another, in accordance with the law of conservation of mass and energy (including losses). Therefore, regardless of the level of complexity and number of processes inside the machine, the input-output balance should be maintained. According to this assumption, the model also applies the laws of thermodynamics.

In the case of refining and petrochemical complex, the most important elements, which constitute the essence of its existence, are refining, petrochemical, energy parts. The make it possible to transform feedstock into desirable products, i.e. fuels, chemicals, and utility energy (heat and electricity). In a simple way, three elements may be consider as feedstock – crude oil, other raw materials and energy sources (e.g. natural gas), and water. Depending on the current needs and complexity of the plant, these streams are routed to individual units. Economic and environmental factors favour usage a range of auxiliary modules, among which a key role is played by wastewater treatment plants, waste incinerators or flue-gas treatment units. They do not only allow meeting strict environmental standards, but also contribute to improving the efficiency of processes, e.g. by water recycling or obtaining additional energy from waste incineration. Such auxiliary units in the production cycle cause that flows become more advanced and complicated. Still, as shown in Fig. 2, types of output streams do not change significantly. Only their sources are moved. Foregoing considerations lead to the conclusion that the models presented in Fig. 1

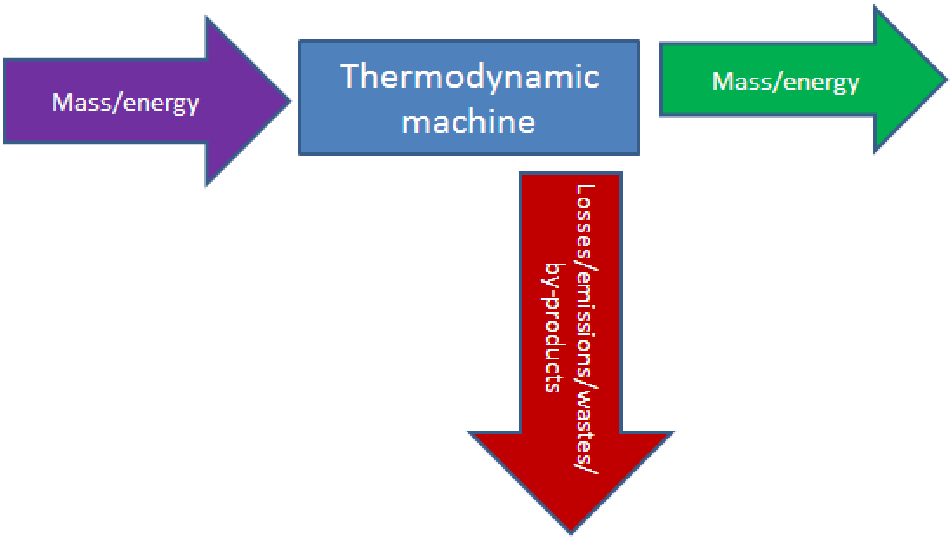

Fig. 1. Simplified model of industrial complex considered as thermodynamic machine

and 2 show the exactly the same. Regardless of how much we extend thermodynamic machine; and how much flows are inside, the final result will be similar with changing the distribution of individual products only (understood as everything, which is the output of the machine).

Abovementioned is evidenced by usage of wet limestone flue-gas desulphurization. It significantly reduces sulphur dioxide emissions to air from combustion units. When it comes to increasingly stringent environmental regulations, this technique is becoming more and more popular. Considering the influence of desulphurisation on only one environmental component (air, atmosphere), formation of significant quantity of solid by-product (gypsum) is not taken into account. Thus, SO_2 abatement is achieved at the expense of other substances, more or less troublesome for management and utilisation.

5. Summary

1. The situation of refining and petrochemical industry against environmental conditions and requirements in the face of challenges and competitiveness is unenviable
2. While building a competitive advantage and positive image of the company, environmental issues are becoming important elements.
3. It is impossible to find waste-free and emission-free processes. They require a large amount of intermediate streams, which allow controlling the quantity and quality of desired and undesired products, based on the thermodynamic laws and mass conservation law.

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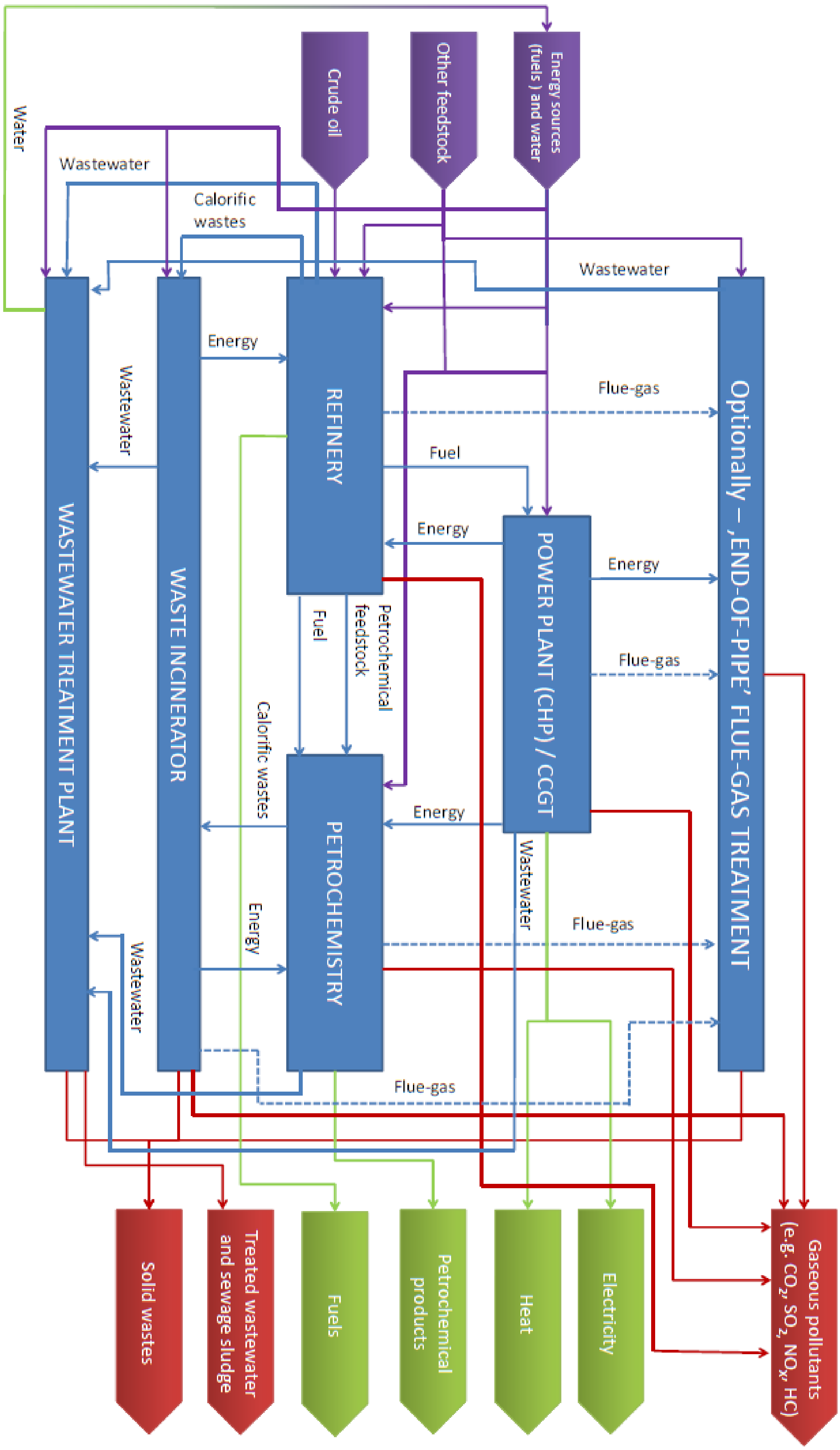

Fig. 2. Model of streams in refining, petrochemical and energy complex