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Leakage Diagnosis of Heat Exchangers in a Refinery by a Radioisotope Labeled Compound

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1. Introduction

Radioisotopes have been used widely for an industrial plant diagnosis for troubleshooting and a process optimization. When plant engineers find abnormalities with a product or a plant itself, it is very hard for them to say exactly which part of the plant makes the major contribution to this situation. They analyze all the data they can acquire for a clue to the cause of the trouble. In most cases, they only find several possible issues to be confirmed. They don't make any decision for any further action without concrete information because it may cause a tremendous loss of benefit.

There are conventional sophisticated and precise technologies that use non-radioactive energy for the same purposes but most of them are only available after shutting down plant processes. As soon as a plant is stopped, the physical and chemical condition of the plant is no longer the same as before the shutdown. In addition, a shutdown procedure requires a significant period of time since refinery/petrochemical plants are operating at high temperature and pressure conditions.

Radioisotope application technology has remarkable advantages over others such as radiography and ultrasonic tests. It can offer information on in-service plant processes without an interruption of an operation and a disturbance to process media. In spite of its advantages, there are challenges with refinery and petrochemical plants operating in a severe atmosphere. The process media is basically organic and it is running through pipelines under an extremely high pressure and temperature. Any small mistake can lead to a disaster like an explosion and massive damage.

Since the final product from the plant under investigation revealed a deteriorated quality, it was suspected that the process has a leakage flow between the upstream and downstream inside the heat exchangers. A radioisotope labeled organic compound was used to establish if there is a leakage inside the heat exchangers for an oil cracking process. The compound was injected through a valve located before the pumping station, generating more than 100kg/cm^2 of a pressure. The temperature around the injection port was as high as 185 degree Celsius.

2. Methods and Results

2.1 Tracing Agent

For tracing organic fluids, p-dibromobenzene labeled with ^{82}Br is widely used as a tracing agent because of its physical stability at a high temperature and its relatively high gamma energy and short half-life. However, under the circumstances that there is no possibility of producing adequate radionuclide for this study from a nuclear reactor, ^{131}I-MIBG, one of the most frequently applied radiopharmaceuticals to diagnose and treat cancers, specifically Pheochromocytoma, was chosen.

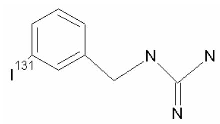

Fig. 1. ^{131}I-MIBG (metaiodobenzylguanidine) used for leakage test study with a heat exchanger process under a high temperature and pressure.

The dimensions of the steel pipelines on which 2×2inch NaI scintillation sensors shielded with 1cm thick Pb collimators were located, were 8inch in diameter and 1inch in thickness. The activity of MIBG was calculated with the help of MCNP software programmed by CEA in France, specifically for an industrial application of radioisotopes. The simulated efficiency of the radiation detection was approximately 1.5×10^5counts·sec^{-1}/Ci·m^{-3}. On the assumption that there is a 0.1% leakage and 30cps would be far enough to distinguish any leakage from background radiation, 200mCi of ^{131}I was injected. Once the tracing agent is injected into the pipeline, it will be mixed well with the process media by means of the pumping station located at the downstream of the injection port.

2.2 Injection and Measurement

Due to the risk of an accidental mechanical problem, a special injection system was designed for minimizing the radiation exposure in the case of an injection failure by using a heavy tungsten alloy as a shielding material and a pneumatic pressurizing manipulator that can withstand up to 150kg/cm^2 and 16kg/cm^2 of pressure, respectively.

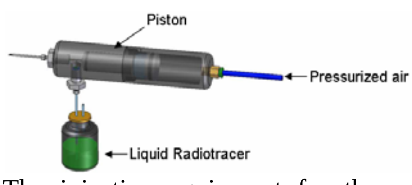

Fig. 2. The injection equipment for the radioactive tracing agent designed for a remote operation.

The responses of the NaI scintillation detectors to the injected radioisotope were recorded with a multi-channel radiation data acquisition system fabricated by the KAERI R&D team. The detectors were installed as shown in Fig. 3 in order to monitor the injected agent in the tube side of the heat exchangers as well as in the shell side that represents a leakage from a high pressure tube side to a low pressure shell side.

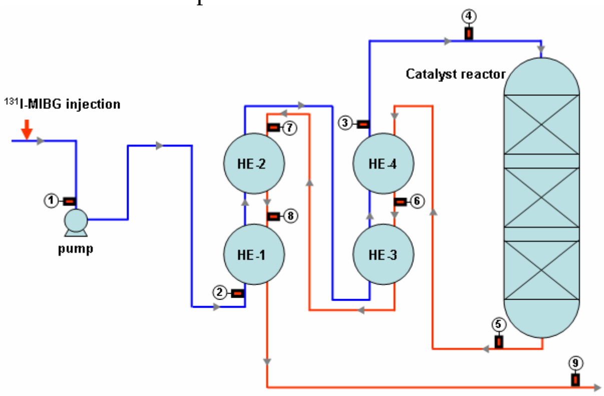

Fig. 3. Schematic diagram of the experiment where 9 NaI scintillation detectors were installed on the tube-side and shell-side pipelines.

2.3 Results

From the responses of detectors 1 and 2 shown in Fig. 4, it is evident that the tracing agent was injected successfully as a pulse, and mixed well in the pumping station. For safety reasons, however, the injection needle couldn't be inserted beyond the valve that is located 5cm above the pipeline and some portion of the agent was trapped inside this space under the valve resulting in the long tails of detectors 1 and 2.

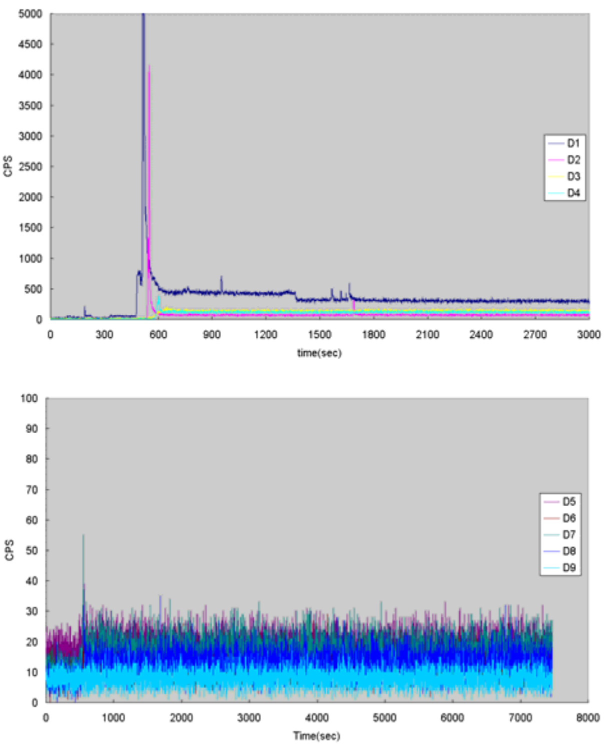

Fig. 4. The responses of the detectors to injection of the radioactive tracing agent.

By measuring the dose rate on the surface of the valve, the radioactivity of the trapped agent was estimated to be approximately 39mCi which is 25% of the total activity. There is no radiation intensity change in detectors 5 to 9 installed on the low-pressure shell side of the heat exchanger process. This implies that there is no leakage inside any of the heat exchangers. The deterioration of the product quality could be accounted for by an other part of the process such as the catalyst reactor.

3. Conclusions

A radiopharmaceutical agent was used successfully to trace an industrial organic flow under a high temperature. The injection equipment operated as planned without a mechanical failure that can lead to a serious problem. The scintillation detectors were collimated and shielded with a lead material and protected from the heat with a light insulator without compromising the radiation detection intensity.

However, a couple of issues need to be discussed. The injection system needs to be modified so that the injection could be made without leaving any trapped agent. A radioactive labeled material should be developed for an organic phase tracing under an extremely high temperature. There is an on-going effort to use nano technology for preparing an industrial tracing agent. It is expected to be able to supply radioactive material that is so stable in the harsh environment of a refinery/petrochemical industry to visualize the dynamic characteristics of process media.

Acknowledgement

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