

Application of Radiation Sources in the Oil & Gas Industry and Shortages in their Services

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ABSTRACT

Oil and gas industry utilize many radiation sources in various applied radiation-based technologies. Those technologies provide significant benefit to the daily operations of the industry. Gamma emitter sources of Caesium-137 (^{137}Cs), Cobalt-60 (^{60}Co) and neutron source Americium-241/Beryllium ($^{241}\text{Am-Be}$) are used in well logging. Barium-133 (^{133}Ba), ^{241}Am and ^{137}Cs sources are used in multiphase flow meters technology at platform of oil and gas production facilities. Gamma sources like ^{137}Cs and ^{241}Am are used in transmitted level gauges for tanks in refineries while X-ray fluorescence (XRF) are used for sulfur gauges in laboratories. Cadmium-109 (^{109}Cd) and Iron-59 (^{59}Fe) are used in alloy analyzers in refineries and workshops. Neutron sources like Californium-252 (^{252}Cf) or $^{241}\text{Am-Be}$ are used in density gauges. Iridium-192 (^{192}Ir) and ^{60}Co are additional examples of routinely used radiation-based technologies in industrial radiography. Bismuth-113 (^{113}Bi) and x-ray machines are used routinely in industrial security. To maximize benefits and minimize hazards associated with utilization of radiation-based technologies, national radiation protection standards are implemented. Utilize of radiation sources is controlled by international and national rules and regulations. The use of radiation sources needs regular services. There are shortages in the needed radiation sources' services within the kingdom. This paper will outline samples of radiation-based technologies used in the oil and gas industry and paying particular attention to shortages in the radiation services needed to the safe handling of the sources that need to be rectified in order to encourage the new radiation sources' users to utilize radiation-based technologies to the industry.

1. INTRODUCTION

For nearly a century, radiation-based technologies have been positively contributing to industry, medicine, agriculture, and research. The use of radiation sources in industry has significantly increased in the past 20 years due to advances in technologies that take advantage of the unique properties of ionizing radiation. Currently ionizing radiation sources are used in many industries, including: automotive, semiconductors, oil, petrochemical, cement, detergents, paper, etc.

Radiation-based technologies are valuable tools and widely used by oil and gas industry, in areas such as oil and gas exploration, production, industrial inspection, refineries, laboratory analysis, security inspection. All equipment, tools and machinery have hazards associated with their use, and radiation-based technologies are no different. It is important to follow proper operating and protection procedures to maximize the benefits and minimize the risk of such technologies.

In dealing with man-made radiation sources, radiation protection objectives are achieved by following the national and international radiation protection regulations. Also by providing continuous radiation services to the sources as per the regulations like leak test, calibration of survey meters, easy importation procedure, maintaining services and available overseas carrier. This paper outlines the useful application of radiation sources in oil and gas industry and highlights the shortages in radiation sources' services that need to be rectified in order to encourage the new and old radiation sources' users to utilize the needed radiation-based technologies to the industry.

2. APPLICATION OF RADIATION SOURCES IN OIL & GAS INDUSTRY

Part of the radiation-based technologies that are used in oil & gas industry are as follows:

2.1 Application in exploration

There are two types of radiation sources used in well logging, sealed radioactive sources and neutron generator sources. Sealed radioactive sources have been encapsulated in a material specifically designed to ensure no leakage or escape of radioactive material. These sources are "special form," which means that the capsule can only be opened by destroying it. Special form sources must comply with stringent international standards and be rigorously tested to ensure compliance with those standards (ISO, 1999). Radioactive sources routinely used in oil & gas well logging operations are:

- Caesium-137 (^{137}Cs), gamma source.
- Cobalt-60 (^{60}Co), gamma source.
- Americium-241/Beryllium ($^{241}\text{Am-Be}$), neutron source.

Neutrons in some logging tools are produced by neutron generators where charged particles are accelerated towards a target impregnated with hydrogen isotopes. Deuterium and tritium ions are principally used in this technique.

Using specialized subassemblies which contain sealed radioactive sources and radiation detectors, information can be attained relating to the following (Abu-Jarad, 2007; IAEA (2005a))

- Formation porosity.
- Formation lithology.

- Estimated shale volume.
- Gas bearing zones.

Measurement while drilling can be performed by using specialist subassembly units fitted to the drill string. These will provide real time information that can be used to assist both drilling operations and reservoir evaluation. Density information is gained from detecting gamma radiation, backscattered from formation rocks and fluid contents (Figure 1). A sealed radioactive source in the tool is emitting gamma radiation to the formation before they are backscattered to the detectors. The radiation passes through the formation and interacts with the medium it comes into contact with. By being aware of typical densities and the backscatter of radiation, the information can be characterized for the particular formation being evaluated. A formation density log is cross plotted against a neutron log for lithology determination and better porosity estimation IAEA (2005a).

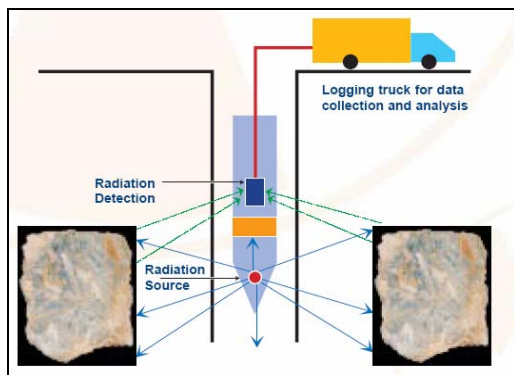


Figure 1: Schematic diagram for the well logging tools including the radioactive sources (Abu-Jarad, 2007)

2.2 Applications in producing

a- Multiphase flow meters (MPFMs)

The radiation-based multiphase flow meter (MPFM) is relatively new technology to Oil industry. MPFMs are used to measure the phase fraction of oil, gas and water in the flow from an oil well. The conventional methods used to measure the phase fraction in the flow for each well at wide intervals that could span over several months. The radiation-based MPFMs provide such information instantly, easing monitoring problems and enabling quick access to data, which allows rapid decisions to be made on well performance. The wealth of data accumulated by radiation-based MPFM can be fed into reservoir simulation codes to enhance their accuracy and reliability. These instruments are installed in remote platforms and working places and moreover, the radiation dose-rate at one meter from any of these instruments is minimal, Scheers (1998).

The operation principle of radiation-based MPFMs is a gamma source (either ^{133}Ba , ^{241}Am or ^{137}Cs) placed on one side of a pipe and a detector on the other. The gamma source is continually emitting radiation and the detector is continually detecting radiation (Figures 2). The liquid which is flowing through the pipe will attenuate the radiation therefore restricting what is picked up by the detector, and by knowing the densities of different liquids/gases information can be obtained on the contents of the material flowing through the pipe. MPFMs are

used to measure the surface flow rate and the phase fraction of oil, gas and water in the flow from an oil well providing instant information about the condition of the production and allowing rapid decision making on well performance. This technique is considered superior to the conventional techniques involving well testing at much longer intervals of days and up to months. Oil industry is making widespread use of MPFM and will be increasing the use of this technology Scheers (1998).

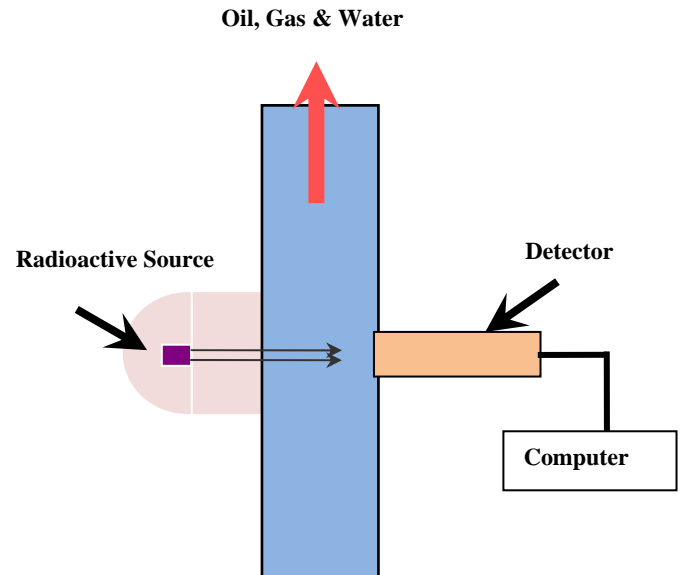


Figure 2: Schematic diagram for the radiation-based multiphase flow meter (Abu-Jarad, 2007)

b- Radioactive Tracers

Radioactive tracers are radioactive liquids which are injected by specialized equipment into selected oil and gas field wells for special reservoir and production evaluation studies by specialist contractors. In this type of operation, small amounts of radioactive materials (like Gold-198 (^{198}Au), Iodine-131 (^{131}I), Antimony-124 (^{124}Sb)) with relatively short half-lives (few days) are injected into the wells to trace the fluid flow in the formation rocks or behind the casing and tubing of the well. After the radioactive material is injected, a spectral gamma ray logging tool is run in the well to detect the fluid movement and the anomalies. The logging information is used to evaluate the formation fractures and reservoir permeability. In some production studies, the logging data is used to determine leaks and behind pipe flow of the casing and tubing of the well.

2.3 Application in inspection of facilities

Radiation technologies are based on utilizing some of radiation's physical properties to yield a useful result. The high ability of gamma and x-rays to penetrate matter is applied in the inspection of structures for weakness and flaws in industrial radiography. Generally in the inspection of facilities radiation sources are used for applications such as:

- Industrial Radiography

- Alloy Analyzers
- Density/Moisture Gauges

Outline of those technologies are as follow:

(a) Industrial radiography

Industrial radiography is an important non-destructive testing (NDT) technique. It is used for the quality assurance of welds during facility and pipeline construction. It is also an important diagnostic tool throughout facility/pipeline operational lifetime used for inspection of welds, valves, and corrosion detection. The cost avoidance and benefits as a result of using this technique are incalculable.

In industrial radiography, highly penetrating ionizing radiation (gamma or x-ray) is used. The radiation is obtained from industrial x-ray.

(b) Alloy analyzers

Metals such as steel are used with various alloys in oil/gas facilities structures, pipelines/tubing and various equipment. The need for quality assurance is present in all phases of the metal's life cycle. The alloy analyzer is an irreplaceable helper in every stage where metal identification is required - fabrication, quality control, incoming inspection, maintenance and failure analysis.

(c) Nuclear moisture-density gauges

Nuclear moisture-density gauges are advanced radiation based technology which provides highly accurate measurements of moisture content, compaction and density of soil and construction materials such aggregate and asphaltine concrete without the use of core samples or other destructive methods. Usually a nuclear moisture gauge contains a gamma radioactive source such as ^{137}Cs and neutron source such as (^{252}Cf) or $^{241}\text{Am-Be}$. The density measurements are based on the attenuation of gamma radiation emitted by a Cesium-137 source due to scattering and absorption of radiation, which are directly related to the electron density of the materials being measured. The radiation detector located in the gauge indicates the mass density of the materials with a chemical composition similar to the earth crust. The moisture content measurements are based on the interaction of neutron radiation emitted by the neutron source with the hydrogen atoms in the materials to be tested. Special neutron detectors located in the gauge detect the scattered neutrons and through microprocessor determines the moisture content in the tested medium.

2.4 Application in Refineries

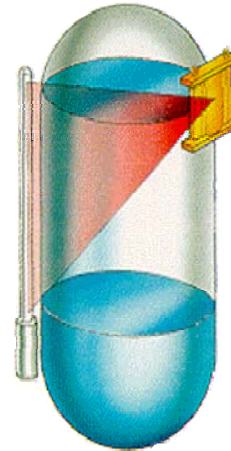
Refineries use radiation sources in applications such as:

- Transmission Level Gauges
- Sulfur analyzers

Transmission Level gauges:

In refineries on-line identification of vessel content is very essential. In this case, the use of nuclear level gauges is the most suitable choice. It has special characteristics: lower cost, ease of operation, and higher performance than other types of conventional gauges. Level gauges are used to measure the level of a liquid or solid in a tank or a vessel. A sealed gamma source is placed at one end of the tank/vessel and a radiation detector is placed at the other (Figures 3 (a)). The source is continually

emitting gamma radiation that is continually being detected by the detector. As the level of the material in the tank changes, the amount of radiation detected will also change, indicating the level of the material within the tank.



(a)



(b)

Figure 3: (a) Principle Operation of Radiation-based Level Gauges

(b) Real Radiation-based Level Gauges at the bottom of a tank (Private ref.)

The change in density caused by the rising and falling of the medium level (liquid or solid) in the vessel to measure its content is reflected in the changes in radiation intensity registered at the detector placed at the opposite side of the radioactive source on the same vessel. The lower the received radiation, the higher the level is, and the higher the radiation, the lower the level is. In certain refineries, nuclear level gauges used to enable control of the catalyst flow through the Catalyst Reactor Regenerator Column by controlling the level in the Disengaging Hopper on top and by controlling the level in the lock hopper below it. Figure 3-b show real level gauge at the bottom of a tank.

Sulfur Analyzer

It is important to determine sulfur content in saleable petroleum products such as gasoline and diesel accurately and rapidly. As environmental regulations become stricter, the need increases for a reliable and robust method for the detection of low levels sulfur in petroleum products. The use of X-ray fluorescence (XRF) analysis has been demonstrated to be a reliable and accurate method for sulfur detection in petroleum products. This direct measurement technique require no sample conversion, consumable gases or high temperature operations. Furthermore, the level of radiation associated with these devices is generally low. This technique is widely used in oil refineries.

2.5 Application in Laboratories

Radiation-based techniques are become more widely used in advanced laboratories. The main advantage of radiation-based technique is its ability to provide the needed information without destroying the sample, accurate analysis results, ease of use, cost effectiveness and rapid data acquisition. Usually, in oil industries laboratories several radiation based techniques are used for various analytical purposes such as:

- X-ray Fluorescence (elemental analysis)
- X-ray Diffraction
- CT Scanners

2.6 Application in Industrial Security

X-ray equipment is commonly used by oil industry to inspect packages for security purposes. X-ray penetrates the package and detected by special radiation detector. The detected radiation carries information about the content of the inspected package. This information is displayed as an image on a Cathode Ray Tube (CRT) screen. Also, ^{113}Bi (beta emitter) source is used as part of drug detector applied for industrial security.

3. Radiation Protection Requirements

Most technologies such as electric devices or mechanical equipment have hazards associated with its use. Following proper operating and protection procedure maximizes the benefits of such technologies and minimizes its hazards. Similarly, radiation technologies are extremely beneficial if used with proper safety precautions, yet can be a potential hazard if used without adequate training or protection measures (IAEA, 2001).

All sealed radioactive sources are manufactured to comply with stringent standards specified in ISO (1999) Sealed Radioactive Sources. This ensures that the radioactive material is wholly encapsulated within a protective capsule and prevents the spread of material from the capsule.

In Saudi Arabia there are established government requirements that control the import, transportation, use, storage, disposal and port of radioactive sources (KACST, 2007). The regulation guided by the international regulations (ICRP, 1990; IAEA, 2005-b).

On the operational side, several requirements must be fulfilled according to National Radiation Protection Authority (NRPA) Regulations. These can be summarized as the following:

- Obtaining a radiation practice license from the government.
- Legal importation of sources after obtaining import permit from the government.
- Availability of written operational procedures.
- Transportation procedure.
- Training radiation workers and presence of certified Radiation Protection Officer (RPO).
- External radiation personnel monitoring.
- Personal Protective Equipment (if needed) such as employees working with open sources.
- Routine Radiation surveys and leak tests.
- Emergency plans.
- Records.
- Good security and control of sources.

To maximize benefits and minimize hazards associated with utilization of radiation-based technologies, radiation protection standards, procedures should be implemented.

4. SHORTAGES IN RADIATION SOURCES' SERVICES

Although the application of radiation sources in industry is increased but the services of handling these sources and the radiation survey meters used to monitor the doses from those sources are not increased in the same level. Summary of present shortages in radiation services are as follow:

Leak test analysis: As per the regulation of the National Radiological Protection Authority (NRPA) in the Kingdom, every radiation source should be checked for leak test at least once per year. These wipe test samples need to be analyzed by a sensitive and specialized technique capable to detect the low level of radiation on the wipe. The obstacle here is that there is no enough licensed facilities in the kingdom capable to perform leak test analysis. This forced the users of radiation sources to perform the leak test analysis through identities not licensed by NRPA and they have to wait for a period of more than month to get the results of analysis of one sample which usually not need more than five minutes by an analysis technique like Liquid Scintillation Counter.

Import of radiation sources: The needs for the usage of radiation sources in the industry (especially in Oil and Gas industry) are essential. Some times the urgent need arises to import those sources within short period of time (within 1-2 months). The present importation procedure it takes too long. This delay may be due to initial mistake occurred by the users themselves while preparing the import request from to the NRPA. Time needed to inform the user about his mistake or shortages in his application might take several months due to the fact that the request pass through different stages and different official identities. Also, other source of the delay is the handling of the importation request by more than one official identities and lack of communication between those identities and the users. In order to ease the import procedure, it might be more practical to gather

the representatives of the different official identities in one building and to be located in a centralized location in each province and direct contact between the users and this new office to be allowed.

Carrier of radiation sources to the kingdom: Most of the radioactive sources are imported from outside of the Kingdom. Thus, the sources should be transported to the kingdom through an approved carrier by IATA. At present time, only one carrier is allowed to carry the radiation sources to the kingdom and not for all type of sources. This case add another obstacle in front of the radiation sources users and hinder them from import their needed sources within an acceptable time. It might be more practical if the NRPA approach Saudi Airlines on behalf of the radiation sources users in order to accept to handle this issue because they operate daily flights from overseas to Saudi Arabia and since it is the national airline, it might be more feasible to solve the national need more than the foreign airlines.

Calibration of survey meters: As per the regulation of the NRPA, every radiation survey meters should be calibrated at least two times per year (especially the ones used for industrial radiography). But, there is no enough calibration identities licensed or qualified to perform the calibration of the survey meters within the kingdom. Also, the rules not encourage the calibration of the survey meters to be conducted outside of the kingdom. This forced the radiation sources users to calibrate their survey meters within the kingdom with the assumed licensed identities and the waiting time to perform calibration for one survey meter might takes more than two months. This issue needs to be addressed by the NRPA and more calibration facilities needs to be encouraged and licensed within short period of time.

Maintenance of the radiation survey meters and IR projectors: Most of the radiation sources users handle the damaged/malfunction survey meters and IR projectors by put it aside and instead they buy new ones or send it outside of the country for repair. This is due to the lack of qualified technicians who can repair them within the kingdom and the high cost (some time more than the price of a new meter) and need long procedure to send it to outside the country. This force the users to buy more survey meters or equipment as spare and thus add more cost and obstacles to the users efforts to keep their operations running smoothly. Thus, qualified center capable to repair the damaged radiation survey meter, IR projectors and other equipment contain the radiation sources need to be established to solve the shortage of this type of services within the country.

Approval of radiation protection qualified expert and radiation practice license to a new facility: New facilities applying for radiation practice license of certain types of radiation sources need services of radiation protection qualified expert to handle and advice the management of the new facilities about their need. There is no licensing program within the NRPA to approve any personnel as qualifies expert. The questionnaire about the qualified expert for any facility is stated in the first page of any type of NRPA radiation practice license forms. But in real life, it is not recognized within the kingdom. Also, the application of a new facility to obtain radiation practice license might take more than one year between review, comments and visit to the site. This will delay the potential of applying new radiation-based technologies within the kingdom. This delay and the long procedure to obtain the radiation practice license force the

radiation sources' users to look for an alternative technique that does not need strict regulation (even it might cost them more and will be less beneficial to its application in the industry), like the use of Ultrasound technique instead of Industrial radiography in NDT of a facility.

5. CONCLUSION

Radiation sources are used daily and intensively in various applications in oil and gas industry. These applications are associated with exploring and producing hydrocarbons (well logging and MPFMs), refining and related processes (level gauges and alloy analyzers), protecting the industry's infrastructure (inspection), providing analytical support (laboratories), and maintaining industrial security. There are several radiation services need to be available in parallel to the wide spread of the use of radiation sources in the industry. The shortages in radiation services are summarized as follow: (i) lack of enough overseas carriers (ii) lack in licensed national centers to analyze (a) leak test samples (b) to calibrate the survey meters and (c) to maintain the survey meters and IR projectors (iii) delay in processing the import permits and radiation practice licenses and finally (iv) no approval program is available to authorize radiation protection qualified expert as this qualification is required in every NRPA radiation practice licenses application's form.

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