CONF-790701--36

# IMPLEMENTATION OF THE ENGINEERING SAFEGUARDS PROGRAM (ESP) INTO NUCLEAR FUEL RECYCLE FACILITIES

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Paper to be presented at the Twentieth Annual Meeting of the Institute of Nuclear Materials Management (INMM) in Albuquerque, New Mexico, July 16-19, 1979.

*Operated by Union Carbide Corporation under contract W-7405-eng-26 with the U.S. Department of Energy.

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## Abstract

The principal objective of ORNL-ESP is to demonstrate process monitoring as it might be accomplished by inspectors of any nuclear fuel recycle facility. Improved instrumentation and computer interfacing, currently being installed, provide the ORNL $^{233}U$ Pilot Plant with the capability of a dynamic volume balance in the solvent extraction system. Later, an accurate, (almost) instantaneous fissile mass balance will be routinely obtainable in the Pilot Plant. Subsidiary objectives include minimizing MUF/LEMUF, detecting material diversions, and alerting appropriate authorities in control of the facility in case of process anomalies.

A continuing program will examine technology which might be utilized for facility design. Ultimately, process monitoring/control integrated with safeguards can convert the ORNL $^{233}U$ Pilot Plant into a partial safeguards demonstration facility.

## Introduction

Safeguards is the system that ensures the protection of a nuclear facility and the materials therein, particularly the special nuclear material (SNM), with a maximum of confidence. The Oak Ridge National Laboratory (ORNL) $^{233}U$ Pilot Plant safeguards system incorporates three functions: physical security, materials and personnel control, and accountability. The concept of graded safeguards is derived from the increase in surveillance of and protection for more vulnerable and/or more attractive nuclear material. In general, the attractiveness of any particular material is directly attributable to its usefulness in a nuclear explosive device and inversely proportional to the efforts required to convert the material to a form usable in a device. Likewise, the vulnerability of materials must be defined in terms of different potential threats, which include national diversion, sabotage, theft, etc. The response to an abnormal situation must be graded to the seriousness of the offense and potential consequences from theft or damage.

Two types of threats can be directed against a nuclear facility:

1. A repeated, covert misappropriation of small quantities of nuclear material. This type of clandestine diversion requires special knowledge of the facility and its operations by authorized personnel with or

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without the aid of unauthorized personnel. Diversion of material is defined as unauthorized operations and unauthorized movement of material within authorized areas. The diversion becomes a theft when the diverted material is removed from authorized areas. The personnel involved in this type of threat would probably want to escape detection.

2. An overt attack on, takeover of, or large-scale theft from the facility. This type of open action may not require either inside personnel or knowledge of the facility or its operations. An armed attack on a facility is only likely to be made by a group of terrorists dedicated to sabotage of the facility and/or theft of SNM. The takeover of a facility would probably involve a host nation attempting to nationalize an internationally operated or monitored facility. The overt theft is presumably a one-time attempt to net enough material for at least one nuclear explosive device. Although not requiring inside personnel, the overt theft would require knowledge of the facility and its operations.

Several advanced safeguards schemes, which have been proposed to counter a national threat against an international facility, include: fuel cycle centers; certain types of process modifications; real-time accountability; coordinated command, control, and communication ($C^3$) centers; continuous inspection; and denial mode operations. These same schemes can be applied to the safeguards systems of national facilities. The objective is defeat of attempts at sub-national diversion and theft of SNM or terrorist attack and sabotage of the facility.

## Operational History

During a recent operational period, the ORNL $^{233}U$ Pilot Plant prepared $^{233}UO_2$ for irradiation tests in a reactor. The operations performed within the Pilot Plant were dissolution, solvent extraction, ion exchange, and oxide conversion. The operations carried out off-site were blending, pelletization, and fuel rod fabrication.

The operational period, six and one-half years, began February 1970 and ended November 1976. Over that period of time, the total material unaccounted for (MUF), as $^{233}U$, was 3.861 kg with a limit of error on MUF (LEMUF) of 4.340 kg $^{233}U$. The equivalent percentage deviation on the total accountable quantity was $0.23 \pm 0.13\%$; this is an unprecedented achievement for a fuel reprocessing facility. This performance was made possible because of the following reasons: (1) consistent quality of process materials; (2) non-varying process conditions; (3) time-share computer assistance for inventories; (4) nondestructive analysis (NDA) of waste materials (continual gamma counting over 90 days); (5) accountability by routine shutdown-cleanout inventory; (6) the luxury of ceasing operations, when closing the material balance; and (7) the large amount of samples taken, larger than normal for a production facility.

Programs of this type conducted at the $^{233}U$ Pilot Plant are providing useful technological experience in the handling and accountability of fissile materials. Future $^{233}U$ operations will be helpful and complementary to ESP demonstrations.

## Discussion

The principal objective of the ORNL Engineering Safeguards Program (ESP) at the $^{233}U$ Pilot Plant is to demonstrate process monitoring as it might be accomplished by inspectors of any nuclear fuel recycle facility. Subsidiary objectives include minimizing the MUF/LEMUF, quickly detecting covert/overt material diversion, and alerting the appropriate authorities in control of the facility in the event of anomalies. In addition to alerting the appropriate authorities, simulated denial, by reversible means, of operator/manager access to portions of the process and/or parts of the facility will be demonstrated. All normal functions of ESP will be transparent to the operators.

Improved instrumentation and newly installed computer interfaces will allow the ORNL $^{233}U$ Pilot Plant operators to establish an accurate volume balance in the solvent extraction system (see Fig. 1). Subsequently, with later addition of appropriate instrumentation for measuring concentration and flow rates, a fissile mass balance will be routinely obtainable. The technology demonstrated in this program may also be applicable to the retrofit of already-built facilities. A new generation of instrumentation will provide an increased technological capability which, when demonstrated, could be applied to new, yet-to-be-designed recycle facilities. Any reprocessing/refabrication facility should be able to utilize this technology, regardless of the nuclear fuel cycle involved.

There are three major parts to ESP: analytical development, computer ($C^3$) system safeguards, and detailed operations control.

The analytical development portion of ESP will provide improvement in the instrumentation necessary to measure liquid levels, liquid densities, temperature, fluid flow rates, heavy metal concentrations, and acidity. This upgrading is necessary for maintaining constant, essentially instantaneous, and total awareness of process operations. Fulfillment of the initial goals will demonstrate how a generic facility can accomplish the ESP objectives using current technology.

Development of an "in-line" analyzer for uranium is being pursued. This analyzer, [redacted], provides a direct determination of uranium concentration. Future development of similar analytical methods for thorium and plutonium will be necessary to ensure adequate performance capability in fuel recycle facilities.

The basic computer hardware and software support has been acquired for ESP. The computer system will be dedicated to the task of demonstrating equivalency to a $C^3$ System. The $C^3$ System provides an on-site and/or off-site link to nuclear fuel operations and is the controlling link between full-time inspection and international safeguards.

Whereas the $C^3$ System software will provide overall process safeguards and physical site protection, detailed operations control (DOC) is needed to provide a separate, independent monitor for each segment that makes up the overall $C^3$ picture. DOC is a new, promising method for statistical evaluation of process data, and a major development effort will be made over the next year to prove the value of DOC. (The original concept comes from R. Davis Hurt of ORNL's

Engineering Technology Division.) The logic, looking at each operational element of the total material balance, could be designed to pinpoint deviations in small segments of the process which might otherwise be overlooked in the overall system balance. The logic may also prove capable of detecting sources of excessive or previously unresolved error, if material mass does not match expected results or MUF/LEMUF values appear to be larger than expected. Other applications for the DOC logic, if successful, may include: detection of equipment failures and operational deficiencies, improvement of operational safety, personnel control, and physical security. This new technique is neither a substitute for nor an independent method of safeguards control. Proper use of the DOC logic and C$^3$ System could ensure improved safeguards for the Pilot Plant.

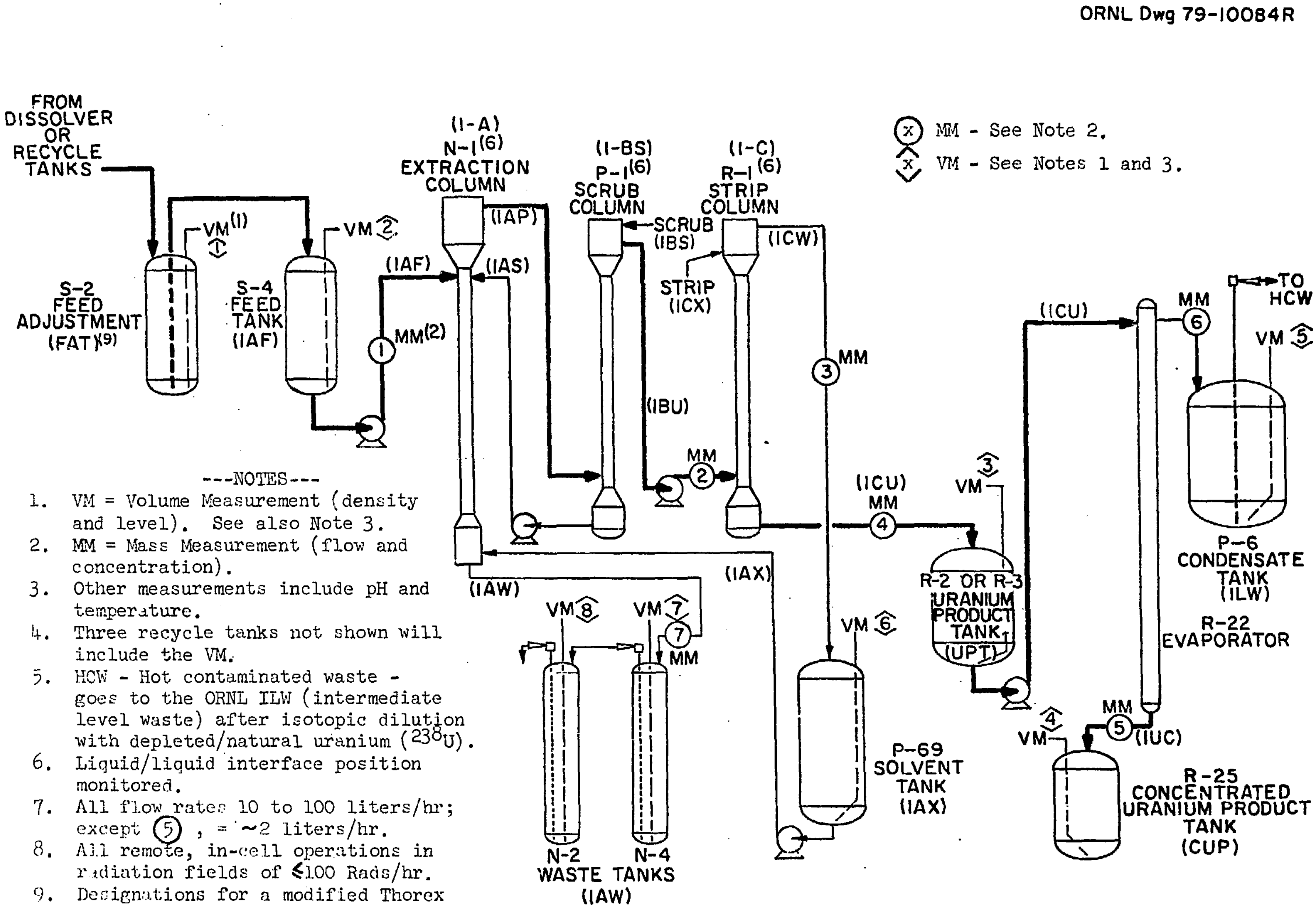
Although commercial nuclear fuel facilities would be adverse to active use-denial mechanisms within the site, automatic, passive use-denial coupled with computer operations will eventually be required in all facilities that process significant quantities of SNM. Because criticality is the worst potential hazard, the $^{233}$U Pilot Plant has a manually activated "Scram System," which will be linked to the dedicated computer as part of ESP. This Scram System is tested periodically and has been operational for more than ten years. The Scram System is a reversible, use-denial safety device that shuts down the $^{233}$U process operations if a potentially hazardous situation or accident occurs, rendering a systematic shutdown impossible or undesirable because of possible risk to personnel. The actions taken by the Scram System include power disruption to all pumps, valve closure on all steam and transfer lines (air-to-open), and shutdown of valve supply air headers.

## Summary

Within the next two years, demonstration of the (almost) instantaneous fissile mass balance will provide the Pilot Plant with a capability for near-real-time SNM accountability. The Pilot Plant will also demonstrate process monitoring/control capability integrated with the appropriate material safeguards and site physical protection; when this has been accomplished, the Pilot Plant can become a partial safeguards demonstration facility.

## Conclusions

- The effectiveness of a safeguards system is based upon delay of unauthorized movement and use of SNM by the stacking of barriers in a defense-in-depth concept.
- Basically, there is no fool-proof nonproliferation scheme currently in existence - properly designed safeguards can provide a timely, though probably short, warning.
- Several promising safeguards concepts are currently under study and development.
- The ESP development can provide both technological improvements and design information for implementation of safeguards systems into existing and yet-to-be-designed facilities.
- The Building 3019 Pilot Plant could be used as a partial safeguards demonstration facility.




---NOTES---

1. VM = Volume Measurement (density and level). See also Note 3.
2. MM = Mass Measurement (flow and concentration).
3. Other measurements include pH and temperature.
4. Three recycle tanks not shown will include the VM.
5. HCW - Hot contaminated waste - goes to the ORNL ILW (intermediate level waste) after isotopic dilution with depleted/natural uranium ($^{238}U$).
6. Liquid/liquid interface position monitored.
7. All flow rates 10 to 100 liters/hr; except (5), = ~2 liters/hr.
8. All remote, in-cell operations in radiation fields of ≤100 Rads/hr.
9. Designations for a modified Thorex Flowsheet.

Fig. 1. $^{233}U$ Solvent extraction system in the Building 3019 Pilot Plant.

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