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INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0354

# NuFab™ Anti-Contamination Suit

Deactivation and
Decommissioning Focus Area

*Prepared for*
**U.S. Department of Energy**
Office of Environmental Management
Office of Science and Technology

February 1998

INNOVATIVE TECHNOLOGY
Summary Report

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# NuFab™ Anti-Contamination Suit

OST Reference # 1855

Deactivation and
Decommissioning Focus Area

*Demonstrated at*
Chicago Pile 5 (CP-5) Research Reactor
Large-Scale Demonstration Project
Argonne National Laboratory-East
Argonne, Illinois

INNOVATIVE TECHNOLOGY
Summary Report

## *Purpose of this document*

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov.

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# SECTION 1

# SUMMARY

## Technology Summary

### Problem

Radiation workers at all U.S. Department of Energy (DOE) sites require some form of protective clothing when performing radiological work. A large number of contaminated facilities at DOE sites are currently or will eventually undergo some form of decontamination and decommissioning (D&D), requiring some type of protective clothing, often in multiple layers. Protective clothing that does not allow perspiration to escape causes heat stress, which lowers worker comfort and productivity.

### How it Works

This report describes the NuFab™ anti-contamination suit manufactured by Kappler Corporation, which can be worn during D&D activities to protect workers from contamination. The suit is a one-piece, disposable, breathable, waterproof coverall with a single front zipper as seen in Figure 1. Constructed of tri-laminated composite material using spun-bonded polypropylene and microporous film layers, the suit is certified as incineratorable.

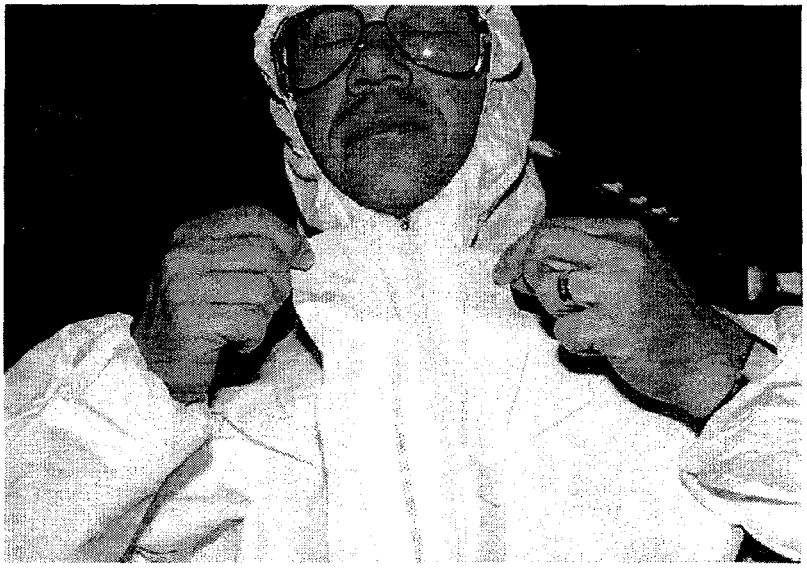

**Figure 1. NuFab™ suit with front zipper.**

### Commercial Availability

The suits are readily available from Kappler Corporation, which sells them through authorized distributors. The suits are available in various sizes. Correct fit depends on the body size of the worker and/or the type of undergarments worn during D&D activities.

## Demonstration Summary

The demonstration was held at the JANUS Reactor D&D Project at Argonne National Laboratory-East (ANL-E) from August 4–7, 1997 during concrete demolition activities. Workers performing jackhammering, lifting, and moving activities were chosen to wear the NuFab™ suits and evaluate them relative to the Tyvek® baseline suits. The Tyvek® anti-contamination coverall (#14261), manufactured by Mar Mac, Inc., is worn with blue hospital scrubs as modesty garments underneath the coveralls.

### Key Results

The key results from the technology demonstration of the NuFab™ suits are as follows:

- The NuFab™ suits were roomier and allowed for ease of movement during work activities.
- The suits were much hotter than the baseline Tyvek® suit; however, the baseline suit was not waterproof and did not provide the same level of protection as the NuFab™. Workers noted they had pools of sweat in their respirators and gloves after working with the NuFab™.
- The suits were more comfortable to the skin than the baseline suit.
- The suits were more difficult to don than the baseline suit. The liner would stick together.
- The suits tended to rip easier than the baseline suit, especially where the legs joined the booties.

## Contacts

### Technical

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### Demonstration

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### CP-5 Large-Scale Demonstration Project or Strategic Alliance for Environmental Restoration

Richard C. Baker, U.S. Department of Energy, Chicago Operations Office, (630) 252-2647, richard.baker@ch.doe.gov

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Terry Bradley, Strategic Alliance Administrator, Duke Engineering and Services, (704) 382-2766, tlbradle@duke-energy.com

### Licensing Information

No licensing or permitting activities were required to support this demonstration.

### Web Site

The CP-5 LSDP Internet address is http://www.strategic-alliance.org.

### Other

All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 Web site, provides information about OST programs, technologies, and problems. The OST Reference # for the NuFab™ suit is 1855.

SECTION 2

# TECHNOLOGY DESCRIPTION

## Overall Process Definition

The purpose of the anti-contamination suit is to act as a barrier between the worker and the surrounding environment. The demonstration goal was to evaluate the NuFab™ suit with the baseline Tyvek® suit. Parameters compared included

- Ability to protect the worker
- Donning and doffing ease
- Fit, including size, adjustability, slack, and catch/trip hazards
- Comfort, including heat and perspiration, skin sensation, and personal mobility
- Work efficiency factors, including productivity, vision, manual dexterity, communication, and balance
- Durability
- Waste generation

The NuFab™ anti-contamination suit is intended to enhance transmission of moisture generated by the body to outside the suit. The NuFab™ suit is a one-piece, disposable coverall with a single, front, zip-lock closure. It is constructed of spun-bonded polypropylene and microporous film layers to make the suit breathable and waterproof. A proprietary process is used to ultrasonically seal the seams of the suit during manufacturing, a sealing process typically known as NSR (no sewing required).

In comparison, the baseline suit was constructed of untreated Tyvek® material. Tyvek® combines lightweight, durable wearability and high barrier characteristics with low linting and anti-static properties. The baseline suits worn during the demonstration had a sewn seam, which is an overedged, serged seam construction that protects against many dry particulates and light sprays.

The NuFab™ suit has no system operations associated with it. It is a coverall type of clothing that is worn by inserting the individual's arms and legs into the suit and closing by the zipper. There is no secondary waste associated with wearing the suit. Additionally, the NuFab™ suit is certified incineratorable.

# SECTION 3

# PERFORMANCE

## Demonstration Plan

The NuFab™ suit anti-contamination coveralls from Kappler Corporation were evaluated as part of the Large-Scale Demonstration Project (LSDP) at Argonne National Laboratory-East (ANL-E) in accordance with the *Test Plan for the Demonstration of NuFab™ Suit at Chicago Pile 5 (CP-5)*. The suits were tested during the evaluation period of August 4–7, 1997 at the JANUS Reactor D&D Project at ANL-E. The JANUS Reactor was a light-water moderated reactor, which operated at a thermal power range from 20 to 200 kW.

The NuFab™ technology was evaluated against the baseline technology, the Tyvek® anti-contamination suit (#14261) manufactured by Mar Marc, Inc., in the areas of heat stress, cost effectiveness, worker comfort, donning/doffing, durability and waste generation.

Workers were briefed on the particulars of the demonstration before the start. The following steps were performed for each work session in the demonstration:

- Perform daily pre-job briefing for all personnel involved in the demonstration.
- Take area temperature and humidity readings.
- Don the appropriate protective suit.
- Complete the work session.
- Doff the protective suit.
- Take temperature and humidity readings.
- Perform exit interview with the workers wearing the suit.

Activities associated with the demonstration included jackhammering. The work consisted of breaking up concrete with a 90-lb jackhammer and then moving the pieces to the disposal container. The work area contained scaffolding that the workers climbed on, over, and around during the course of the demonstration. Air conditioning was used to reduce the heat stress potential to the workers. The temperature maintained at 68°F and the humidity at 50 percent.

## Performance of the NuFab™ Suit

The performance of the NuFab™ suit was determined from questionnaires filled out by the workers who wore the suits during the demonstration. Two men participated in the demonstration, each wearing the baseline suit then the NuFab™ suit. The Tyvek® suits were worn the first day to establish the baseline for comparison for 1 hour, 15 min with a 40-min break, then again for 1 h, 10 min. The NuFab™ suits were worn on the third day of the demonstration. One worker only wore the suit for 35 min as he was not feeling well and was getting too hot. The second worker wore the suit for 1 h, 35 min. One h, 15 min after the last worker doffed his suit, both workers re-entered the work area for 1 h, 45 min.

A questionnaire was used to obtain information from the workers about the NuFab™ suit compared with the baseline. The results were based on subjective opinions rather than quantitative results. No effort was made to measure stay times or medical conditions (breathing rate, heart rate, blood pressure, core body temperature, skin temperature) of the workers during the demonstration. A summary of the questionnaire results are provided in Table 1. The workers were instructed to rate the suits on a scale of 1 to 5, with 1 being worse than the baseline, 3 being the baseline value, and 5 being better than the baseline.

**Table 1. Questionnaire Summary**

| ACTIVITY | SCORE 1 | SCORE 2 | AVERAGE |
|---|---|---|---|
| | | | |
| **DONNING/DOFFING** | | | |
| Ability to manipulate closures | 3 | 3 | 3.0 |
| Amount of effort required | 4 | 3 | 3.5 |
| Location of closures (such as in the front) | 3 | 3 | 3.0 |
| Length of time required | 3 | 3 | 3.0 |
| **SUBTOTAL (baseline = 12)** | **13** | **12** | **12.5** |
| | | | |
| **COMFORT** | | | |
| Body heat | 2 | 2 | 2.0 |
| Perspiration rate | 1 | 1 | 1.0 |
| Skin sensation | 4 | 2 | 3.0 |
| Weight to wear | 3 | 2 | 2.5 |
| Placement of seams/rivets | 3 | 3 | 3.0 |
| Personal mobility | 4 | 4 | 4.0 |
| **SUBTOTAL (baseline = 18)** | **17** | **14** | **15.5** |
| | | | |
| **TOTALS (baseline = 30)** | **30** | **26** | **28.0** |

The workers ranked the NuFab™ suits well for roominess, which enabled easier movement. The seams tended to rip easier where the legs joined the booties. It was noted that the suits felt more comfortable to the skin than the baseline. The workers concluded that the NuFab™ suit was hotter than the baseline, and more perspiration was produced by the workers wearing the NuFab™ suit than the baseline; however, the Tyvek® suit was not waterproof and did not provide the same level of protection as the NuFab™.

SECTION 4

# TECHNOLOGY APPLICABILITY AND ALTERNATIVES

## Competing Technologies

The competing technologies include other similar types of anti-contamination coveralls produced by various manufacturing companies. The major difference is the type of fabric and the type of seam. NuFab™ suits have a heat-sealed-type seam, which classifies the suits as waterproof, versus typical sewn seams, which are not waterproof.

## Technology Applicability

The suits are applicable for work in radioactive environments to prevent the worker from coming in contact with contaminated material. Anti-contamination clothing is an item of standard issue in the D&D industry. The NuFab™ suits could be beneficial due to roominess, which enables ease of movement while performing D&D operations. Since the suit is waterproof, it provides a greater level of protection than the baseline Tyvek® worn in the demonstration.

# SECTION 5

# COST

## Introduction

This cost analysis evaluates the cost of the NuFab™ worker protection suit and compares this suit with the conventional clothing for worker protection, Tyvek®, also known as the baseline suit. This cost analysis considers only the material costs of the worker protection suits. Any productivity loss or gain that is associated with wearing either the NuFab™ or the Tyvek® is not considered. Although durations were measured for performing D&D activities with each suit, definitive and measurable quantities of work (i.e., decontaminating a specific number of square feet) were not measured. Therefore, accurate productivity rates cannot be derived from the data provided. It was subjectively determined that the NuFab™ suits allow more room for movement but are hotter to wear than the Tyvek® ,which is not a waterproof suit like the NuFab™.

## Methodology

This cost analysis compares two lightweight worker protection suits—one representing an innovative technology, the NuFab™ suit, and the other one representing a baseline technology, the Tyvek® suit. Both suits were demonstrated at ANL-E under controlled conditions, which facilitated observation of the work procedures and typical durations of those procedures. The suits were demonstrated for nearly identical activities. The observed activities consisted of operating a 90-lb jackhammer, climbing scaffolding, kneeling and bending down, and picking up concrete pieces..

The selected basic activities being analyzed were obtained from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS), U.S. Army Corps of Engineers, 1996. The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with established national standards.

## Cost Analysis

Observed unit costs for both the innovative and baseline suits are presented in Table 2.

**Table 2. Summary of Unit Costs Observed During the Demonstration**

| | INNOVATIVE TECHNOLOGY NuFab™ Suit | BASELINE TECHNOLOGY Tyvek® Suit |
|---|---|---|
| **Cost Element** | **Unit Cost** | **Unit Cost** |
| Materials Purchase | $28.88/S-XL suits and $31.50/XXL suit ($30.19/suit average) | $4.50/suit |

## Summary of Cost Variable Conditions

The DOE complex presents a wide range of D&D work conditions encompassing a variety of functions and facilities. The working conditions of an individual job directly affect the manner in which D&D work is performed; and, as a result, the costs for an individual job are unique. The innovative and baseline technologies presented in this analysis are based upon a specific set of conditions or work practices found at the ANL JANUS Reactor, and are presented in Table 3. This table is intended to help the technology user identify work differences that can result in cost variances.

**Table 3: Summary of Cost Variable Conditions**

| Cost Variable | NuFab™ Suit | Tyvek® Suit |
|---|---|---|
| Scope of Work | | |
| Type and Quantity | D&D work, no specific amount of work was measured | D&D work, no specific amount of work was measured |
| Location | JANUS Reactor | JANUS Reactor |
| Nature of Work | Operating a jackhammer, climbing scaffolding, and picking up concrete pieces (68 degrees Fahrenheit with 50 percent humidity) | Operating a jackhammer, climbing scaffolding, and picking up concrete pieces (68 degrees Fahrenheit with 50 percent humidity) |
| Work Environment | | |
| Worker Protection | Anti-contamination coveralls with hood, and full-face respirator | Anti-contamination coveralls with hood, and full-face respirator |
| Level of Radioactivity | Radiation area with airborne contamination | Radiation area with airborne contamination |
| Work Performance | | |
| Acquisition Means | Material purchase by the site | Material purchase by the site |
| Production Rates | N/A | N/A |
| Equipment & Crew | Two Facility Operations personnel in suits with one health physics technician (HPT) providing continuous support. | Two Facility Operations personnel in suits with one HPT providing continuous support. |
| Work Process Steps | 1. Suit-up (don)<br>2. Enter area and setup<br>3. Operate jackhammer, climb scaffolding, and lift concrete pieces<br>4. Un-suit (doff) | 1. Suit-up (don)<br>2. Enter area and setup<br>3. Operate jackhammer, climb scaffolding, and lift concrete pieces<br>4. Un-suit (doff) |
| End Product | Worker protection | Worker protection |

## Cost Conclusions

The Tyvek® baseline suits used during the demonstration were an average $26.69 less expensive per suit than the NuFab™ suits ($30.19 was the average cost of the NuFab™ suit versus an average cost of less than $4.50 for the Tyvek®). Considering that one worker may use several or more suits per day, this cost difference may prove to be significant. In regard to productivity, the NuFab™ suit was considered to be a much warmer suit to wear; but its waterproofing offered more protection to the worker. Additionally, it was noted that the NuFab™ was roomier in the upper body. Determining the applicability of each suit would have to include consideration of the necessity of a waterproof suit and the added level of protection it provides.

# SECTION 6

# REGULATORY AND POLICY ISSUES

## Regulatory Considerations

The regulatory/permitting issues related to use of the NuFab™ suit at the CP-5 LSDP consist of the following:

- Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1926.28, *Personal Protective Equipment*
- OSHA 29 CFR 1910.132, *General Requirements (Personal Protective Equipment)*
- 10 CFR Part 835, *Occupational Radiation Protection*
- DOE CFR Part 745.101, *Protection of Human Subjects*

Disposal requirements/criteria include the following U.S. Department of Transportation (DOT) and DOE requirements:

- 10 CFR Part 71, *Packaging and Transportation of Radioactive Material*
- 49 CFR Subchapter C, *Hazardous Materials Regulations*

Waste generated by the NuFab™ suit demonstration consisted of the used suits and was added to the existing waste streams for the CP-5 project. No special waste was generated as part of the demonstration.

Since the NuFab™ suit is worn when decontaminating structures, there is no regulatory requirement to apply CERCLA's nine evaluation criteria. However, some evaluation criteria required by CERCLA, such as protection of human health and community acceptance, are briefly discussed below. Other criteria, such as cost and effectiveness, were discussed earlier in the document.

## Safety, Risks, Benefits, and Community Reaction

The risk of the NuFab™ suit depends on its ability to transfer heat from the worker to outside the suit. Based on the results of the demonstration, the suit could have an impact on worker health and safety due to heat stress.

The benefit of the suit is its roominess, which enables workers to move about more freely. There are no measurable impacts on community safety or socioeconomic issues associated with using the NuFab™ suit versus the Tyvek®.

# SECTION 7

# LESSONS LEARNED

## Implementation Considerations

The NuFab™ suits are commercially available and come in a variety of sizes. Due to the heat stress indicated by the workers during the demonstration, the following factors should be considered before implementing the suits: the type of work to be performed, the need for waterproof suits, and stay time in the suits.

## Technology Limitations and Needs for Future Development

The technology is limited by heat stress considerations. The NuFab™ suit is still beneficial in situations requiring waterproofing. Future development should focus on ways to prevent body heat from building up inside the suit to increase the comfort and efficiency of workers.

# APPENDIX A

## REFERENCES

*Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, 1996. Headquarters U.S. Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, D.C., 20314-1000.

*Technology Data Report for the Kappler Corporation NuFab Suit*, CP-5 Large-Scale Demonstration Project, September 1997.

*Test Plan for the Demonstration of NuFab Suit*, CP-5 Large-Scale Demonstration Project, August 1997.

# APPENDIX B

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ANL-E | Argonne National Laboratory-East |
| CFR | Code of Federal Regulations |
| CP-5 | Chicago Pile-5 |
| D&D | decontamination and decommissioning |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| FETC | Federal Energy Technology Center |
| HPT | Health Physics Technician |
| HTRW | Hazardous Toxic Radioactive Waste |
| kW | kilowatt |
| lb | pound(s) |
| LSDP | Large-Scale Demonstration Project |
| NSR | No Sewing Required |
| OSHA | Occupational Health and Safety Administration |
| PPE | personnel protective equipment |
| RA | Remedial Action |
| WBS | Work Breakdown Structure |