

INDUSTRIAL EXPERIENCE WITH POWERED AIR PURIFYING RESPIRATORS

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Abstract

Aerojet Heavy Metals Company (ARMC) operates a Computerized Numerical Control Lathe Operation, Rolling Mill and Foundry, utilizing depleted uranium. Depleted uranium is a toxic metal which oxidizes easily, generating an airborne dust. This dust is controlled primarily through the use of engineering controls. Certain production operations and limited maintenance functions require the use of respiratory protection. In the past we have used the conventional negative pressure half-mask as the primary source of personal protection.

Increases in uranium-in-urine excretion levels were attributed to employees unintentionally wearing the half-mask respirator improperly. During strenuous activities, it was found that perspiration on an employee's face broke the seal. Often during communication exchange, the mask was pulled from the individual's face and not re-fitted properly. These actions greatly reduced the protection provided by the respirator. Our solution was to provide the employee with a respiratory protective device which afforded maximum protection without the stringent fitting requirements of a negative pressure respirator.

This paper discusses the selection, proof of performance, and employee acceptance of a powered air purifying

respirator (PAPR). Several different PAPR's were evaluated before one was found that met our needs. The RACAL Airhat has been adopted by our facility and the results have been positive. Measurements have been taken during actual work activities and indicate protection factors of 400 and greater have been obtained. The average uranium-in-urine measurements of workers who routinely use the airhat dropped by a factor of 2, with one individual decrease of about 4. Employee acceptance of the airhat has been outstanding.

Introduction

Aerojet Heavy Metals Company (AHMC) operates a Computerized Numerical Control Lathe Operation, Rolling Mill and Foundry, utilizing depleted uranium. Depleted uranium is a toxic metal which oxidizes easily, generating an airborne dust.

The dust is controlled primarily through the use of engineering controls, localized ventilation and complete enclosures. However, specific operations and processes at AHMC require the use of respiratory protection. This paper discusses:

1. Our program utilizing the negative pressure respirator as our primary source of protection and the problems encountered.
2. The acquisition of several types of powered air purifying respirators in an effort to upgrade our existing program.
3. Field studies performed on the PAPR's and results of these studies.

Problems Encountered

Operational Requirements

Requirements for respiratory protection at AHMC consist mainly of special activities such as entering operational enclosures and maintenance activities. These activities typically produce excessive amounts of airborne dust (on the average three-to-four times Maximum Permissible Concentration). Thus respiratory protection is essential. In the past the conventional negative pressure half-mask respirator has been used as the primary source of personal protection.

Training

Requirements for training employees in the use of negative pressure half-mask respirators are extensive. Fit tests and training sessions are held twice yearly covering wear and care procedures for the respirator, storage requirements, and performance of a field fit test each time the mask is donned. The training is thorough, but, worker acceptance is less than desirable, which can impact compliance.

Worker Compliance

A negative pressure respirator is only as effective as the employee and job allow it to be. Efficiency can be

impacted by improper usage of the **respirator**, by not wearing it **properly**, wearing it properly but not performing a field test to assure proper fit, strenuous jobs that may **affect** the **face-to-facepiece** seal and not be recognized by the employee. With the need for communications, the mask might be pulled from the employee's face for a **short** period of time, therefore reducing the protection **afforded**. Heat and physiological stress are also factors which sometimes lead to non-compliance.

Maintenance

Because of the number of respirators **used** in the **company**, a significant amount of **time** is required for maintenance. In addition to routine cleaning after **each use**, the cartridges are placed on a resistance tester turned to 42.5 lpm to check for significant pressure drops:

In-House criteria is 50% above the initial pressure drop. A Geiger-Mueller probe is then used to detect radiation emitted from the cartridges. The major concern in this test is the potential effect of beta radiation on the eyes. Cartridges must pass both the resistance and radiation tests or they are discarded.

Facepieces are washed and inspected, then hung up to air-dry. Problems have been experienced from the straps not drying and causing irritation around the **employee's** neck, the inhalation valve sticking to the cartridge seat, unpleasant odors being detected by the wearer, and warped **facepieces**.

Results

The half-mask respirators used (2 types, 5 sizes) provide good protection and are generally accepted. However, there are many problems associated with them:

- Reliance of employee to perform field fit test.
- Improper wearing of respirator,
- Improper storage.
- Physiological stress associated with a hot environment, perspiration breaking the seal of the respirators.
- Need to communicate.

Increases in **uranium-in-urine** excretion levels were attributed to employees unintentionally wearing the respirator improperly.

Solution

Based on the problems encountered with the half-mask respirator, it was evident that a solution was necessary. The solution was to provide the employee with a respiratory protective device which afforded maximum protection without the stringent fitting requirements of a negative pressure respirator.

Powered air purifying respirators were analyzed because they were positive pressure, did not require stringent fitting requirements, alleviated the physiological stress, **provided** moving air in hot environments, and also provided head and eye protection.

Several types were tried and the most important factor for choosing one, after meeting our requirements for face and head protection, was input from our employees.

The Breezer PAPR was tried; however, the **light-weight head** cover did not allow adequate peripheral vision **nor** head protection. The belt-mounted filter housing and two battery packs were too bulky and heavy to wear for an extended amount of time.

The 3M PAPR was accepted because of the light-weight battery pack being the only item that was belt-mounted. For work not requiring any bending over or work in the

horizontal position, it worked well. With the filter in the helmet itself, it posed **some** discomfort to employees and although it does contain a chin strap, it tends to slide when the employee bends over.

Because of the above problems listed, a third PAPR was analyzed: the **RACAL** airhat. The light-weight helmet alleviated neck fatigue and was the most desirable for work requiring bending over. The battery **pack and filter housing** were mounted on the belt. Yet, the design allowed easy mobility for sliding the unit around on the belt.

This unit was chosen because it best fit our needs and was well received by our employees.

Results

Protection Factors

PAPR's are assigned a standard protection factor of 1,000. However, under actual work conditions the assigned factor may decrease. A study was performed to determine protection provided by the airhat during actual strenuous work activities.

A RACAL airhat was modified by drilling **a** hole through the faceshield and attaching a tubing connection.

A personal sampling cassette was mounted to the outside of the faceshield designed to pull a sample from inside the helmet using a personal sampling pump. Another personal sampling cassette was fastened to the lapel of the employee's coveralls designed to pull a sample outside the helmet (One personal **sampling pump** with **a "T"** connection or two separate pumps can be used). In this case two pumps were used. The cassettes were within 4-6 inches of each other, thus allowing us to gather good comparison data for determining concentrations inside and outside the helmet. The results were as follows:

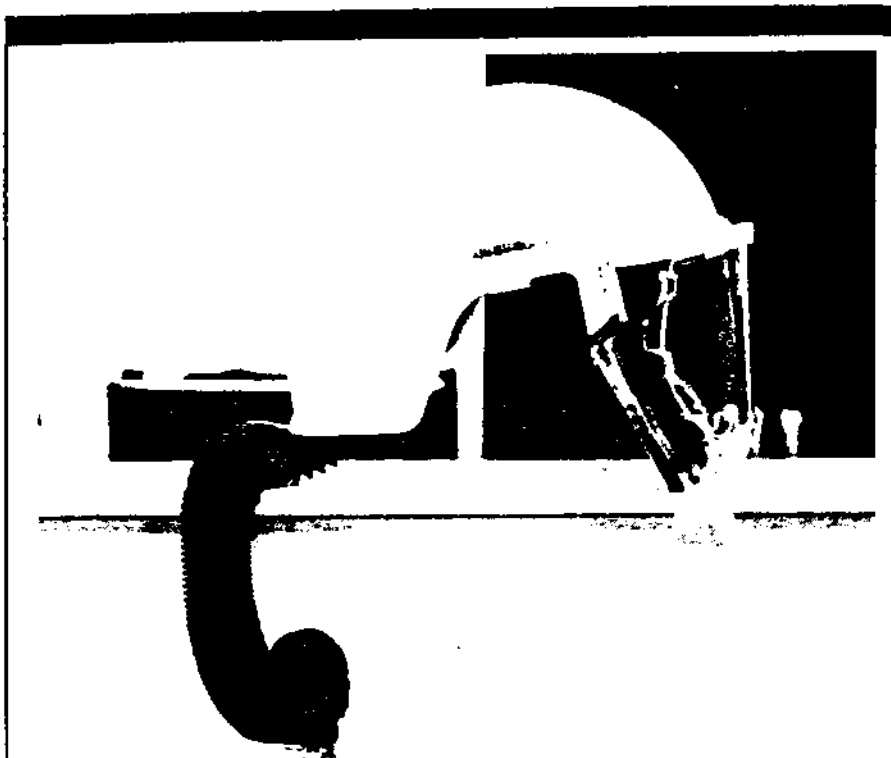


Figure 1
The RACAL AH3 Powered Air Purifying Respirator (Airhat)

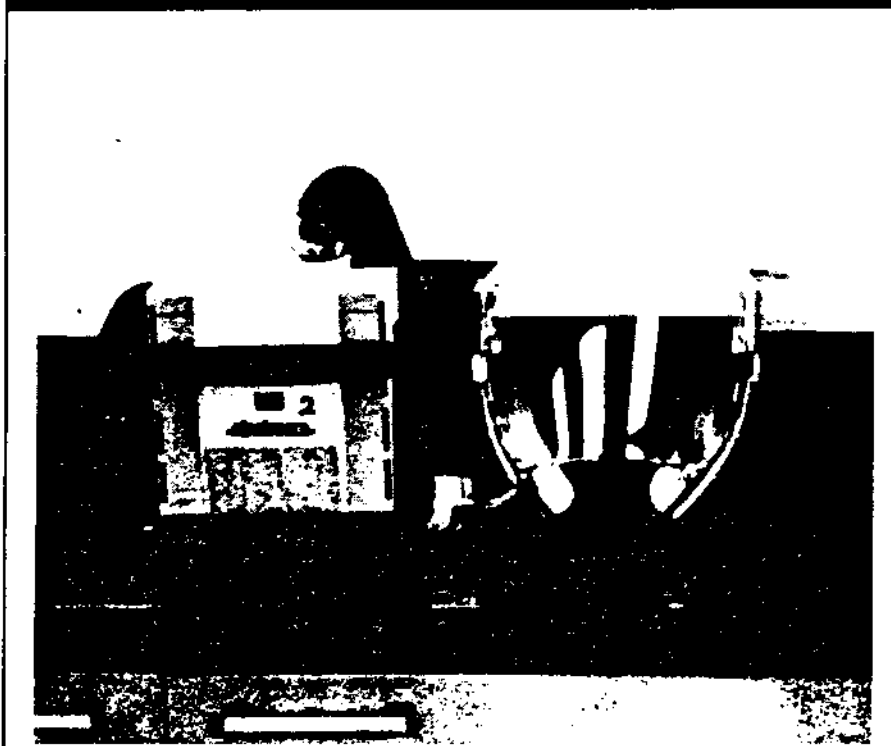


Figure 2
Modified facepiece with cassette attachment used to sample inside the airhat

- Eight tests were performed and the protection factors ranged from **100-560**, with the average around 220. The low numbers were a result of not being able to sample in **environments** with high Maximum Permissible Concentrations: The numbers found were typically the same inside the airhat for all eight tests, with the minimum **detectable** limit at 3% **MPC**. A **300-400%** concentration outside the helmet would thus result in a protection factor of 100, where it could easily be 300-400. Twice, we sampled in environments reaching approximately 1800%, with the concentration in the airhat just above detectable limit of 3%, **thus** our protection factor **of** 560.

Two studies were performed to determine protection factors in a controlled (**non-work**) environment. The Butyl Acetate chamber was used (adopted from DuPont Protocol).

A seventy-gallon plastic bag was hung upside down, mounted to a **24"** diameter wooden cylinder. A hook was screwed into the wood so acetate-soaked rags could be hung at the top of **the** bag.

The test subject entered the bag and, with a butyl acetate detector tube, pulled a sample at waist height and at head height. An average concentration was calculated **for** the comparison. In our test there was minimal **difference**. The test subject then spent approximately ten minutes inside the bag, talking, breathing light and heavy, performing knee bends and head **movements**. He detected no butyl acetate.

An olfactory sensitivity test was set up prior to the test to determine at what level the test subject could detect butyl acetate - in this case 1 ppm. The results far exceeded 1,000, as noted in the following pages.

AIRHAT PROTECTION FACTORS

Work Environment (Controlled Environment)

92
102
170
208
238
361
559

Figure 3

Protection factors obtained in the work environment during strenuous activities

The second test was the quantitative ethylene gas hood test (adopted from **Draeger** test). A hood was placed over the **RACAL** helmet and 15% **ethylene-in-air** was introduced into the hood to produce an approximate 15,000 ppm hood concentration. A detector tube (range **2-10** ppm) was hooked up and a sample pulled from within the facepiece using the modified facepiece. **After** the allotted pump **strokes**, the stained to unstained area on the tube was between 3.5 and 4, so 4 was assumed. The protection factor was calculated by simply dividing **15,000** by 4. Following are the results for the non-work test.

Summary

The standard protection factor of a **PAPR** helmet is 1,000. Our studies in a work environment resulted in protection factors ranging from **100-600**. In the **non-work** environment, protection factors ranging from 3,000-5,000 were obtained. The error for detector tubes is +/- 25%, but even on the low side, the protection factors well exceeded 1,000. Figure 5 **shows** a com-

parison of all the protection factors. These numbers tend to quantify the higher protection factors obtained in the work environment. I will speculate and say **that** if air concentrations **had been generated to** much higher levels in the work environment, we would have seen protection factors in the work environment reach and exceed 1,000.

Versatility

The **RACAL airhat** is a very versatile respiratory device. It allows the individual adequate mobility with minimal restrictions. The helmet can be used as a welding helmet while providing positive pressure protection. The **RACAL BreathEasy** is a unit that filters a combination of dust, fumes, mist and organic vapors. (The **DFM** cartridge is **high-efficiency**). There is **also** a (self supporting) clear plastic hood which is desirable for complete head and neck protection. A good application for this unit is decontamination work.

Employees use the helmet while driving a **forktruck**, working in horizontal positions in tight areas and in hot environments.

Training

We found that employees training in **the** use of the airhat was extremely easy, requiring approximately ten minutes in explanation and a single trial use. Semi-annual **fit** tests were alleviated and the time associated with maintenance was decreased.

AIRHAT PROTECTION FACTORS

Non-Work

Butyl Acetate Chamber

3000

5000

Ethylene Gas

3750

Figure 4

Protection factors obtained in the non-work environment

AIRHAT PROTECTION FACTORS

Work Environment
(Controlled Environment)

92

102

170

208

238

361

559

AIRHAT PROTECTION FACTORS Non-Work

Butyl Acetate

3000

5000

Ethylene Gas

3750

Figure 5
Protection factors comparison

Exposure Results

An increase in **uranium-in-urine** for a specific group of employees was noted in the first quarter of 1983. The individuals were working in an area where air concentrations were between one and ten times **Maximum Permissible Concentrations** and using **half-mask** respirators. Following is a graph showing **exposure** (black) versus **production** (red) for Individual A (Figure 6). Note: The **airhat** was introduced in May. The **uranium-in-urine** measurements showed a significant decrease before leveling off. The average decrease was about a factor of two. The average production levels remained relatively constant. Individual A also showed a significant decrease when the airhat was introduced. His average decreased by an approximate factor of four. The fourth quarter (not shown) showed the levels continuing a slight decrease before leveling out.

Worker Acceptance

Employee acceptance of the airhat has been outstanding. The helmet takes the place of head protection and face protection; therefore, the employees have more readily accepted it. Comfort, light weight and confidence were the prime factors for the **RACAL Airhat** being chosen, with confidence appearing to play the most important role.

Summary

Operational requirements and employee exposure at AHMC prompted us to evaluate several different types of **respiratory** protection. The **RACAL Powered Air Purifying Helmet** was chosen because it best met our needs. It has well exceeded our performance criteria and employee acceptance of the airhat **has** been outstanding, due mainly to **comfort**, versatility, **light weight**, and providing the individual with confidence. **Initial cost of the unit is higher**

than the conventional **halfmask** and full-face respirators. **However**, the **day-to-day** maintenance and upkeep (measured in time and dollars) **is** significantly less. To properly **assess** the benefits the airhat **has** had on our respirator **program**, **we must** look at the results.

1. **Alleviate** the reliance of fit test on employee. This helmet **can** be put on and taken off over the course of a work **shift** without the concern that a field test is being performed.
2. Assurance of proper fit. With minimal training, an employee can learn how to use the unit and be confident of a proper fit.
3. The physiological stress associated with a hot **environment**, perspiration breaking the seal of the respirator are alleviated. The employee can feel air **on** his face. Therefore, his confidence in the respirator increases.
4. Problems with communications are much less than with any negative pressure respirator. The entire face is visible so that non-verbal communication efforts are not hidden.
5. Worker acceptance. A respiratory protection program cannot function efficiently and properly without employee cooperation and compliance. This addition to our program has been well-accepted and the results positive.

Acknowledgments

The author would like to acknowledge the assistance of Health & Safety Specialist Michael **Loveday**, who set up and conducted several of the field tests.

Disclaimer: Comments made referencing specific products in this paper are based solely on **Aerojet's** experience with them and how **applicable** they were to **us**.

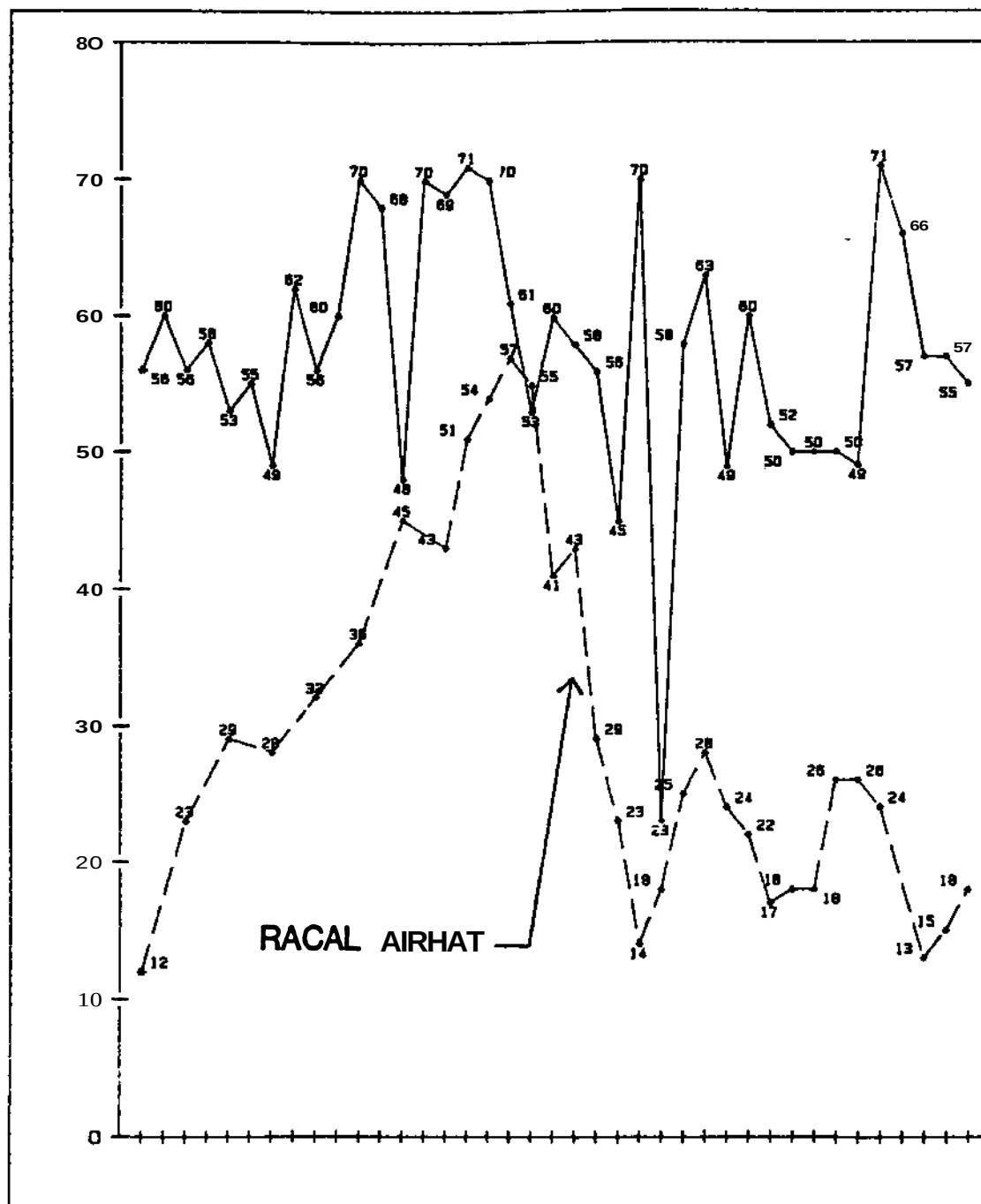


Figure 6

Worker's exposure (uranium-in-urine) versus production level's high-lighting the introduction of the airhat

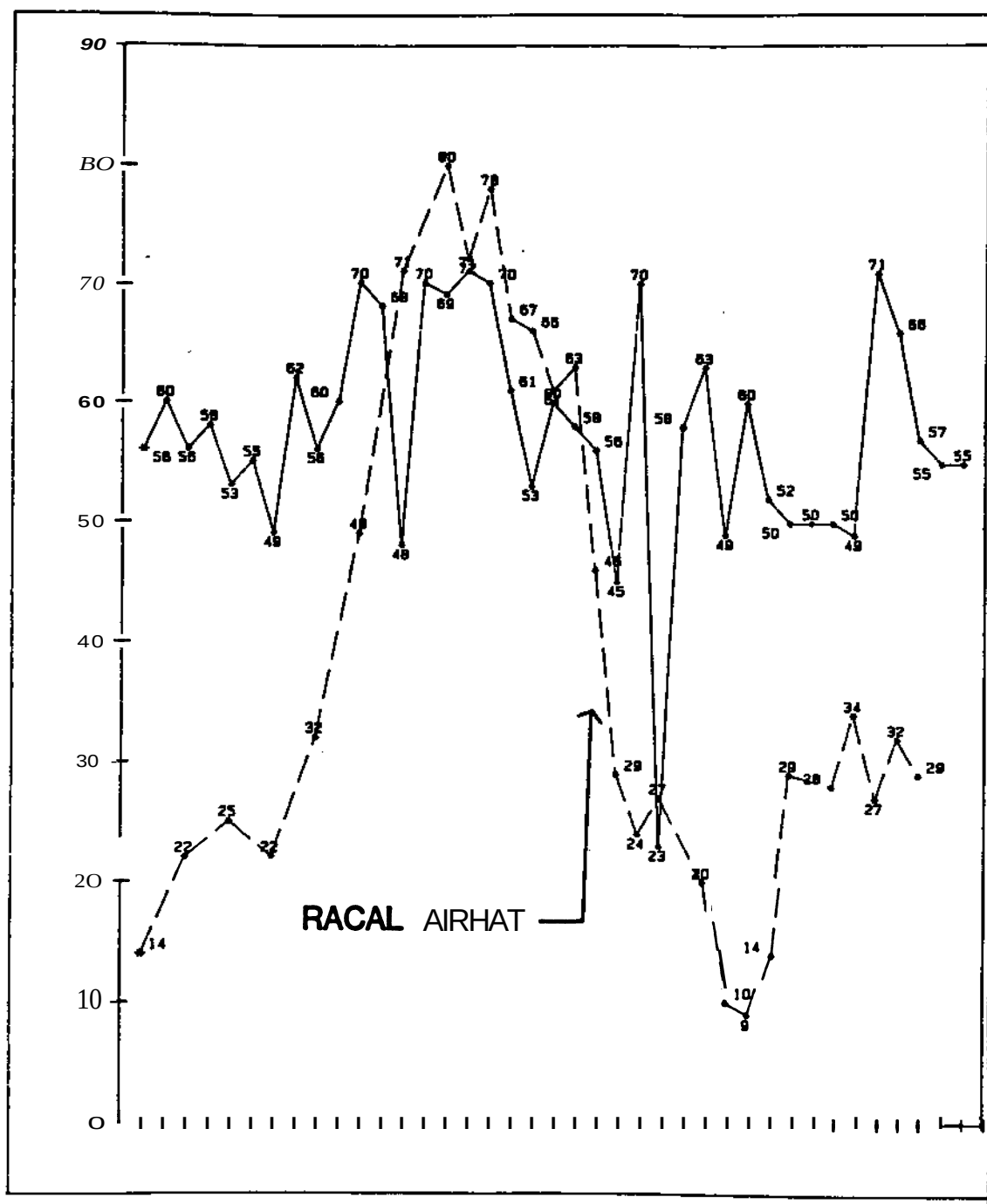


Figure 7
Worker's exposure (uranium-in-urine) versus production level's high-lighting the introduction of the airhat