

The Development and Testing of a Ventilated Impermeable Suit, for Use in an Environment Contaminated with Tritiated Water Vapor in Ontario Hydro's Nuclear Generating Stations

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Acknowledgment

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PART 1

Development of Ventilated Impermeable Protective Suits for Use in Ontario Hydro's CANDU Nuclear Generating Stations.

Ontario Hydro's experience with impermeable suits began with the commissioning of the Nuclear Demonstration (NPD) Reactor (20 MW(e)) at Rolphton near to the Chalk River Nuclear Laboratory (CRNL), in 1962. The designers had provided unventilated suits, identical to those used at the CRNL facilities, without realizing that the higher temperatures in the Nuclear Reactor Building (25-30°C) would lead to a significant amount of discomfort to the suit users. In order to overcome these problems, the Health Physics Department began a series of low-key, low-cost, development programs.

By the time the Douglas Point

reactor (200 MW(e)) was commissioned in the period 1965-1968, the standard impermeable suit was the 'zip suit'. This was a slightly modified MSA vinyl coverall, taped over a pair of rubber overboots at the ankles, and over rubber gloves at the wrists (using ordinary masking tape). The Encon air cooling harness with either a 'funnel' attachment for use with a hood, or a Willson half mask, provided the respiratory protection.

This equipment was also provided at the Pickering generating station (4 x 540 MW(e)), when the first unit was commissioned in 1971.

The users had many complaints about this suit. It restricted movements, it was poorly sized, vision through the hood was poor, the Encon air cooling harness required a lot of maintenance, it was uncomfortable, body cooling was poor, and it was difficult to remove the suit at the end of a work program. There were other problems, perhaps the most important being difficulty in communicating due to high noise levels in the work area (frequently > 90 dBA) and high noise levels from the air cooling harness (also > 90 dBA).

Consequently, the Health Physics department began working on new, improved protective suits and ancillary equipment. This program began in 1970.

Ontario Hydro's needs were 'different':

- They were related to the fact that the CANDU power reactor is

heavy water cooled and moderated. Tritium is produced by neutron absorption in deuterium atoms of the heavy water. Tritium is the third isotope of hydrogen, it is radioactive, emitting a 20 KeV (Emax) beta particle. Since the fuel coolant system, with a tritium concentration lying between one and two curies per kilogram of heavywater, operates at a temperature of 250°C and a pressure of 1500 psig, some tritiated water vapor leaks into the reactor building atmosphere.

This source of tritiated water vapor causes 'tritium' "maximum permissible concentration" in air (MPC(a)). It can be inhaled, or absorbed through the skin of the workers, with resulting radiation dose to the whole body.

Similarly, spills of moderator water at approximately 15 curies per kilogram of heavy water cause 'tritium' concentrations in air varying between 0.1 and 15,000 MPC(a).

- Ontario Hydro's radiation protection policy is to thoroughly train its nuclear station personnel in radiation protection, theory and practice so that they can make and interpret their own radiation protection measurements. The workers then select the protective equipment they need, don it unaided, perform their work tasks in the reactor building, then remove the protective equipment from their persons - again without assistance from a second person

(Health Physics surveyors are not employed).

- The reactor buildings are large and complex. At any given time, up to 60 people may be present in a reactor building, each one wearing an air supplied suit. Hence there are problems (still not solved) in providing respiratory protection to workers from the moment they enter the reactor building, until they connect to an air header at their own work location.

In 1977 a MK I ventilated suit was introduced to Pickering GS as a replacement for the zip suit. Since it also had many problems, it was withdrawn from service and the station reverted to the zip suit just about one year later. A MK II suit was in development at that time, but it was not ready for station use.

One benefit from the problems related to the MK I suit was that the nuclear generation division prepared a list of design requirements for their 'dream suit'. A brief summary of these

requirements is given below:

- The suit must not decrease the general level of occupational safety of the user. Factors which are considered to be important include good vision, freedom of movement, minimum tripping and slipping hazards, nonflammability of suit material, regular use of safety equipment (hard hats, safety spectacles, safety shoes /boots, and belt in appropriate circumstances), and communication headsets. The noise level from air supplied to the suit must be less than 80 dB. We must minimize components which may get caught in rotating machinery or snagged on projections. The suit must be easily and quickly removed in emergencies.
- The suited person must be reasonably comfortable when working. In this context the user must be able to dress himself (unaided) in the suit in less than 3 minutes, and to undress himself in less than 2 minutes;

both with a minimum of training. Suits and associated equipment must be reliable in field use and should be waterproof (e.g. for showering to remove surface contamination prior to undressing). The number of components that a user must assemble when dressing in a suit should be minimized, and should be less than 5 items (including a hood or respirator, but counting a pair of gloves as 1 item). All Hydro employees must be able to wear the suit but not more than 4 sizes should be provided.

- It must be possible to decontaminate and return to service one batch of suits (about 20) in less than 3 hours. (The batch size is dependent upon the facilities available; Pickering GS facilities may be considered typical). "Return to service" includes monitoring and inspection for defects. If visual inspection is not applicable, the test procedure must be quick and simple. The suit must be durable - the defect

TABLE 1

Estimate of the Increased Workload Associated with the MK IV Suit

Test Subject:	Clothing	Activity	Observed Heart Rate	VO ₂ Max.*	Estimated Heart Rate	Energy Expenditures KCals/Min	At KCals/min	% Increase
#1	Browns	a	82	50	165	7.7		
		b	99	50	165	9.3		
		c	101	50	165	9.5		
	MK IV Suit	a	113	50	165	10.6	2.9	38%
		b	118	50	165	11.1	1.8	19%
		c	124	50	165	11.6	2.1	22%
	Browns	a	99	60	190	11.1		
		b	109	60	190	12.2		
		c	115	60	190	12.9		
#8	MK IV Suit	a	111	60	190	12.4	1.3	12%
		b	122	60	190	13.6	1.4	11%
		c	123	60	190	13.8	0.9	7%

VO₂ max. in ml/kg/min.

The increase in energy expenditure between the activities carried out in radiation area clothing (Browns) and the same activities carried out in the MK IV suit is assumed to be due to the weight and bulk of the MK IV suit. It can be seen that the increase in energy expenditure by the younger but heavier test subject #8 is significantly less than the increase observed in the older, lighter test subject.

TABLE 2
Air Sampling Results
Tritium Concentrations in Air (MPC(a))*

	Browns			MK IV Suit		
	Bubbler	Syringe	Diffusion	Bubbler	Syringe	Diffusion
Test Subject #6	.185 ± .02	.17 ± .02	.183	160 ± 6	166 ± 5.8	158
Test Subject #1	.565 ± .07	.41 ± .02	.48	261 ± 11	250 ± 9.7	235
Test Subject #8	.62 ± .02	.40 ± .04	.59	210 ± 8.1	223 ± 8.7	187

*Bubbler sample results are the average of two samples run simultaneously.
Syringe sample results are an average of 10 spot samples taken at approximately 15 minute intervals.
Diffusion sample results are an average of 4 samples exposed simultaneously for the full 2 hour exposure period.

rate should be less than 5% (i.e. less than 5 damaged suits per 100 suit uses).

The design requirements were used to prepare a performance specification for the suit (Appendix 1). This was then used in a 'piecemeal' fashion to determine which type of design features would best meet the requirements of the specification. For example, as many forms of glove attachment systems as were known or could be imagined were considered and evaluated on a numerical basis, using a matrix of design requirements for gloves. The highest scoring systems and the better ones were modeled and tried out in order to confirm the best option. A similar approach was used for foot pockets for air hose attachments for suit ventilation systems for hood and air supply systems to the hood.

The Final Design of the MK III suit had the following features:

- the self-extinguishing suit fabric is 400 g/m², PVC on nylon, coated both sides, with a water vapor permeability (ASTM E96) of approximately 27 g/m²/24h at 21.5°C.
- 4 sizes cover the working population (150 cm tall to 200 cm

tall). Special ergonomic features include foot pockets set at 45° below the horizontal, arms set in the suit at the horizontal position, extra material in the back of the suit, sleeves marked to identify right and left hand and the alignment position for the glove thumbs, and color coding for suit sizes.

- Entry to the suit is via the neck. Two zip fasteners placed low across the front of the shoulders, close the suit and can be easily reached by the user.
- An internal air channel encircles the suit at the waist. Two channels from the top side of the waist channel at the back of the suit rise up to the shoulders, then curve down the sleeves to the wrist. Air is discharged into the sleeve via a single 5/16 inch diameter hole at the end of the channel. Two additional channels, from the lower side of the waist channel at the hip, supply air to each ankle, again via 5/16" diameter holes in the fabric of the channel. The suit is supplied with 28 scfm (13 l/sec) of air at a design 'air header' pressure of 75 ± 5 psig (approximately 500 kPa). All the air

supplied to the suit leaves the suit at the neck, to provide the air supply to the hood. (There is no direct connection between the suit and the hood).

- The gloves are attached by means of "glove cuff rings."

For certain types of work, where the hands must be inserted into small spaces, the glove cuff rings may be removed and the gloves taped to the sleeve of the suit.

- The booties on the suit are injection molded vinyl. They are retained on the foot by a rubber strap which dome fastens across the top of the foot.
- Air is supplied to the suit by air hoses which incorporate communication wires. Combined air/communication connectors connect the hose to the suit at the 'air inlet assembly' which is a molded polyethylene component. The air flow to the suit is controlled by means of an orifice, and the noise level is damped to less than 75 dBA by means of a perforated rubber hose which encircles the waist inside the waist airchannel.
- The hood used with the suit is a

TABLE 3
Urine Sample Data and Calculated Protection Factors

	Browns			MK IV Suit			P.F.
	Tritium Level Before Run $\mu\text{Ci/l}$	Tritium Level After Run $\mu\text{Ci/l}$	$\frac{\mu\text{Ci/l}}{\text{MPC-h}}$	Tritium Level Before Run $\mu\text{Ci/l}$	Tritium Level After Run $\mu\text{Ci/l}$	$\frac{\mu\text{Ci/l}}{\text{MPC-h}}$	Browns Suit
Test Subject #6	3.819 E-03 $\pm 2.684 \text{ E-06}$	.1497 $\pm 1.313 \text{ E-05}$	3.940 E-01 $\pm 4.259 \text{ E-02}$	2.097 E-03 $\pm 1.781 \text{ E-06}$	.10424 $\pm 1.608 \text{ E-05}$	3.190 E-04 $\pm 1.196 \text{ E-05}$	1,235 $\pm$ 141
Test Subject #1	6.626 E-03 $\pm 3.475 \text{ E-06}$	.4961 $\pm 4.994 \text{ E-05}$	4.331 E-01 $\pm 5.365 \text{ E-02}$	1.625 E-03 $\pm 1.600 \text{ E-06}$	.1138 $\pm 6.238 \text{ E-06}$	2.137 E-04 $\pm 9.00 \text{ E-06}$	2,026 $\pm$ 265
Test Subject #8	1.144 E-02 $\pm 1.850 \text{ E-06}$	.3575 $\pm 1.091 \text{ E-04}$	2.791 E-01 $\pm 9.00 \text{ E-03}$	5.1120 E-03 $\pm 3.437 \text{ E-06}$	.1174 $\pm 7.743 \text{ E-06}$	2.67 E-04 $\pm 1.029 \text{ E-05}$	1,045 $\pm$ 52.5

'shirt' type. The function of the shirt section is to form a buffer area, purged by the air leaving the suit, to minimize the backflow of contaminated air into the breathing zone of the hood. The dome of the hood is polyethylene coated tyvek (1 1/2 mils), the shirt section is regular Type 1422A Tyvek. The visor is 10 mil thick clear, polished polycarbonate. It attaches by means of dome fasteners to the brim of the hard hat so that it moves with the head to provide the user with a good field of view.

The MK III suit has proven to be very acceptable to the average user. It is easy to get into and out of. Dressing/undressing times (unaided) are of the order of 2 minutes and 30 seconds respectively.

In terms of 'station' requirements, the suit has been a little less successful. It is laundered in an industrial laundry machine in batches of about 20 but the legs of the suit get tangled and it is difficult to remove the suits from the machine. The suit is dried in a hot room (45°C) with a small (3 scfm (1.5 l/sec)) purge of

air in a time period of about 45 minutes.

Before going back into use, the suit is monitored for contamination, checked for damage and repaired if necessary.

A major problem, still not resolved, has been failure of the suit material at the junction of the molded bootie and the foot cover. This necessitates cutting off the damaged bootie and replacing it with a new boot.

It is believed that the suits are reused between 100 and 200 times before they are sent to disposal.

A MK IV version of the suit, Figure 1, has been developed by one of my colleagues. The main reason for this development was a requirement that the suit be dry cleaned instead of laundered (1). For this reason the suit is manufactured from a self-extinguishing type of Neoprene on a nylon base fabric (coated both sides). It is a copy of the MK III suit with the exception that foams pads are inserted over the shoulders to allow a better flow of air into the hood, and the booties are built up from neoprene rubber. The water vapor permeability of this suit mater-

ial is about 8 g/m²/24 h at 21.5°C.

PART 2

Measurement of the Protection Afforded by the MK IV Ventilated Suit

Introduction

As previously stated, the MK IV suit was specifically developed to meet the requirement for a dry-cleanable suit. It was required to provide the user with a minimum protection factor of 500 when supplied with 28 scfm of air. It was never clearly stated in the suit design requirements, but it was assumed that the suit should also protect the user against airborne radioactive fission and activation products, and protect his skin and personal clothing from contamination on surfaces.

The term "protection factor" is defined as the ratio of the 'tritium' uptake (for a specific task) by an unprotected person, to the uptake by the same person, for the same task, when wearing the air supplied MK IV suit with the disposable 'tyvek' hood.

Experimental Procedure

The objective was to measure the uptake of tritiated water vapor by test subjects who are exposed to a known concentration of tritiated water vapor in air, while they carried out a specified (simulated work) program which lasted for a period of 120 minutes. The test subjects were exposed on two occasions; initially whilst they wore the air supplied MK IV ventilated suit (with the disposable Tyvek hood) in a concentration of approximately 150 MPC(a) HTO vapor, and secondly, when they wore normal radiation area protective clothing (brown polyester/cotton coveralls, yellow undershirt, pants and socks, safety shoes and hard hat) at a concentration of approximately 0.5 MPC(a) of tritiated water vapor in air.

The 'tritium' uptake was measured

by requiring each test subject to submit approximately 10 urine samples in the 3 day period prior to his exposure as a test subject, and a further 10 urine samples in the 3 day period after his exposure. Least squares regression analysis was used to determine the equation of the best fitted lines passing through the data points, and these lines were extrapolated and interpolated (respectively) to the point in time immediately prior to, and after, the exposure period. The difference between the tritium in urine concentration prior to and after exposure, as indicated by the extrapolated data points is considered to be the best estimate of the tritium uptake by the test subject.

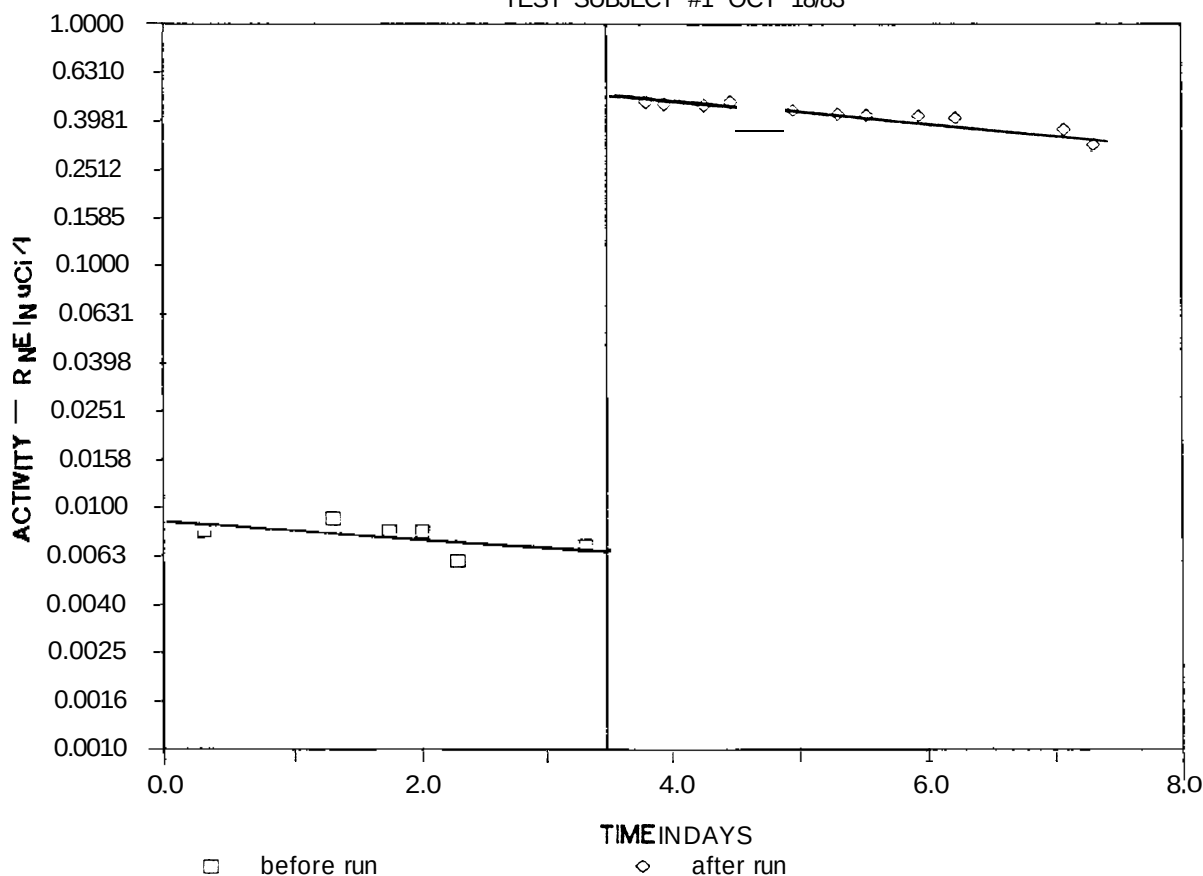
Every effort was made to ensure that the factors which may affect the magnitude of the tritium uptake, were controlled and comparable in

the two measurement on each test subject. Examples of these precautions include:

- The test subject was requested not to go near the generating stations in the 3 day periods during which he was submitting urine samples.
- The tritium concentration in the control area of the exposure chamber was measured and shown to be less than 0.1MPC(a) whilst the test subject was in the area.
- The test subject was supplied with 13.3 l/sec (28.0 scfm) ft/min of air while he was wearing the MK IV ventilated suit. Every care was taken to ensure that he was not exposed to tritiated water vapor when the suit was not air supplied.

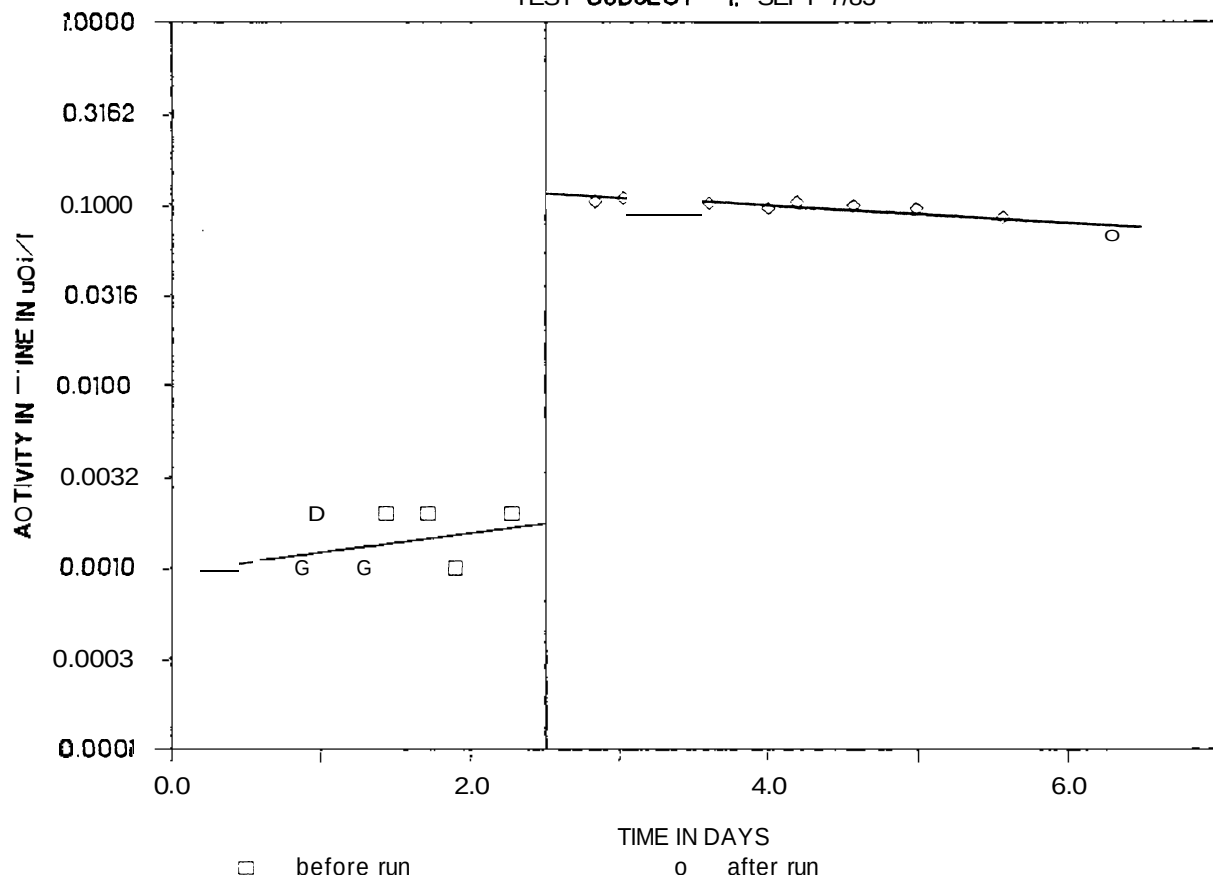
URINE SAMPLE DATA - FIG * 1 - BROWNS

TEST SUBJECT #1 OCT 18/83



URINE SAMPLE DATA - FIG. #2 -MK IV SUIT

TEST SUBJECT * 1, SEPT 7/83



- The temperature at which the experiment was carried out was $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$.
- The work program, by the test subject, is the same for each experiment. It lasts for 120 mins. (± 2 secs); the activities are detailed for each minute and they are intended to represent a moderate work rate (i.e. approximately 250 KCals/hour energy expenditure). The activities include 3 periods of walking on a treadmill (which operates to 1.3 m/sec (3 miles/h)) at 3 levels of inclination, calisthenic exercises (each of 6 exercises for a 1 min. period followed by a 1 min. rest period) and the assembly and disassembly of a slotted angle bench. Complete details of the exercise protocol are given in Appendix 2.

- After the exposure period the test subject remains in the air supplied ventilated suit, for a period of 5 min., while standing in the air lock, to allow the tritium concentration carried into the air lock when the test subject left the exposure chamber, to be extracted, and to allow any tritiated water vapor which may diffuse off the suit surface to be dispersed.

Details Of The Exposure Chamber

The exposure chamber consists of a 3.0 m x 3.6 m x 2.4 m high room in which all surfaces have been lined with 24 gauge aluminum sheet metal and sealed against water vapor. The room contains a treadmill and there is floor space for

exercises and assembly and disassembly of a slotted angle bench. Air is extracted from the exposure chamber at a rate of approximately 2.0 m³/min (approx. 50 scfm) which is high enough to cope with the 131/sec (28 scfm) air flow exhausted from the suit, and to maintain an air flow into the exposure chamber through the cracks around the door seal, etc. (i.e. to prevent tritiated water vapor from diffusing out of the exposure chamber into the air lock and the control area).

Tritiated water vapor is continuously generated by blowing air (1.4 l/sec) through a mildly heated (approximately 40°C) container of appropriately concentrated tritiated water.

The tritiated water vapor is dispersed throughout the chamber by means of a 60 cm diameter fan which is arranged to blow down onto

the container of tritiated water.

Measurement Of Tritiated Water Vapor In Air

The 'tritium' in air concentration was measured in three ways using bubbler samplers, syringe samplers, and diffusion samplers.

In order to get an accurate estimate of the average 'tritium' in air concentration a sample of the air being extracted from the room by the ventilation system was drawn to the sampling ports through a long glass tube, by a mechanical pump, at a flow rate of approximately 4 l/minute. The glass tube was connected to the sampling ports by means of short 'T' pieces. Excess air

from the pump was discharged back into the exposure chamber.

Bubbler Samplers

Each bubbler sampler consists of two bubbler jars in series; (each jar containing 100 g of water). The sampling rate, 1.01 per minute, is measured by a differential pressure flow meter which had been calibrated by a bubble tube and by a mass flow meter. Two separate bubbling sampling trains are run in parallel and draw a sample of air from the sampling port referred to above. The sampling trains are switched on simultaneously when the test subject enters the exposure chamber and switched off when he leaves. Each sampling train independently integrates the test subjects exposure, to provide a corroborated estimate

of his exposure. The precision of this measurement is estimated to be about $\pm 15\%$ (95% confidence limit).

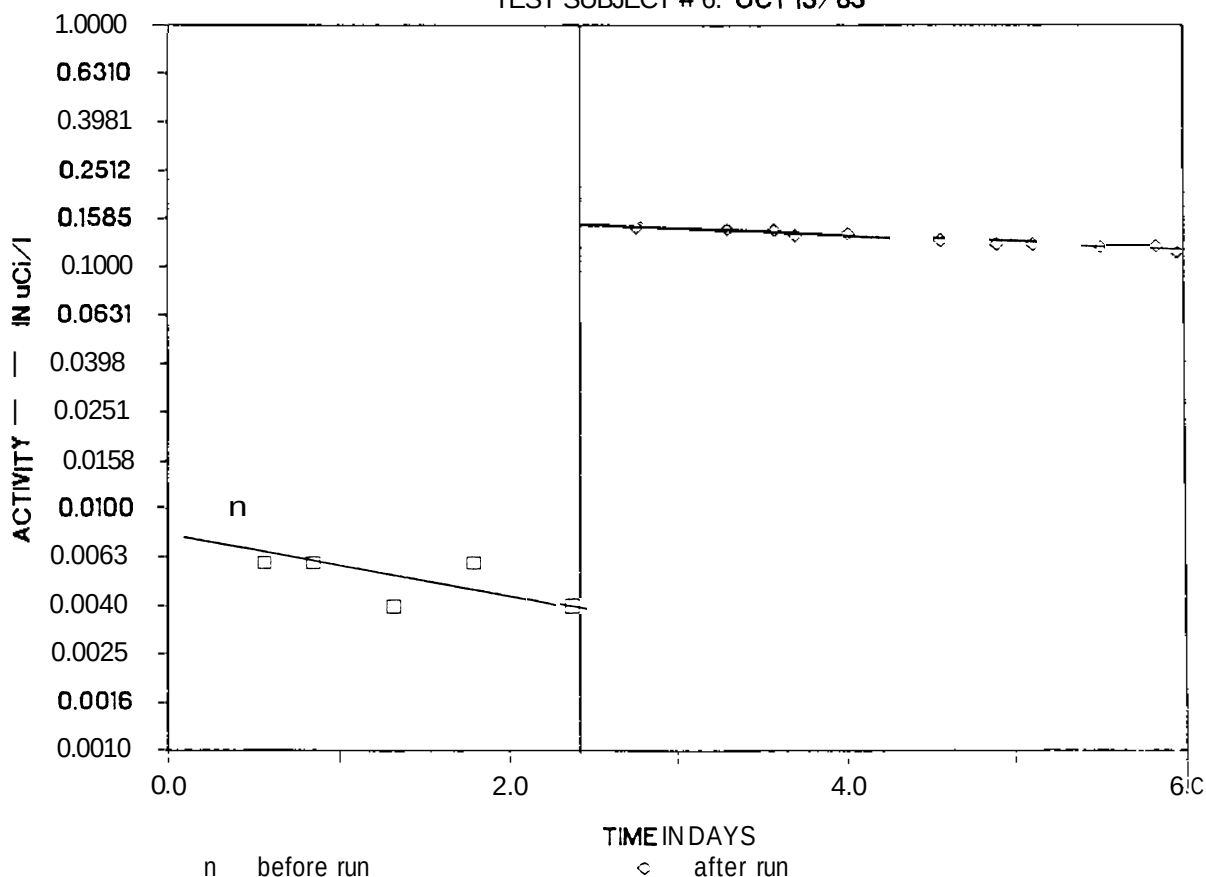
Syringe Samplers

Samples of the air in the exposure chamber are obtained through a sampling port by means of an all glass hypodermic syringe. The 10 cm³ air sample in the syringe is bubbled slowly through 20 cm³ of liquid scintillator contained in a counting vial. This assures quantitative exchange of the tritiated water.

These 'spot' samples are taken every 15 minutes and are counted immediately. They provide an almost immediate indication of the tritiated water vapor concentration in the exposure chamber for control purposes. Later, the samples are counted for at least 10 minutes in

URINE SAMPLE DATA - FIG.#3. BROWNS

TEST SUBJECT # 6. OCT 13/83



order to obtain a more accurate estimate of the tritium concentration. The precision of this method is primarily dependent upon counting statistics, i.e. it varies with the 'tritium' concentration in air, but is believed to be about $\pm 3\%$ at 150 MPC(a) to $\pm 15\%$ at 0.5 MPC(a) (again to 95 % confidence limits).

Diffusion Samplers

Four diffusion samplers are taken into the room by the test subject, when he enters the room, and placed in the central area of the exposure chamber. They are removed from the room when he leaves. These samplers integrate the exposure over the whole exposure period. They are believed to have a precision better than $\pm 10\%$.

Measurement Of 'Tritium' Uptake By The Test Subject

As previously stated, the test subject is required to submit up to 10 urine samples in the 3 day period before/after his exposure. An appropriate regression analysis (either linear or exponential) is applied to the data (depending whether the test subject is excreting tritium from a previous exposure, or whether he was at a low 'background' level prior to the experiment). The urine samples are prepared for counting in a low activity area, and counted on a liquid scintillation counter which has a background count rate of approximately 6 counts/minute. The counting efficiency for each sample is measured by spiking each sample of the urine with a known quantity of

tritiated water. The precision of the method varies with the magnitude of the uptake. It is estimated to be approximately $\pm 4\%$ (to 95% confidence limits) for high uptakes of tritiated water ($>0.5 \mu\text{Ci/l}$) to $\pm 30\%$ for low uptakes or background level measurements.

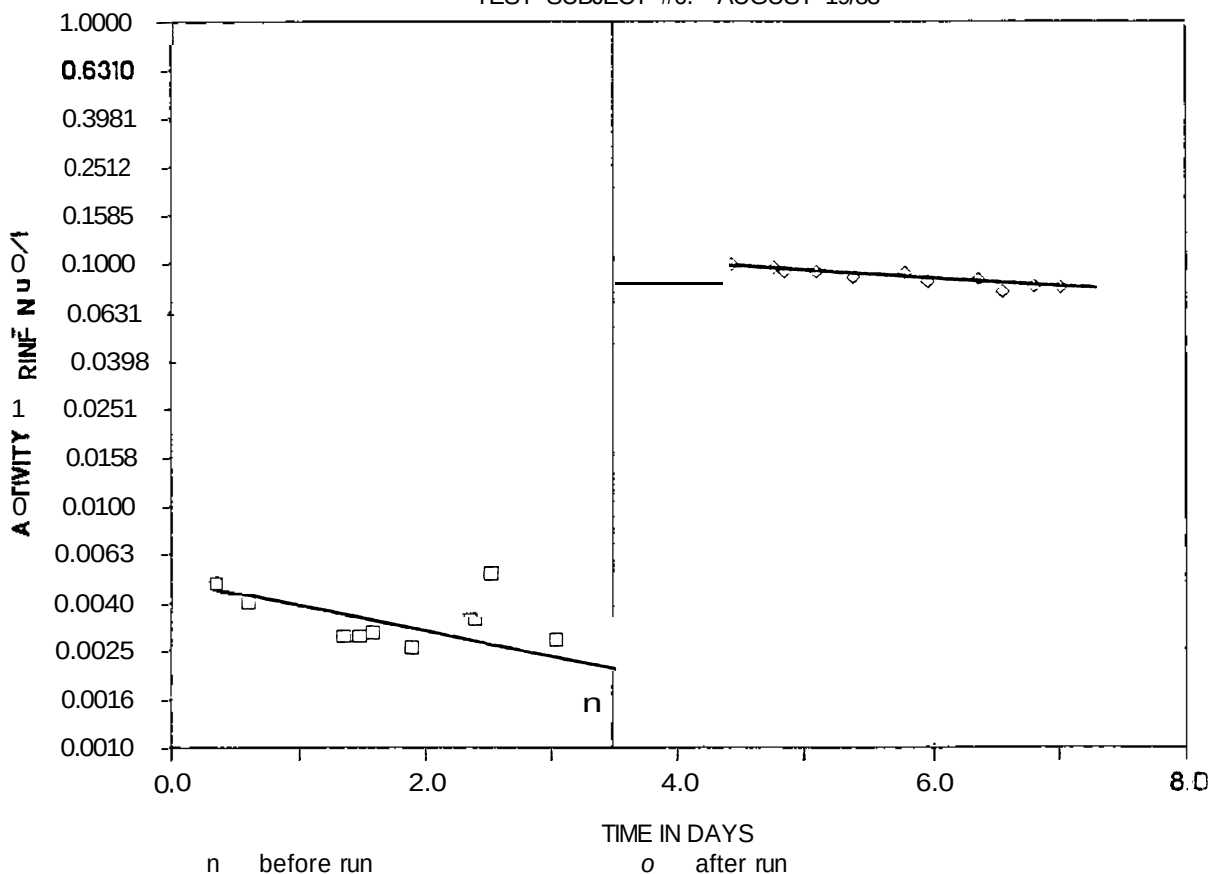
The Test Subject

The physical condition of the test subject was monitored during the exposure period in two ways:

- 1) Using a heart rate monitor (a plethysmograph), attached to the ear, gives a visual and digital indication of the heart rate at a rate of 1 readout every 2 seconds. This data is continuously recorded during the 2 hour simulated work program. To ensure the safety of the test subject an administrative

URINE SAMPLE DATA - FIG.#4 - MK IV SUIT

TEST SUBJECT #6. AUGUST 19/83



procedure requires that if the heart rate reaches 160 beats/min, then the test subject must be asked to rest. Usually 1 or 2 minutes rest restores the heart rate to an acceptable level and the experiment can continue. Two conditions have been observed to raise the heart rate above the permitted level.

- a) Walking on the treadmill when it is inclined (up hill) at 5°, when wearing the MK III suits, when the environmental temperature was close to 30°C (experiments not reported here).
- b) When the level of mental stress in a particular test subject was high, e.g. when assembling the slotted angle bench against a time limit.

- 2) A rectal thermister probe. The test subject is required to rest if the deep body temperature exceeds 38.8°C (this temperature limit has only been exceeded when test subjects were working in environmental temperatures close to 30°C-experimental data not reported here).

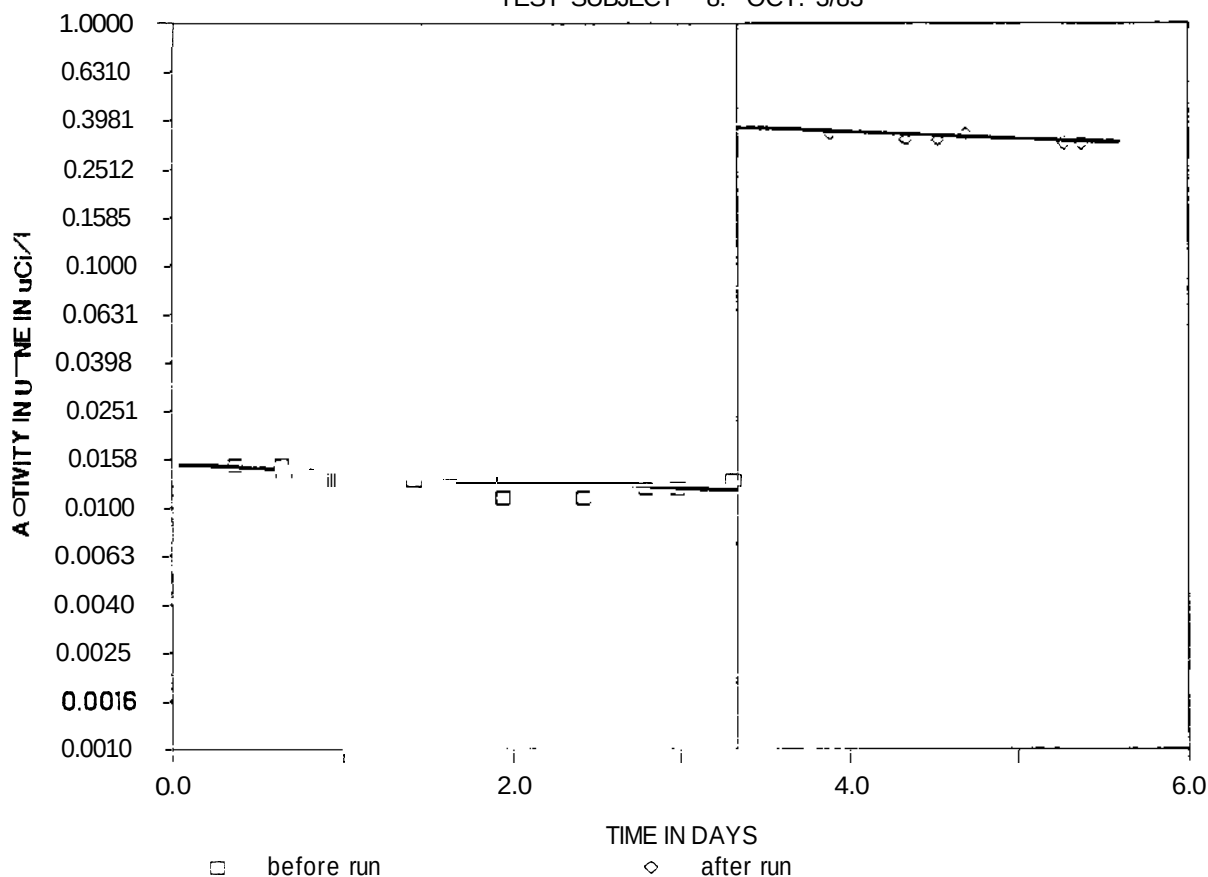
The test subjects who volunteered to assist in measuring the protection afforded by the MK IV suit in the experiment reported here were aged 24, 36 and 53 years, with body weights of 72.5, 90.9 and 61.7 kg respectively. An indication of the effect of the suit upon the user (relative to normal radiation area

clothing) can be calculated from the change in the heart rate, for various stages of the work program, after taking account of the test subjects weight, relative physical fitness and estimating his maximum oxygen uptake rate (VO_2 max.) and heart rate. Table 1 shows this data for test subjects #1 and #8 (data for test subject #6 was lost when the heart rate recorder failed) during each of three selected activities in the work program.

The increase in energy expenditure between the activities carried out in radiation area clothing (Browns) and the same activities carried out in the MK IV suit is assumed to be due to the weight and bulk of the MK IV suit. It can be seen

URINE SAMPLE DATA - FIG. #5 - BROWNS

TEST SUBJECT * 8. OCT. 3/83



that the increase in energy expenditure by the younger, but heavier test subject #8 is significantly less than the increase in energy expenditure by the older, lighter test subject. (The estimates of the energy expenditures is thought to have a precision of the order of $\pm 20\%$.)

Results

Each test subject was exposed in the ventilated MK IV suit with the disposable tyvek hood. In each case the air flow rate to the suit was set at 13.3 l/sec(28.0 scfm).

The test subjects also wore a communication headset to facilitate communications with the program controller. The target tritium concen-

tration in the exposure chamber during this series of experiments was 150 MPC(a).

The tritium concentration in air was significantly higher than the target value in one experiment, due to the fact that the air extract rate from the room was below the normal level, (an adjustment in the extract rate over-looked when a problem arose with part of the test equipment).

Exposures In Radiation

Area Clothing

The target tritium concentration was 0.5 MPC(a). No problems (other than a failure of the heart rate

recorder during one of the experiments) occurred in this series of measurements, which were made several weeks after the measurements of the uptake in the MK IV suit.

Results Obtained

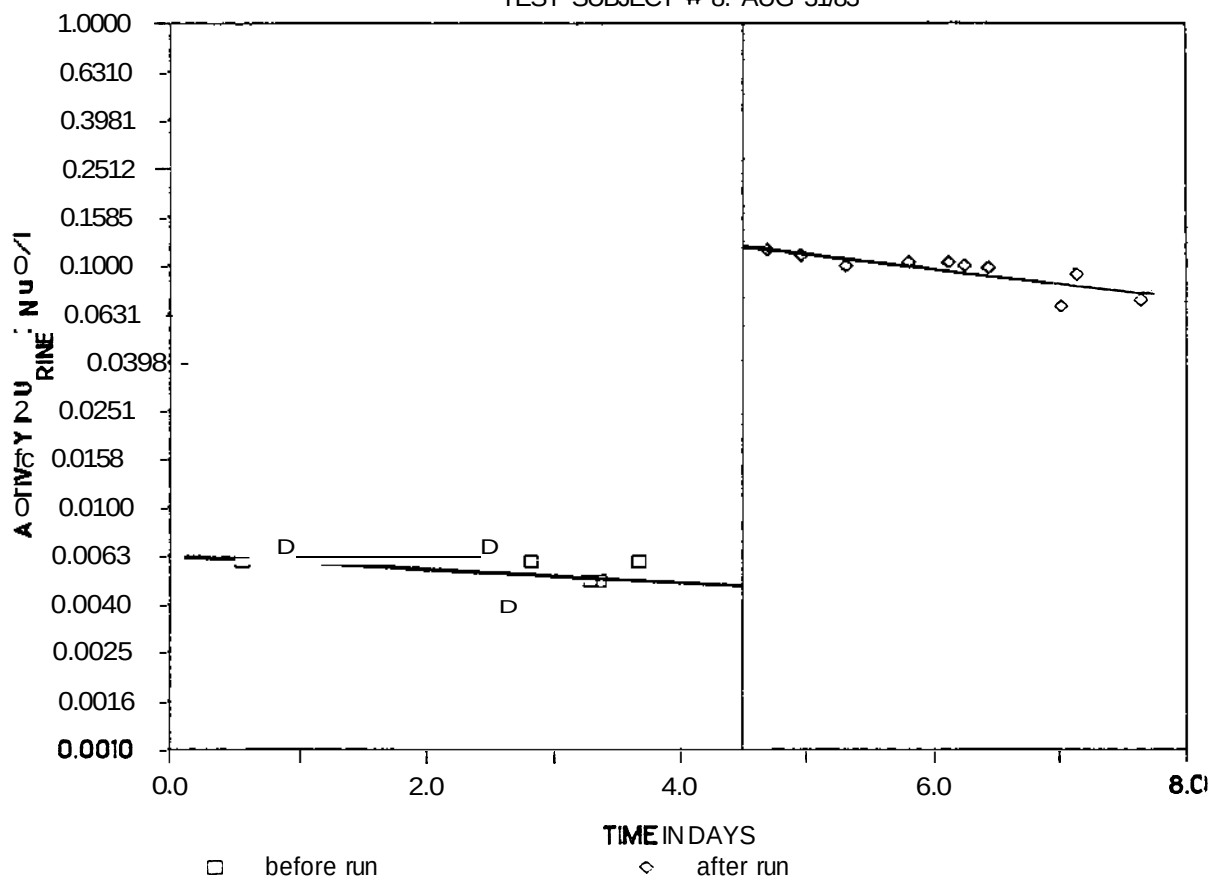
Air sampling data for all six experiments are shown in Table Two.

Urine analysis data is shown in Figures One to Six. A summary of the 'tritium' uptakes and the calculated protection factor for each of the test subjects is shown in Table Three.

The calculation, carried out after 'normalizing' the urinary excretion rate to $\mu\text{Ci}/1$ per MPC-h exposure, uses the relationship.

URINE SAMPLE DATA - FIG #6 - MK IV SUIT

TEST SUBJECT # 8. AUG 31/83



Protection $\mu\text{Ci}/1 \text{ MPC(a)-h Browns}$

Factor = $\mu\text{Ci}/1 \text{ MPC(a)-h MK IV Suit}$

The calculated protection factors (to 95% confidence limits) were:

Test Subject #1	2026 $\pm$ 265
Test Subject #6	1235 $\pm$ 141
Test Subject #8	1045 $\pm$ 52.5

Conclusion

It is concluded that the MK IV suit can provide users with protection factors in excess of 1000 against tritiated water vapor when it is used with an adequate supply of compressed air. The suit meets the user's design criterion, i.e. "it should provide the user with a protection factor of not less than 500 against tritiated water vapor."

Reference

Bennett, J.D.

Operational Design Guidelines for a Dry Cleanable Plastic Suit for Use in Ontario Hydro Nuclear Generating Station: Revision 01 RMEP 1980.

Appendix 1

Performance Specifications for an Air Supplied Suit for Use in CANDU Nuclear Generating Stations

1. The suit must be used with normal radiation area clothing. This clothing consists of hard hat, safety glasses, brown cotton/polyester coverall over cotton pants and vest, knitted socks (yellow), safety shoes or boots (CSA Grade 1 Electric Shock Resistant), hard hat, safety glasses, hearing protectors.
2. The suit must fit all members of the working population in not more

than 4 sizes. The minimum size is 5'0". The maximum size is 6'6". Suits must be marked with the size and color coded.

3. The suit must allow the user normal mobility. There must be no restrictions on range of movement of arms or legs, no restrictions on squatting or other normal movements, or placing the hands into small spaces. The user must be able to dress in the suit in less than 3 minutes (unaided) and remove the suit from his person (unaided) in less than 2 minutes.
4. The suit must provide a protection factor of 500 against tritiated water vapor.
5. The suit material must be non-flammable or self-extinguishing.
6. It must be possible to use communications equipment routinely in areas where the external or ambient sound level is 100 dBA and/or 105 dBC.
7. The hood must provide a normal field of view free from distortion or haze.
8. The air supply to the suit and hood must be capable of maintaining normal body temperatures when the subject is working at a moderate work rate (250 KCals/h) in an environment at 25°C. The air supply to the hood should be not less than 6 scfm. The sound level in the hood related to the air supply to the suit and hood must be less than 80 dBA measured inside the hood at the ears.
9. When using the suit the user must not be exposed to any safety hazards specific to the suit,
 - e.g. • no loose parts which could get caught in rotating machinery

- no slipping or tripping hazards
- must be able to use a safety belt or harness when working at a height above floor level
- it must be possible to remove the suit quickly in emergencies.

10. Training requirements must be kept to a minimum. It must be obvious to the average person how to don the suit, even if he has never seen it before.

11. The suit must be waterproof for showering to remove surface contamination prior to removing the suit. When removing the suit (unaided) the user must not transfer contamination from the exterior surface of the suit to his person or radiation area clothing.

In addition to the above the following 'station' requirements must be met.

1. It must be possible to launder the suit and hood after use in an industrial laundry machine. The suit and hood must be dried in a drying room after laundering. The average batch size will be 20 suits. It should be possible to launder the suits and return them for reuse in a period of 3 hours.
2. After laundering, the suits must be monitored for surface contamination inspected and repaired prior to reissue. If visual inspection is not applicable, then the test procedure must be quick and simple.
3. The suit should be rugged and require minimal maintenance. Fewer than 5 suits in 100 should require repair.
4. The cost of the suit should be acceptably low (>\$500). The design of the suit should be such that at least 200 uses are obtained from each suit.