UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 5, 2003

MEMORANDUM TO: Melvyn N. Leach, Chief
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards
Office of Nuclear Material Safety
and Safeguards

THRU: Joseph G. Giitter, Chief
Special Projects Section
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

Joseph G. Giitter 3/5/2003

FROM: Rex Wescott, Sr. Fire Protection Engineer
Special Projects Section
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

3/04/2003 RJW

SUBJECT: JANUARY 15-16, 2003, MEETING SUMMARY: MEETING WITH DUKE COGEMA STONE & WEBSTER TO DISCUSS MIXED OXIDE FUEL FABRICATION FACILITY REVISED CONSTRUCTION AUTHORIZATION REQUEST

On January 15-16, 2003, the U.S. Nuclear Regulatory Commission (NRC) staff met with Duke Cogema Stone & Webster (DCS), the mixed oxide fuel fabrication facility (MFFF) applicant, to discuss the revised construction authorization request (CAR) submitted to NRC on October 31, 2002. The meeting agenda, summary, handouts, and attendance list are attached (Attachments 1, 2, 3, and 4 respectively).

Attachments:
1. Meeting Agenda
2. Meeting Summary
3. Meeting Handouts
4. Attendance List

cc: P. Hastings, DCS
J. Johnson, DOE
H. Porter, SCDHEC
J. Conway, DNFSB
L. Zeller, BREDL
G. Carroll, GANE
D. Curran
D. Silverman

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ADAMS Accession NO:ML030300126
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OFC	SPIB*	SPIB*	SPIB*	SPIB*	SPIB
NAME	RWescott	LGross	APersinko	DBrown	JGiitter
DATE	2/ 11 /03	2/ 11 /03	2/ 11 /03	2/ 13 /03	3/ 5 /03

OFFICIAL RECORD COPY

MEETING AGENDA
MOX FUEL FABRICATION FACILITY

January 15, 2003

9:00 AM	Discussion of confinement ventilation
12:00 NOON	Lunch
1:00 PM	Discussion of chemical safety
4:30	Summary / Actions
5:00 PM	Adjourn

January 16, 2003

9:00 AM	Discussion of nuclear criticality safety
12:00 NOON	Lunch
1:00 PM	Discussion of nuclear criticality safety
4:30	Summary / Actions
5:00 PM	Adjourn

NOTE: other than start time, above times are approximate.

MEETING SUMMARY
MOX FUEL FABRICATION FACILITY
January 15-16, 2003

Purpose:

The purpose of the meeting was to discuss confinement ventilation, chemical safety, and nuclear criticality safety issues related to the Mixed Oxide Fuel Fabrication Facility Construction Authorization Request (CAR) submitted by DCS on October 31, 2002, or identified in the NRC staff's Draft Safety Evaluation Report (DSER) dated April 30, 2002.

Confinement Ventilation:

As stated in the DSER (Open Item VS-1 in appendix A), NRC staff requires DCS to justify the use of a leak path factor of 1E-4 for two banks of filters under accident conditions. DCS (Gary Kaplan) provided an introductory presentation including an executive summary, followed by a presentation by Dr. Werner Bergman, a consultant in filter performance, which addressed basic filter operation and the effects of soot and moisture on filter performance. Dr. Bergman's presentation was followed by a presentation by DCS (Tom St. Louis) that addressed some of the design aspects of the confinement/ventilation system.

Some of the major points made by Gary Kaplan were:
1) Almost every room can be considered a separate fire area.
2) The roughing filters are the primary protection of the system from burning embers.
3) Soot production from two separate fire areas was considered for the soot loading analysis.

Major points from Dr. Bergman's presentation included:
1) Filters that were fire tested in heated air apparatus still maintained at least 99% efficiency.
2) Particle penetration through filters follows a bell curve, with 0.15 μm diameter particles as the most penetrating, and lesser penetration for smaller and larger particles.
3) Water should not be the first choice for filter fire protection in a new facility; DOE intended it as a backfit for existing facilities.

Major points from Tom St. Louis' presentation included:
1) All fans in the C4 confinement system can be powered by an uninterruptible power supply for one hour to get over the initial transient when the Emergency Diesel Generators are started.
2) Separate housing of filters prevents fire from affecting two trains of filters.
3) Dilution of fire gases from the worst fire area resulted in a temperature less than 390 °F at C3High Efficiency Particulate Air (HEPA) filters.
4) Dilution of fire gases in the C4 system results in temperatures at HEPA filters less than 200°F.

Questions and concerns from the staff included:
1) How will uncertainty be incorporated in the analyses of the effects of heat and soot on filter efficiency? In response, DCS indicated that it performed analyses of soot and temperature effects in multiple fire areas. The staff asked DCS to provide additional information on these analyses. DCS has stated that this is beyond the design basis as supported by the fire hazard

Attachment 2

analysis (FHA) (i.e., the FHA and the Safety Assessment in the CAR demonstrate that a fire will not spread beyond fire area boundaries). However, DCS has agreed to provide information on these sensitivity analyses considering more than one burning fire area.

2) How are fires in the duct work prevented? DCS replied that intermediate HEPA filters located at the gloveboxes and at the C3 boundary capture dust and prevent combustible dust buildup in the ventilation ducts.

3) What are the effects of chemical releases on HEPA filters? DCS found that chemicals such as nitric acid have been found to limit the effective life of HEPA filters by attacking the binding material and destroying the mechanical integrity of the filter, and, thus, rendering the filter ineffective. DCS plans to pretreat the offgases (e.g., by scrubbing) so that filter efficiency is not impacted by the chemicals.

4) Is DCS considering the possible combustion of unburned fire gases in the ventilation ducts? DCS replied that they were considering this phenomenon and expect that its consequences will be limited by dilution.

5) Can burning UO_2 embers travel through the ducts to the HEPA filters? DCS provided overview information on several key historical fire events involving HEPA filters, including one event involving UO_2. DCS stated that their intent was to use non-combustible, pre-filters to capture the UO_2 and any burning particles, and thus preserve the HEPA filters. NRC staff inquired about pre-filter effectiveness for particle sizes. DCS did not have that information available to them at the meeting, but will provide it.

At the end of the morning meeting, Steven Dolley of the Nuclear Control Institute (NCI) commented that he was impressed by the NRC staff's attention to detail. He also commented that he thought by requesting more detail from NRC, DCS was shifting the burden of proof to NRC.

Chemical Safety

Chemical safety was discussed on the afternoon of 1/15/2003 and consisted of presentations by Gary Kaplan and Steve Kimura of DCS.

The first issue discussed regarded releases of hazardous chemicals that could affect facility workers through a flow path from the stack to the Emergency Control Room (ECR) intakes. This issue is identified as Open Item AP-13 in appendix A of the DSER. The NRC stated that this issue is closed based upon the written, qualitative justification from DCS that showed site worker impacts would bound facility worker impacts.

Gary Kaplan provided a presentation on temporary emergency exposure limits (TEELs) as a response to open issues concerning TEELs vs. numerical values (CS-5b, a new issue identified in the January 2003 Monthly Open Items Status Report) and ECR habitability (CS-10, identified in appendix A of the DSER). In regard to control room habitability, DCS stated that monitoring will be performed for those chemicals whose unmitigated release could result in control room concentrations above the TEEL-3 limit. Specific setpoints will be determined during final design. NRC staff mentioned that the regulatory guide on control room habitability is based upon IDLH (Immediately Dangerous to Life and Health) values and the use of Self Contained Breathing Apparatus (SCBA). Preliminary calculations indicate that hydrazine monohydrate or nitrogen tetroxide could result in control room concentrations at or above the TEEL-3 limit. However, calculations will be made during final design to verify the list of chemicals to be monitored. Mr. Kaplan also provided a table showing the changes in concentrations of chemicals that correspond to the various changing TEEL limits. It was noted that in the opinion of DCS, the TEEL values represented the latest information regarding chemical Toxicity and that some of the TEEL values corresponded to emergency response planning guideline (ERPG) values.

The DCS position is that they will base their actions on either numerical values as already presented or the potentially changing TEEL levels depending on NRC's preference. NRC would rather DCS used regulatory based limits such as those from the Environmental Protection Agency, (Acute Exposure Guideline Level), National Institute for Occupational Safety and Health and short term exposure levels. DCS noted that TEEL-3 levels were used for the ECR but that lower, TEEL-2 limits were used for the site worker limits. DCS noted that many of the TEEL values reflect ERPG values. This item was not resolved and will be addressed in future meetings.

DCS indicated the strategy for addressing potential pressure increases in the storage cans (e.g., from radiolysis of water) was still being evaluated. This issue was identified as Open Item MP-2 in appendix A of the DSER. DCS is considering a storage time limit, a moisture limit, a pressure rating approach, a continuous pressure relief of the gases, or reliance on glovebox integrity surviving an over pressurization event, and would inform the NRC of the selected approaches at a subsequent meeting.

The other major issue discussed was the determination of lower flammability limits for mixtures of gases which was part of AP-2 regarding hydrogen generated by electrolysis in the electrolyzer. DCS presented a graph of the flammability limits of Argon-Hydrogen in air at various temperatures. DCS postulated a scenario of the worst case leak into the sintering furnace room and determined a maximum gas temperature of 120°C and an argon concentration of 75%. Under these conditions, combustion could be obtained with an air mixture of 21.7% and a hydrogen mixture of 3.3%. Hence, the lower flammability limit (LFL) thresholds for this event would be 1.6% (50% LFL) and 0.8% (25% LFL). NRC staff also inquired about determination of LFL for combinations of flammable gases and vapors such as might exist in the offgas treatment system. DCS replied that this would be addressed at the ISA stage. This is considered acceptable to the staff.

<u>Nuclear Criticality Safety</u>

Nuclear criticality safety (NCS) was discussed on January 16, 2003. Bill Newmyer and Bob Foster of DCS made a presentation consisting of DCS responses to 8 DSER open items and 10 new questions on the revised CAR.

The first issue (NCS-1) regarded the need for specific Pu/Mixed Oxide (MOX) experience for NCS staff involved in the design stage. DCS's main point was involvement of COGEMA and its subsidiary which have over 20 years of MOX experience. NRC was concerned about loss of subsidiary which have over 20 years of MOX experience. NRC was concerned about loss of experienced individuals presently onboard. In response, DCS stated that it will commit to MOX specific training.

NCS-2 concerned the definition of NCS design basis controlled parameters for Aqueous Polishing and Mox Processing auxiliary systems. Questions from NRC included how backflow will be presented. DCS responded that it will provide information regarding general approaches to prevent backflow. NRC also asked about controls on downblending. NRC stated that in a downblending operation the equipment must be either designed for 100% enrichment of material or there must be a control on enrichment. DCS stated that it would submit change pages.

NCS-3 concerned the justification for the bounding density values assumed in Tables 6-1 and 6-2 of the CAR. DCS stated that maximum theoretical density is assumed in lead-in units. Downstream densities are based on data from France.
Assumed densities below maximum theoretical will be confirmed during startup. NRC is concerned about possible process changes after startup and how these may effect density. DCS agreed to provide a write-up regarding density changes and where density measurements will be made. DCS will also justify that no in-line measurements of density need to be where process changes will not alter density.

NCS-4 concerned the determination of design basis upper safety limits for each process type, and justification for the administrative margin. NRC indicated that more discussion was needed on the last bullet of the third slide for NCS-4 which stated that the loss of one control does not change the value of k-effective. It was not apparent that this meets DCS' commitment to dual parameter control. NRC wants a margin specified for k-effective in normal operations, that in most cases, will be greater than the margin for abnormal operation. DCS will provide a description of its methodology for determining normal condition margin.[1] NRC also stated that the validation report will be reviewed in detail which may result in an open item when the DSER is issued.

NCS-5 concerned the definition of highly unlikely for criticality hazards. Most of the discussion centered around the necessity of of a supplemental likelihood assessment to show that a criticality event was highly unlikely. DCS argued that their response to request for additional information (RAI) 39 proposed deterministic arguments only for strategies that protect the facility worker, and not a likelihood assessment. NRC stated that in cases where deterministic arguments for strategies were accepted, the strategy was almost always a mitigation strategy. For events that were prevented, the staff was able to formulate a likelihood argument based on the type of controls described. DCS will consolidate previous write-ups and provide more discussion regarding determination of control adequacy.

NCS-6 concerning American National Standards Institute (ANSI)/ American Nuclear Society (ANS)-8.1-1983 was considered closed at the time of the meeting.

NCS-7 concerning ANSI/ANS-8.15-1981 was considered closed at the time of the meeting.

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[1]DCS will describe the application of the methodology in the license application for possession and use of SNM.

CS-8 concerning ANSI/ANS-8.17-1984 was considered closed at the time of the meeting.

DCS responses to the 10 new questions on the DSER were considered acceptable with the following qualifications:

- A revision to the CAR will be required for resolution of question 2 concerning the assumed fraction of U235 in the incoming feed materials.
- A revision to the CAR will be required for resolution of question 4 concerning the DCS commitment to ANSI/ANS criticality standards.
- A revision to the CAR will be required for resolution of question 6 concerning the need for a sentence requiring familiarity with NCS programs at similar facilities.
- A revision to the CAR will be required for resolution of question 8 concerning criticality monitoring requirement. The revision will remove the sentence starting with "Criticality Accident Alarm System (CAAS) coverage in shipping containers..."
- A revision to the CAR will be required for resolution of question 9 requesting a clarification of the role of ANSI/ANS criticality standards 8.7, 10, and 12 as design bases.
- A revision to the CAR will be required for resolution of question 10 requesting a clarification of the role of ANSI/ANS-8.23 in design of MFFF processes.

More detail on the NCS open item issues and questions on the revised CAR are provided in the last group of meeting handouts.

At the conclusion of the meeting, Mary Olson of Nuclear Information and Resource Service asked the following three questions:

1) In view of what happened at Rocky Flats, how can NRC be sure that the ventilation design is adequate? NRC replied that at the CAR stage we will assure that the design conforms to presently accepted practices and review specific design details at the license application stage.

2) Are Savannah River Site (SRS) workers being considered as members of the public for 10 CFR 70.61 compliance? NRC replied the SRS site workers will be considered as radiation workers if they receive subpart H training.

3) Will occasional contractors receive training? NRC responded that the staff will find out and respond directly to Mary Olson.

Nuclear air cleaning systems in the U.S.

DUKE COGEMA
STONE & WEBSTER

•Commercial nuclear power plants have air cleaning systems in a stand-by mode for use during and after accidents. The fuel handling building and control room have air cleaning systems operating continuously.

Defense Pu production reactors and most research reactors have on-line air cleaning systems operating continuously in a once-through configuration.

The primary contaminants from nuclear reactors are radioactive gases, thereby requiring carbon filters. HEPA filters are also used to remove a smaller quantity of radioactive particles.

Nuclear air cleaning systems in the U.S. (Continued)

DUKE COGEMA
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•Nuclear weapons and fuel production facilities have air cleaning systems operating continuously in a once-through configuration.

HEPA filters are used in nuclear weapons and fuel production facilities because the primary contamination is radioactive particles.

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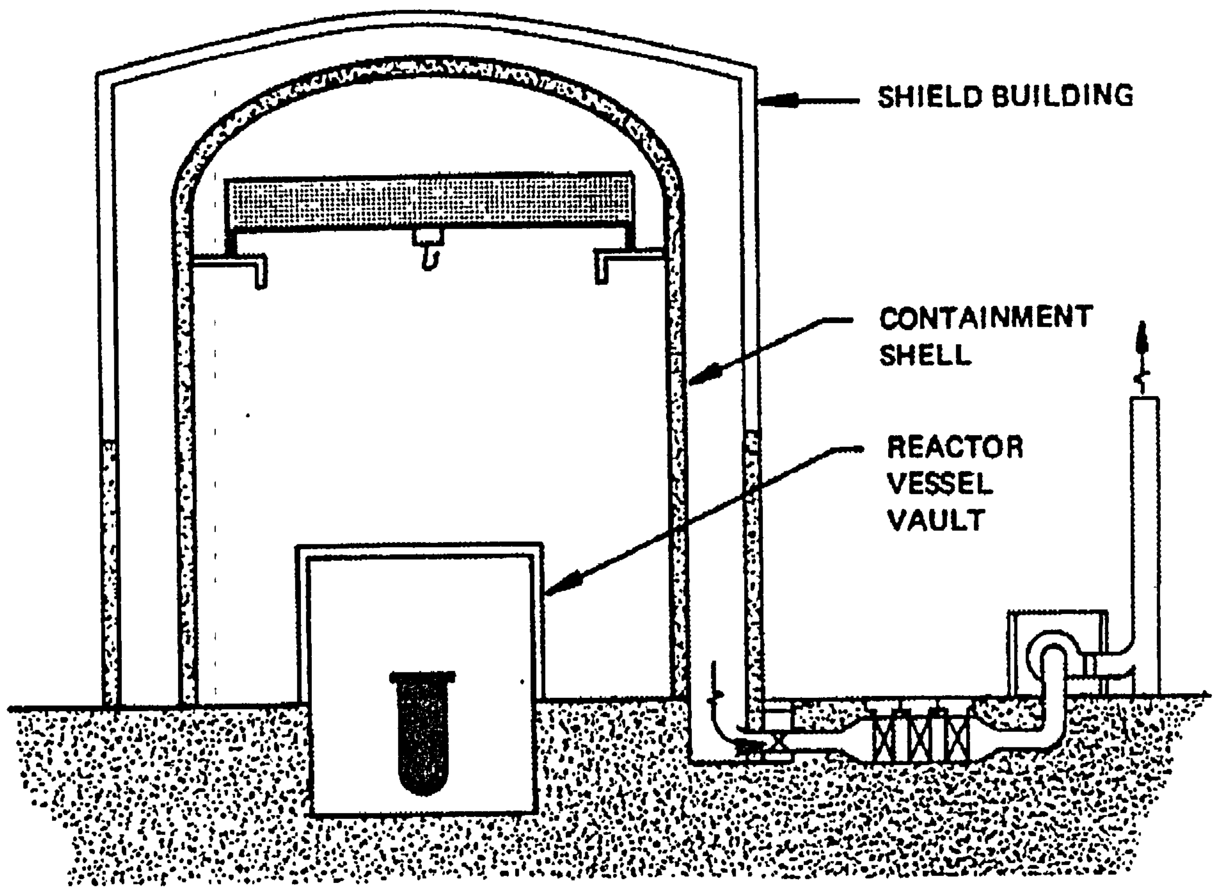
Commercial nuclear power reactors use stand-by emergency filters

- Pressurized water reactors (PWR) have a containment shell consisting of a steel pressure vessel to contain radioactive gases and particles.



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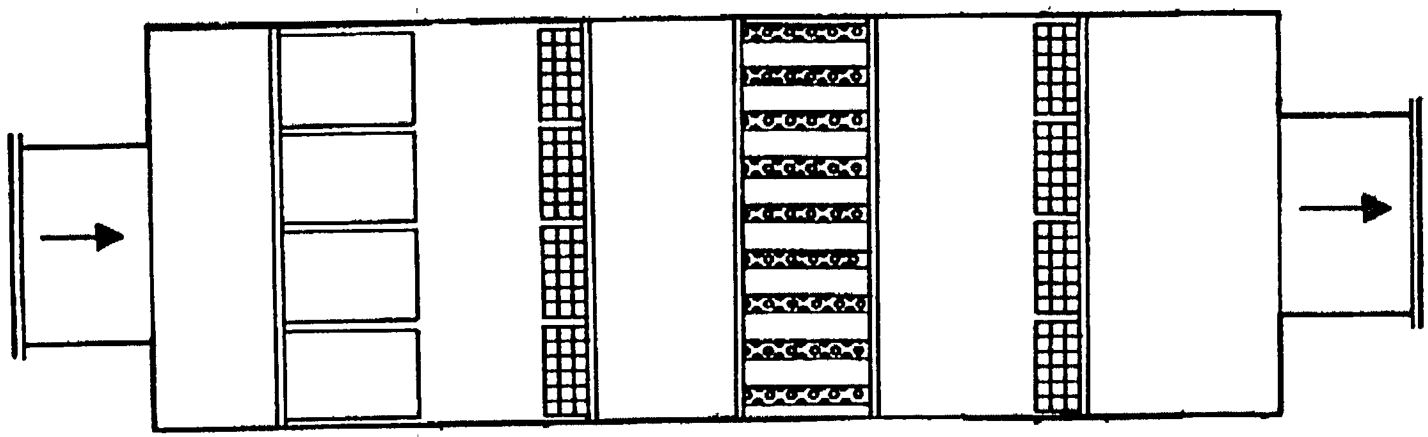
Typical air cleaning system in nuclear reactors

The primary contaminant is gas



Prefilter/ Demister | HEPA filter | Carbon filter | HEPA filter

(not tested, not credited, post-filter used to collect carbon fines)

Nuclear weapons and fuel fabrication facilities have air cleaning systems operating continuously

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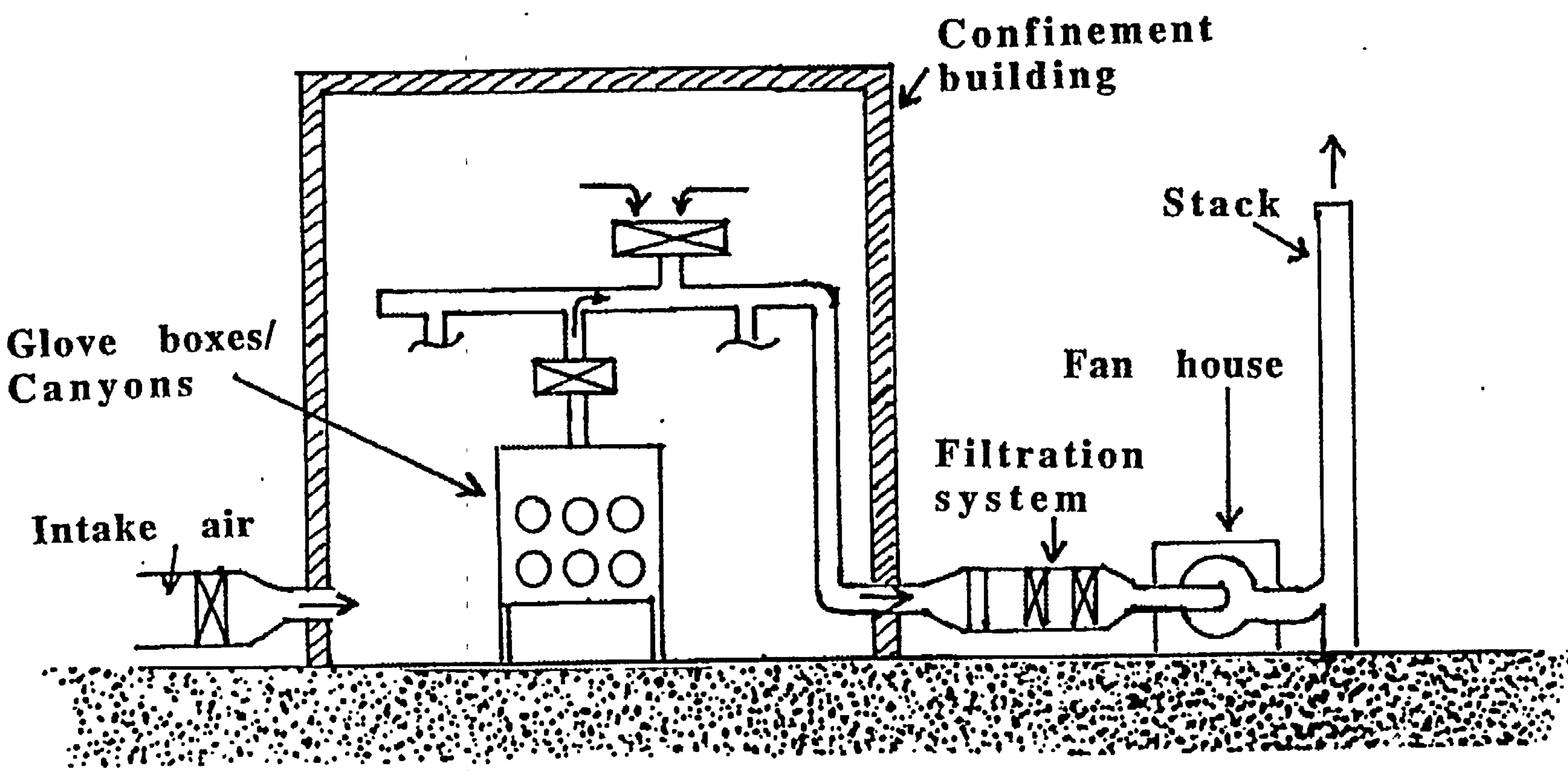
HEPA filters are used because the only contamination is radioactive particles.



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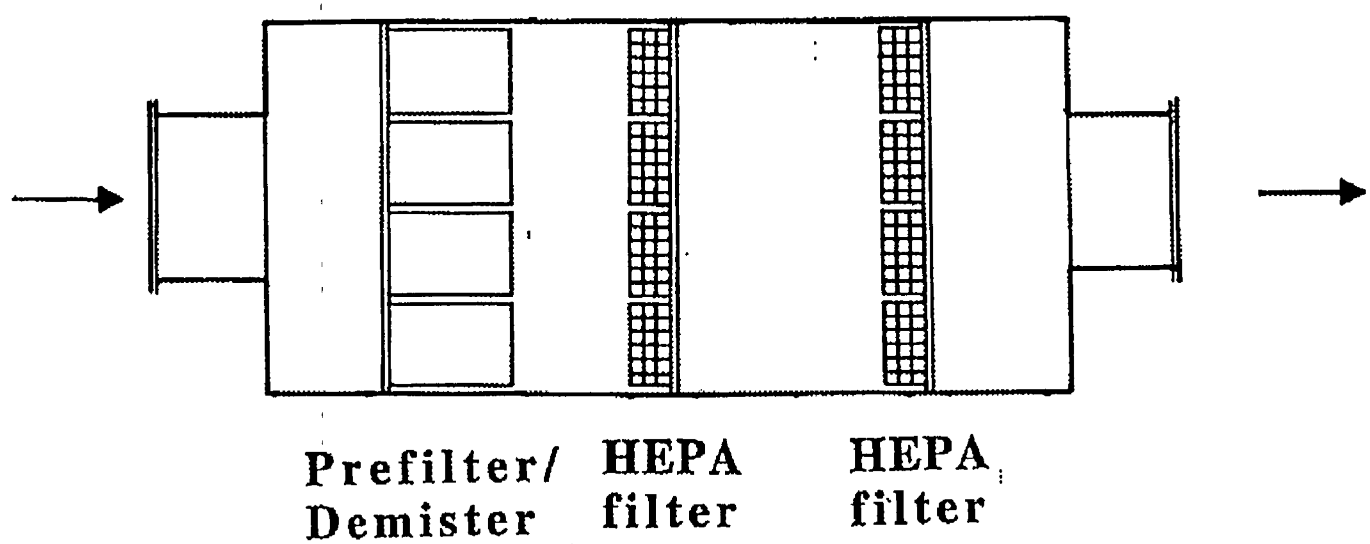
Typical air cleaning system in nuclear weapons and fuel fabrication facilities

- The primary contaminant is particles



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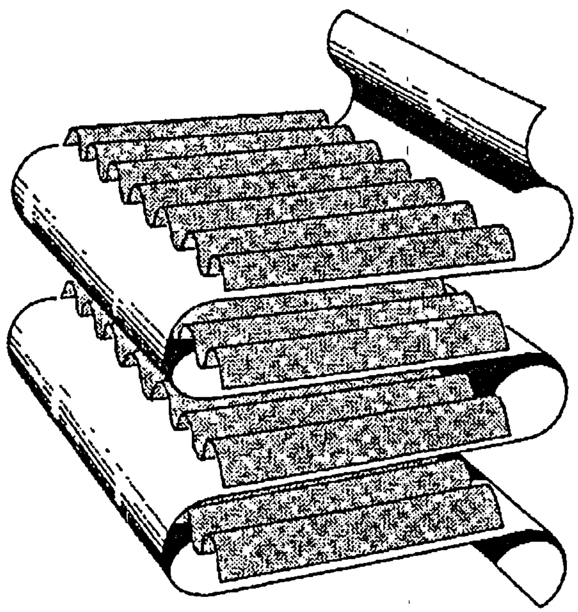
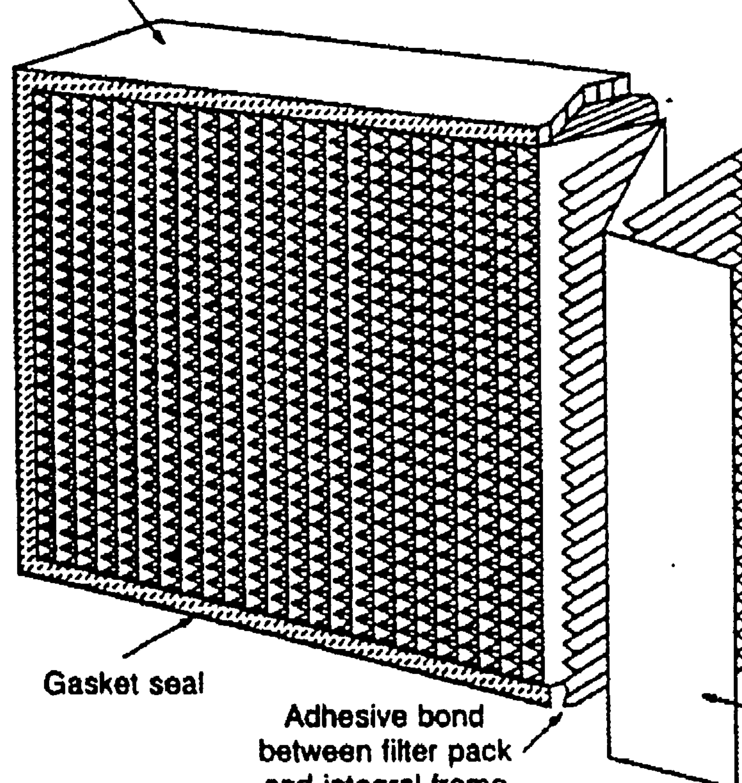
Typical HEPA filter used in nuclear applications

- Deep pleated design with aluminum separators has greater reliability than alternative designs.





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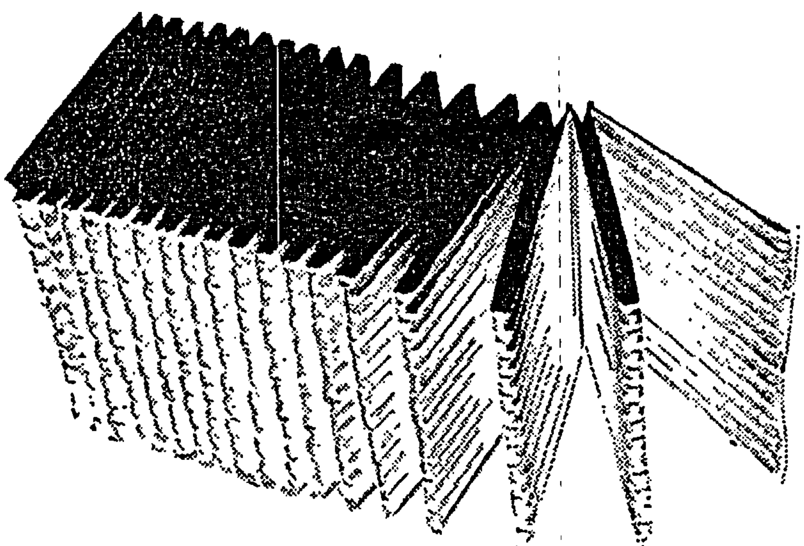
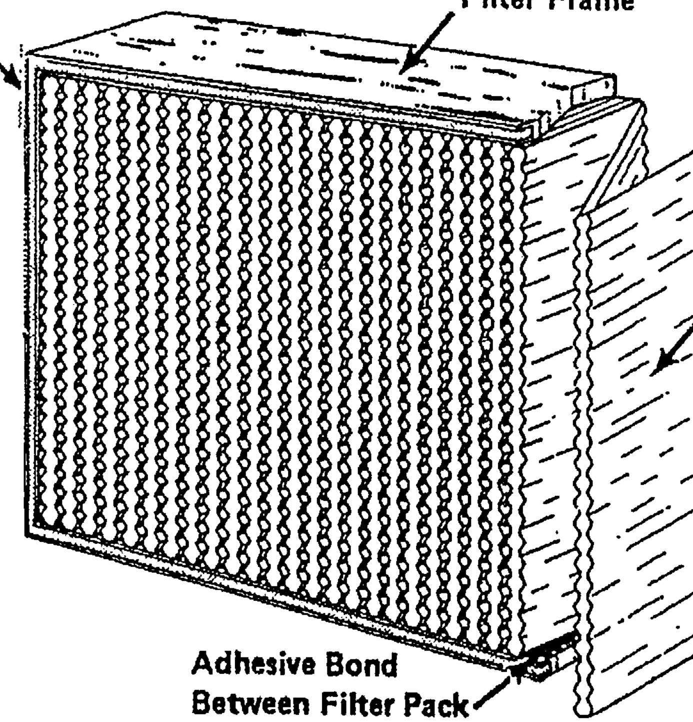
Other HEPA designs are not used as frequently

Separatorless filters meet the requirements, but have less strength.





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STONE & WEBSTER

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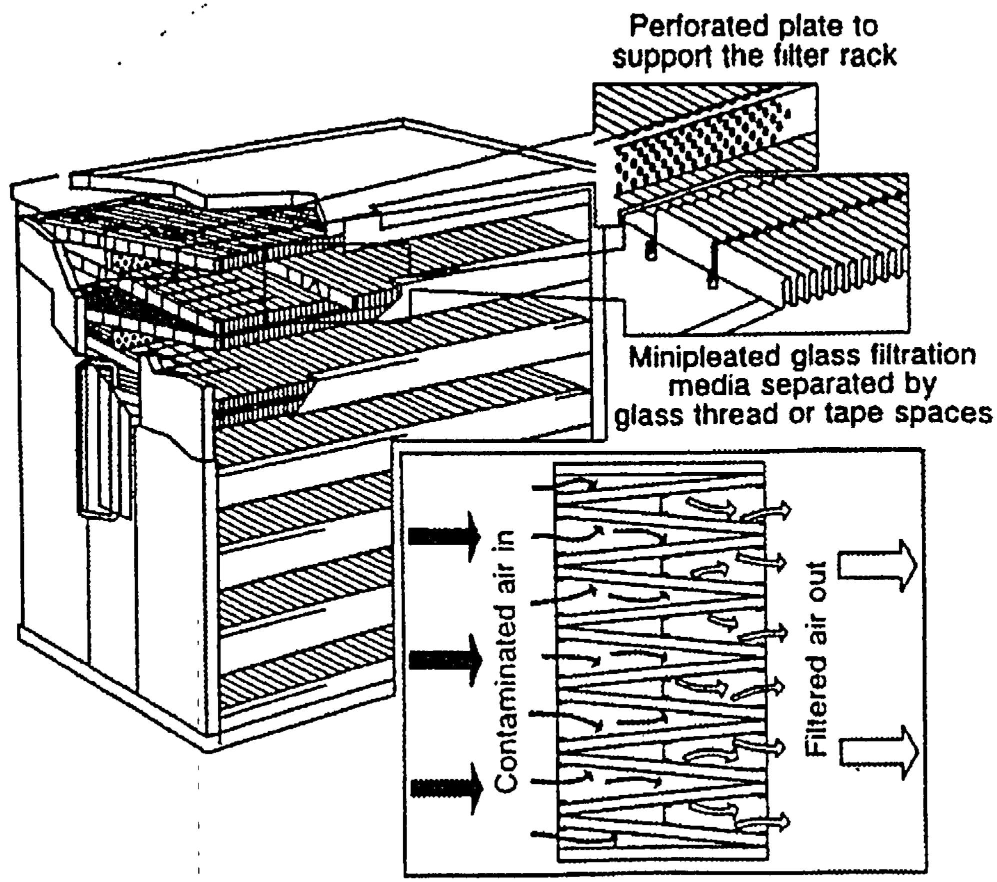

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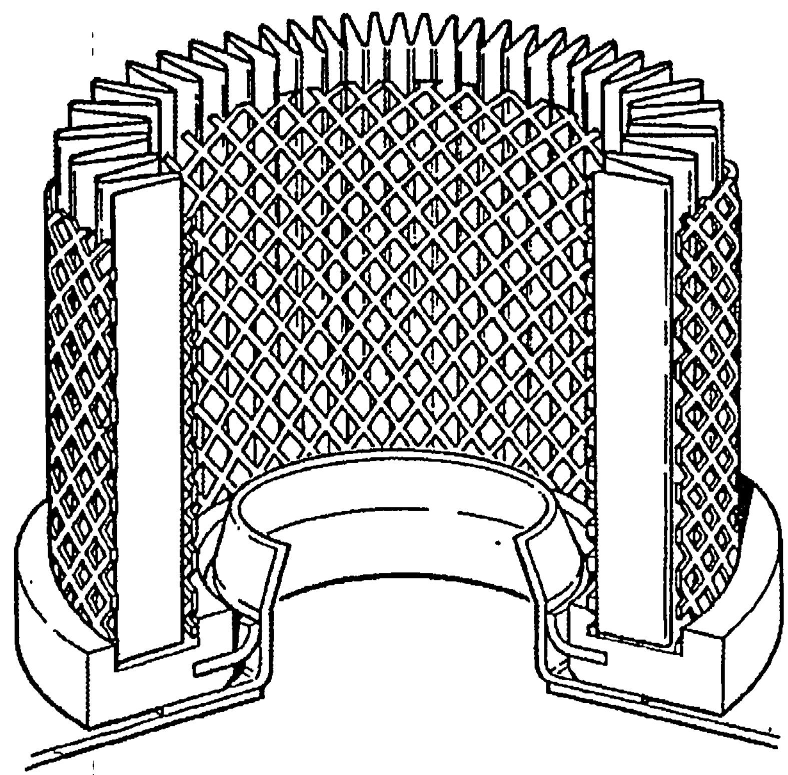
Cylindrical HEPA filters were introduced to the US market in 1998

- This design is widely used in England
- Advantages include improved sealing, more efficient compaction for disposal in drums, no sharp edges, easier construction.



Standards for nuclear grade HEPA filters

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- HEPA filters used in commercial nuclear power plants must meet the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.52 (2001).
- HEPA filters used in plutonium processing and fuel fabrication plants must meet the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 3.12 (1973)
- HEPA filters used in Department of Energy (DOE) nuclear facilities must meet DOE Standard DOE-STD-3020 (1997).
- Both requirements are based on the abandoned U.S. military standards for the HEPA unit (MIL-F-51068) and the filter media (MIL-F-51079).
- HEPA filters for NRC and DOE applications must also pass in-place leak tests prescribed by the American Society of Mechanical Engineers (ASME) in ASME N510.
- Requirements for nuclear grade HEPA filters and the test methods will be given in ASME AG-1(1997), Code on Nuclear Air and Gas Treatment. (Includes requirements from ASME N509.)

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Performance specifications for nuclear grade HEPA filters

- Efficiency of 99.97% for 0.3 um DOP particles at rated flow and at 20% flow.

- Pressure drop less than 1.3" water at rated flow (1.0" for 250, 500, 1000, and 1250 cfm filters).

- Resistance to rough handling (DOP efficiency of 99.97% at rated flow and at 20% flow after vibrating with 3/4 inch amplitude at a frequency of 200 cps for 15 minutes)

- Resistance to pressure (DOP efficiency of 99.97% at 20% rated flow after exposure to moist air at 10" pressure for one hour)

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Performance specifications for nuclear grade HEPA filters (Cont.)

- Resistance to heated air (DOP efficiency of 97% at rated flow after exposure to heated air at 700 F for 5 minutes)

- Resistance to spot flame (no sustained flaming Bunsen burner from filter media)

Tests required for nuclear grade HEPA filters

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- Manufacture must qualify HEPA filters and media in a series of destructive tests every five years.
- Manufacture conducts filter efficiency and pressure drop test on every filter.
- DOE applications require a second independent efficiency test on every filter. NRC abandoned this practice in 1978.
- DOE and NRC facilities require in-place leak tests after HEPA filter installation and every 18 months or less thereafter.

Nuclear grade HEPA filters must pass qualification tests

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- Heated air test: 97% DOP efficiency at rated flow after exposure to 700°F for 5 minutes.
- Pressure test: 99.97% DOP efficiency at 20% rated flow after exposure to moist air at 10" pressure for one hour.
- Rough handling test: 99.97% DOP efficiency at rated flow and at 20% rated flow after strong vibrations for 15 minutes.
- Spot flame test: No sustained flaming
- HEPA media must meet minimum requirements

HEPA filter media must meet minimum requirements

DUKE COGEMA
STONE & WEBSTER

- 99.97% DOP efficiency and less than 1.~~6~~3 inch water pressure drop at 10 ft/min.

- Tensile strength:

  2.5 lb/in in machine direction and 2.0 lb/in in cross direction for new media

  0.6 lb/in in cross direction after exposure to 700°F for 5 minutes

  1.0 lb/in in cross direction after 15 minutes water soaking

  1.0 lb/in in either direction after gamma irradiation

- Water repellency greater than 20 inches water when new and greater than 6 inches water after gamma irradiation.

HEPA filter media must meet minimum requirements

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- Thickness between 0.015-0.040 inch.
- Combustible material less than 7% by weight.
- Flexing resistance: no tears, breaks, cracks or separations after 5 flexings.

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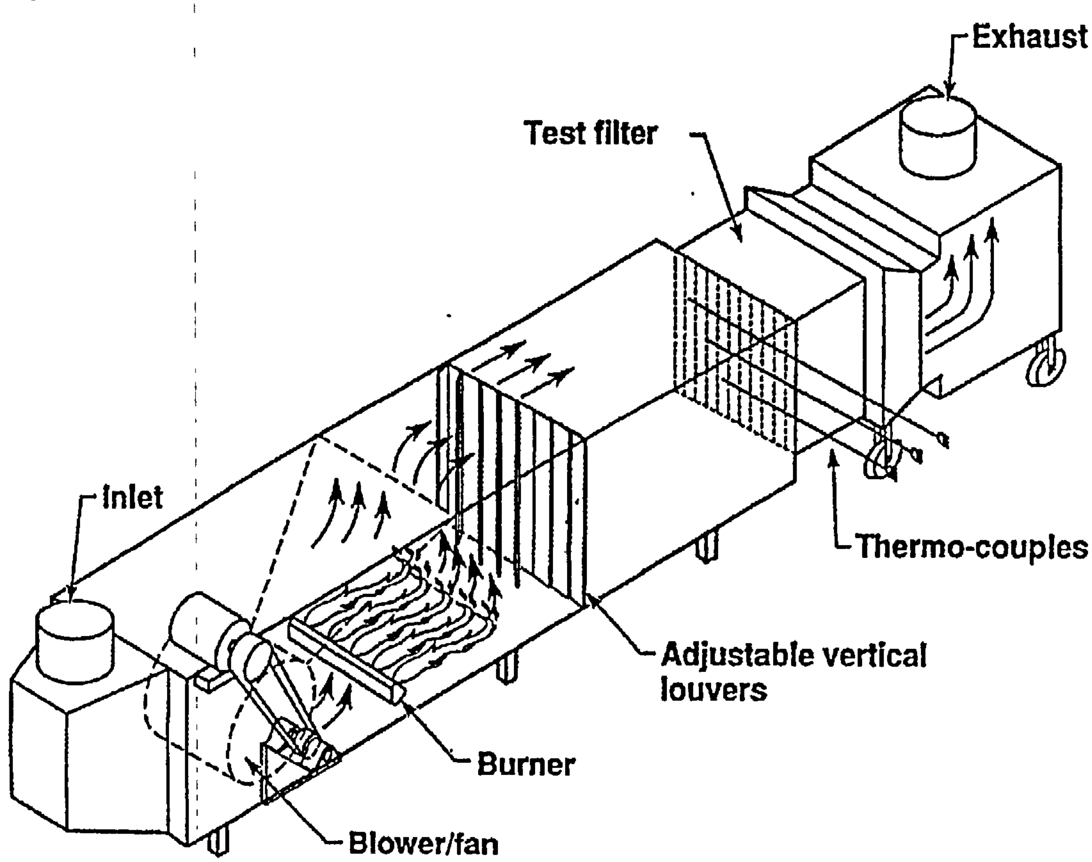
Heated air test apparatus

- **Exposes a filter to an unspecified air flow at 700 F for 5 minutes.**



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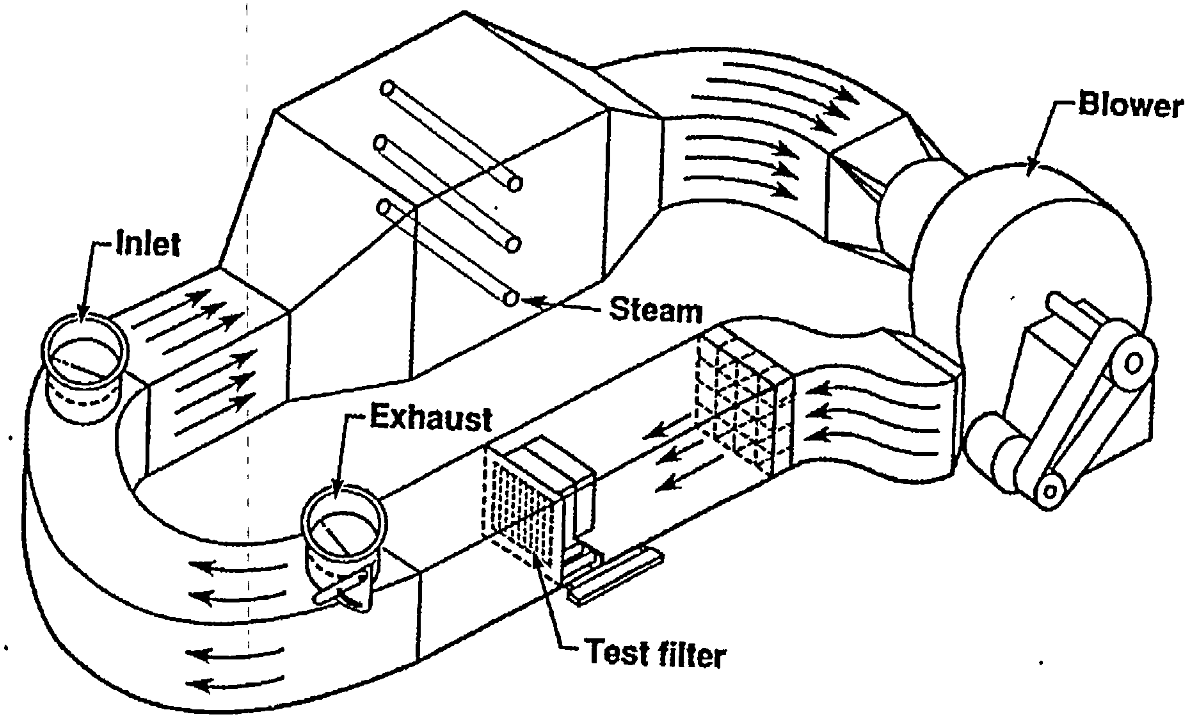
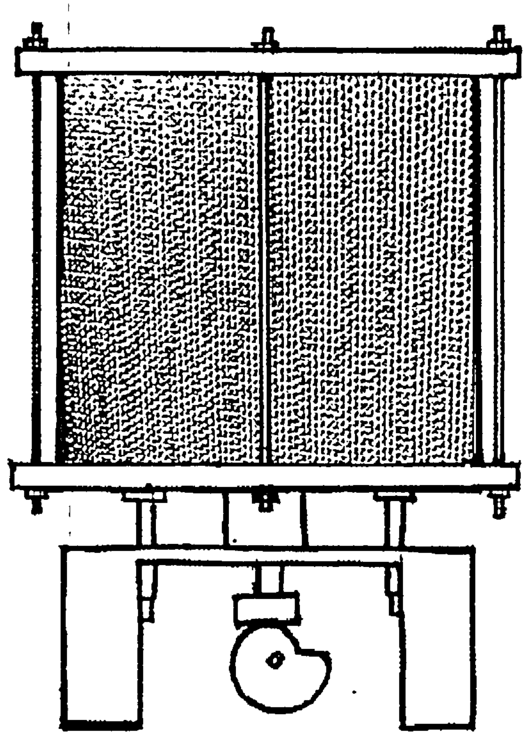
Pressure resistance filter tester

- Exposes a filter to 10 inches pressure with an air flow at 95% RH. for 1 hours



Rough handling machine

- **HEPA filter vibrated at a frequency of 200 cps and amplitude of 3/4 inch for 15 minutes.**



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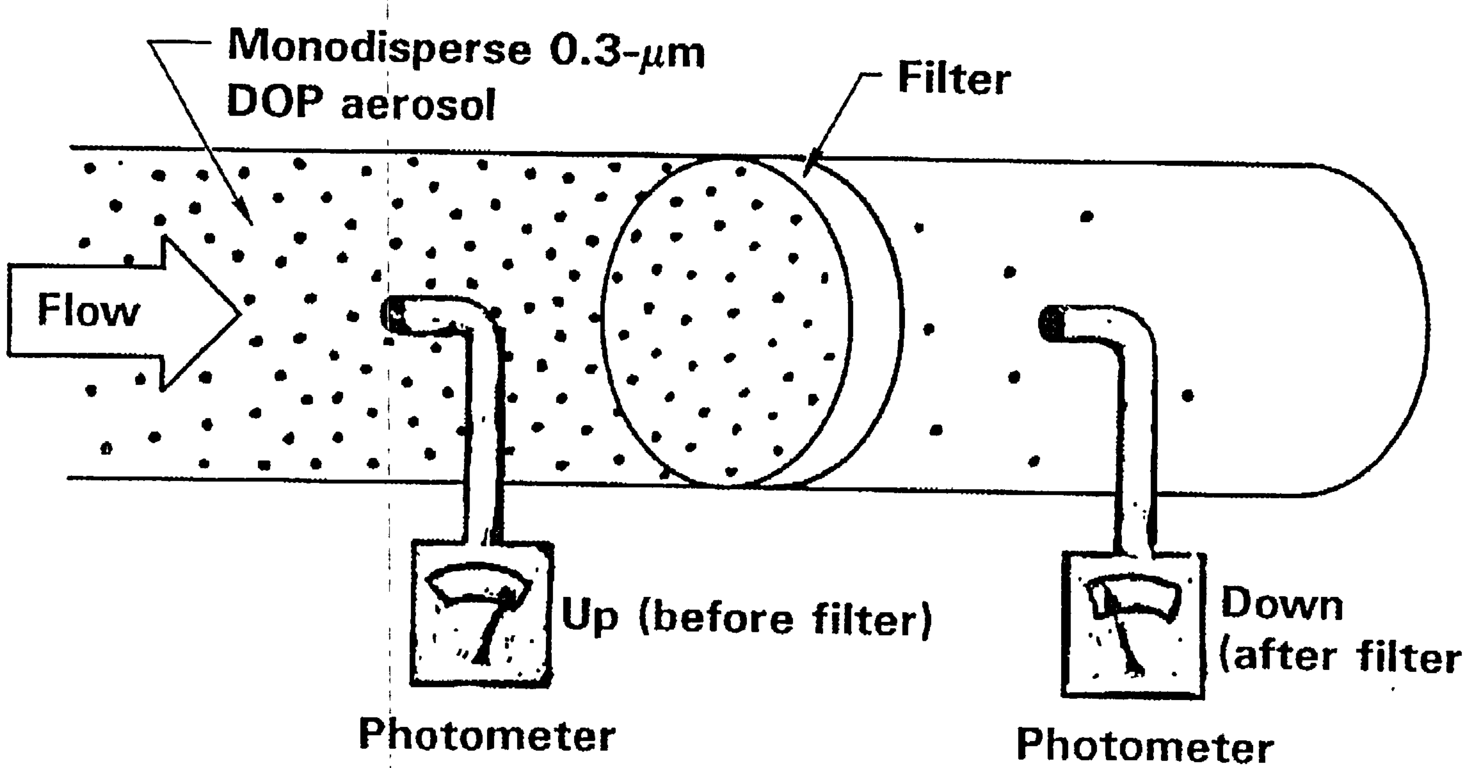
The efficiency of a nuclear grade HEPA filter is determined with the DOP test

- A photometer measures the concentration of relatively monodisperse 0.3 um DOP particles before and after the filter.



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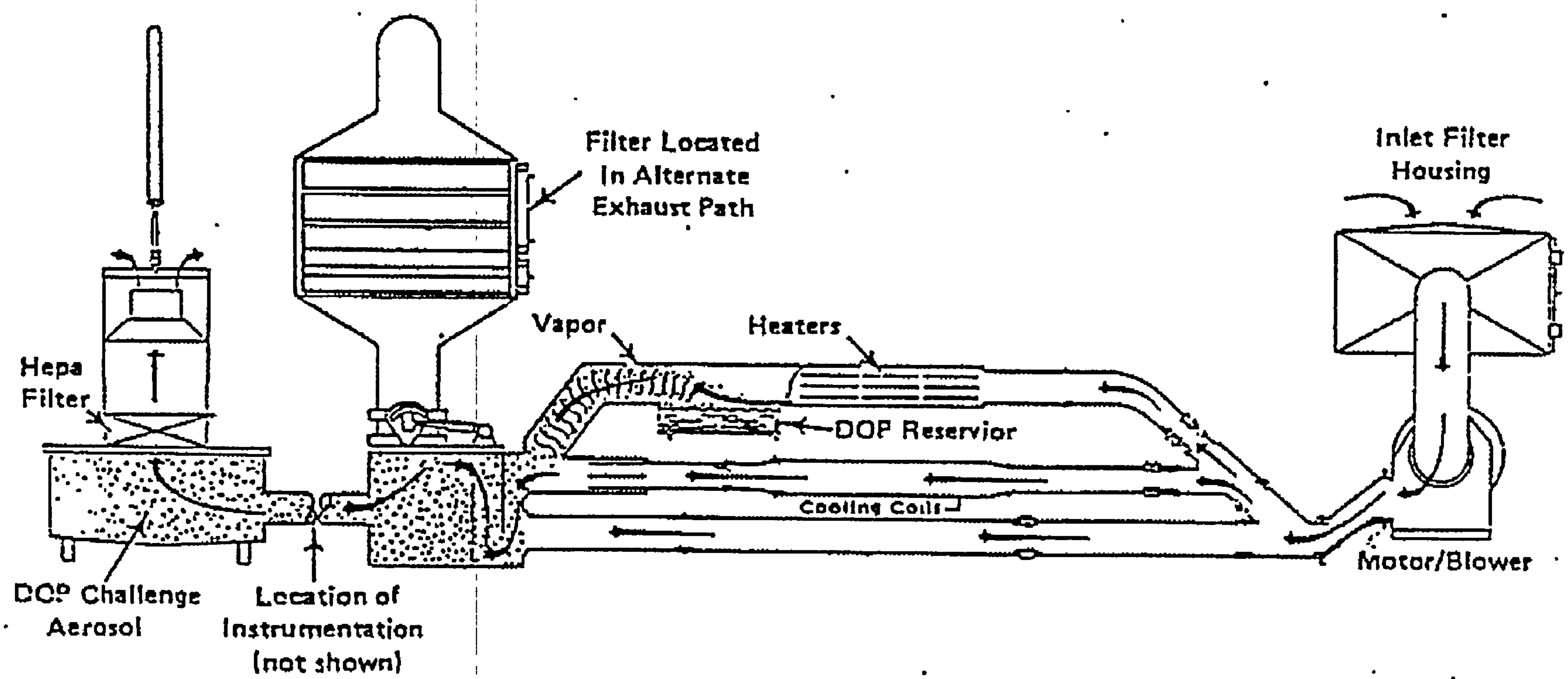
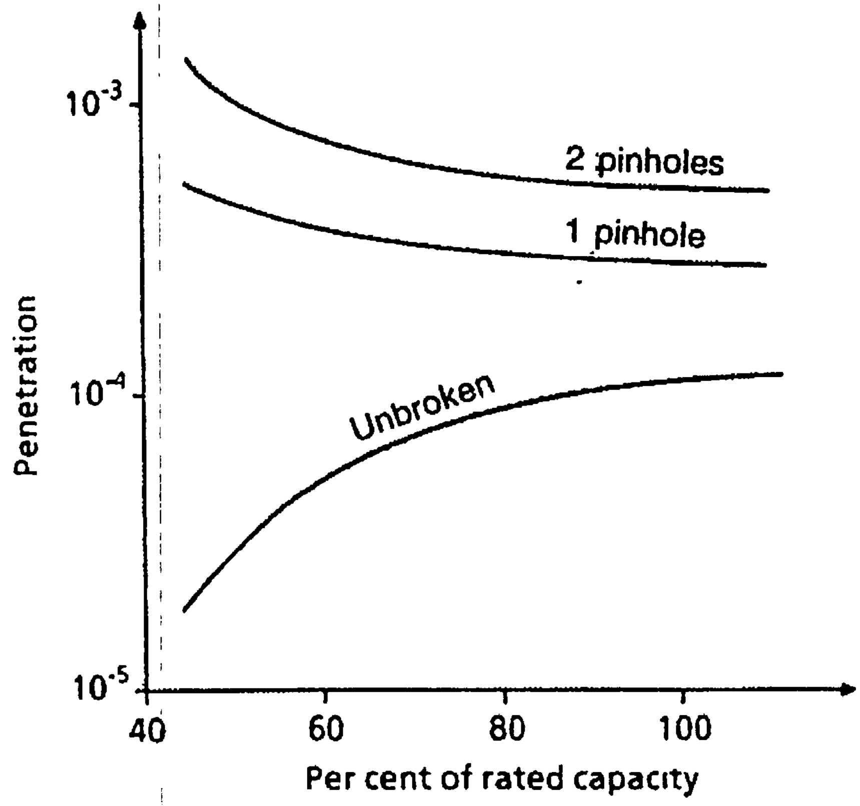
Q-107 DOP penetrometer used for HEPA filter efficiency tests



DUKE COGEMA STONE & WEBSTER

HEPA filters are tested at 20% rated flow to detect unacceptable filter leaks

- Pinhole leaks cause increasing filter penetration at lower air flows.



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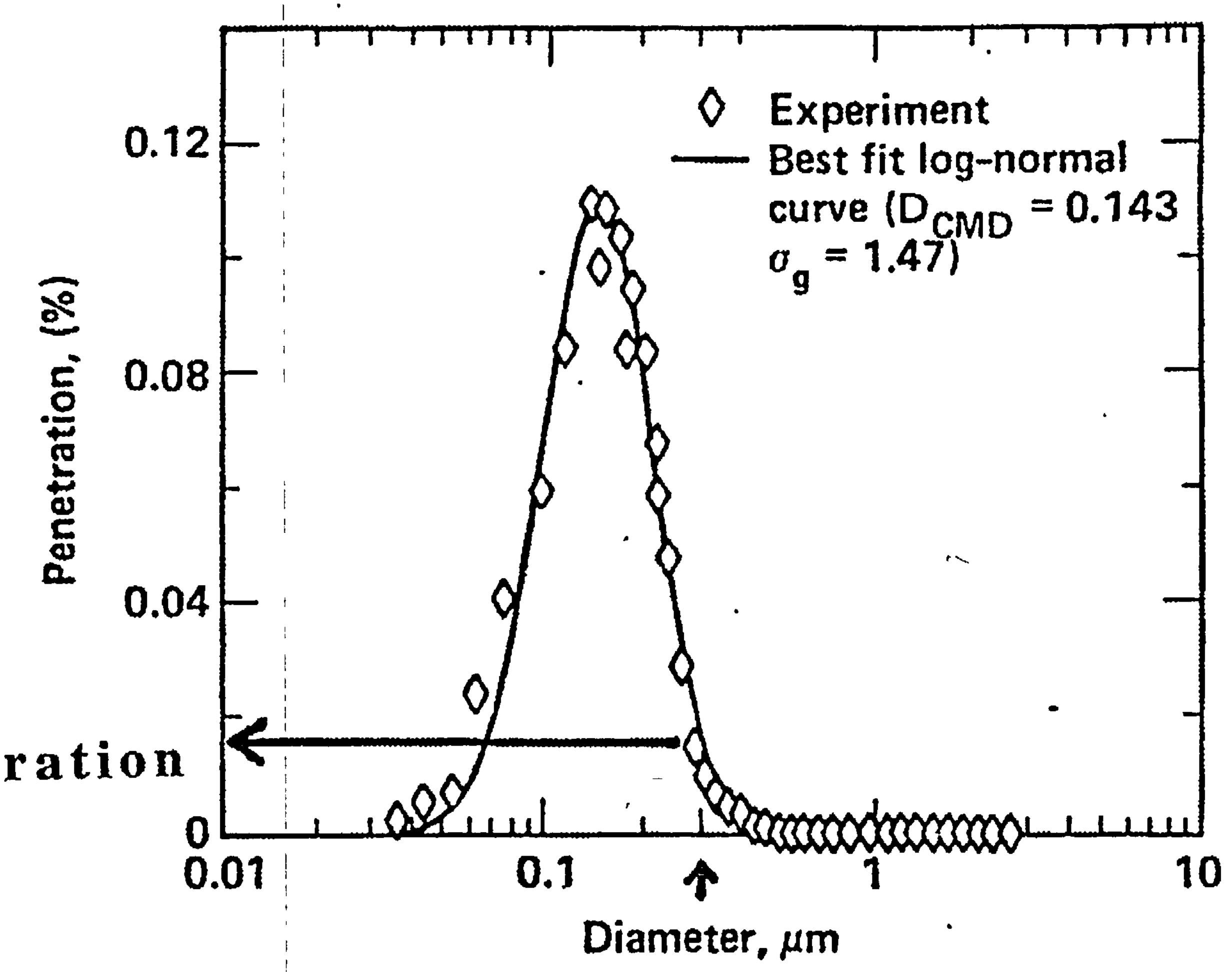
ST

The DOP test does not measure filter efficiency at the most penetrating particle size

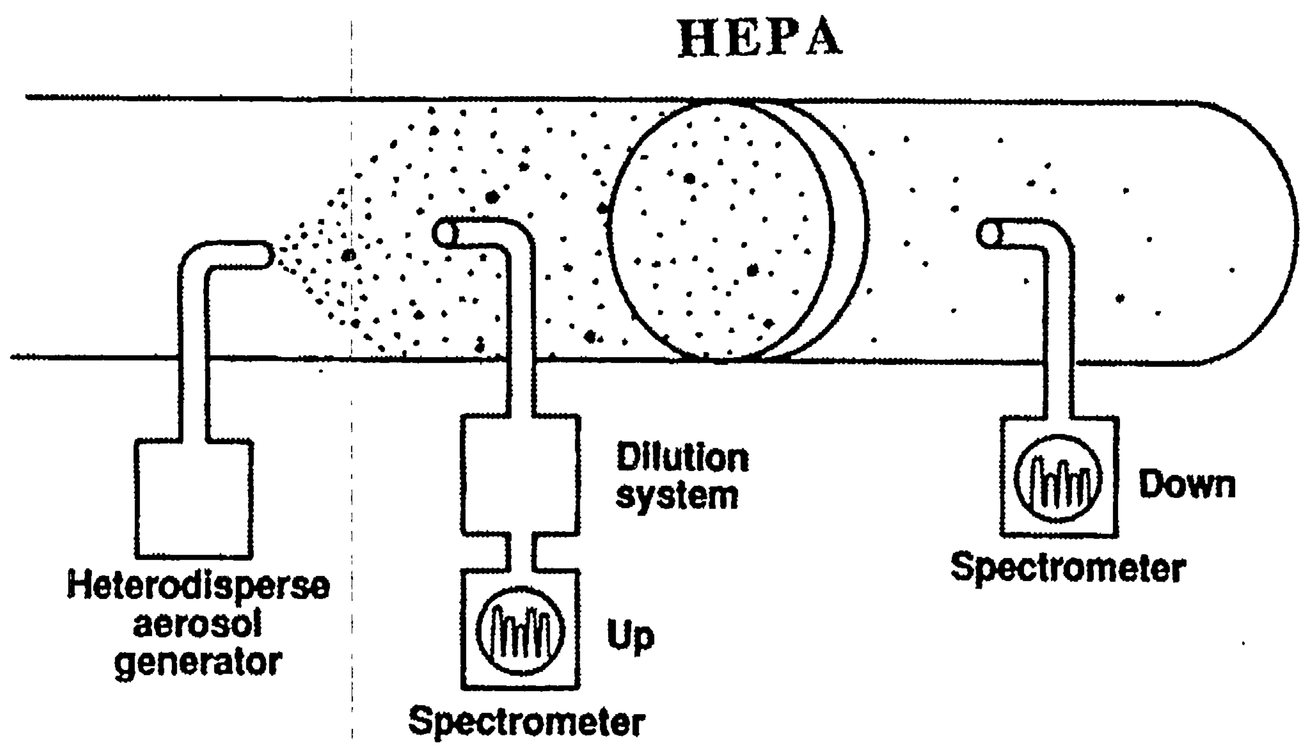
DOP
Penetration



Test methods using laser particle counters are acceptable for the DOP test

DUKE COGEMA
STONE & WEBSTER

- **DOE-STD-3020 and ASME AG-1 allow the use of alternative oils and Laser particle counters.**



Penetration of DOS Aerosols through Stainless Steel/Glass Fiber Prefilter

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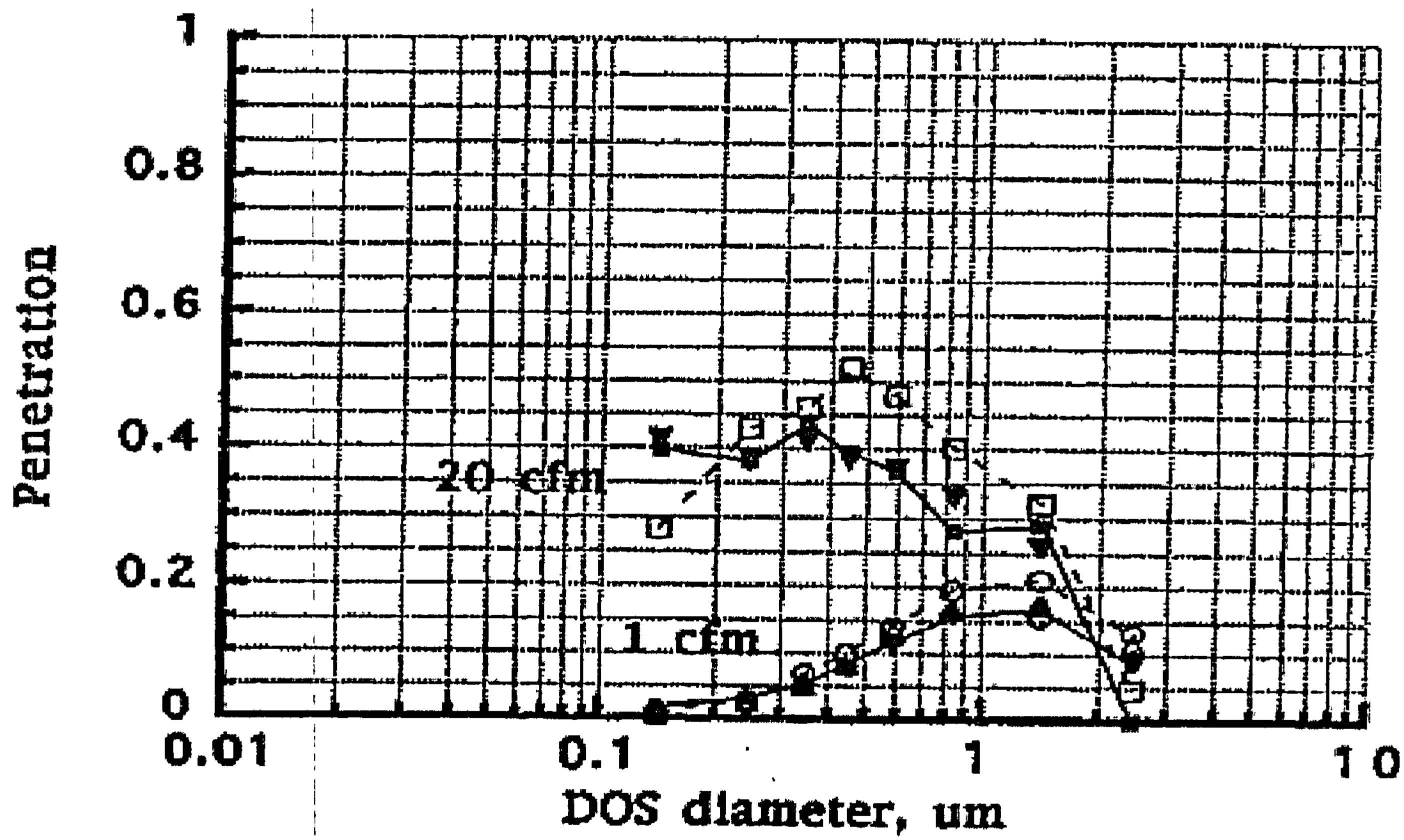

Figure 10. Penetration of DOS aerosols through another demister at 1 and 20 cfm exhaust flow. Open data points were taken at 70 F. Closed data points were taken at 40 F.

In-place leak tests are required to insure HEPA filters are properly installed and not damaged

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- The in-place test is similar to the DOP efficiency test except that a portable, heterodisperse DOP aerosol generator is used.

- The test uses a portable light scattering photometer, similar to that used for the HEPA efficiency test.

- ASME N510 and ASME AG-1 describe the procedures used for the tests.

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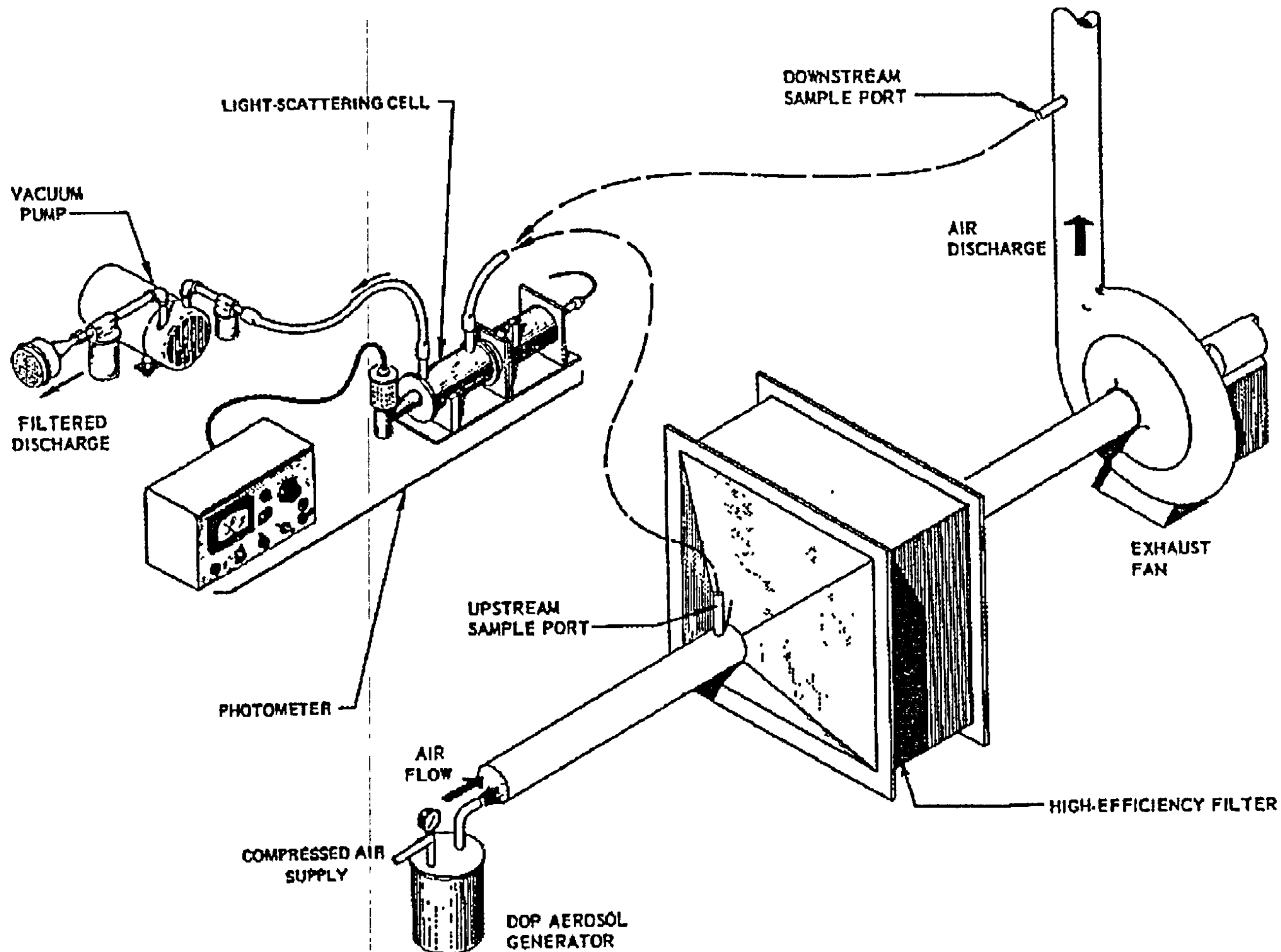
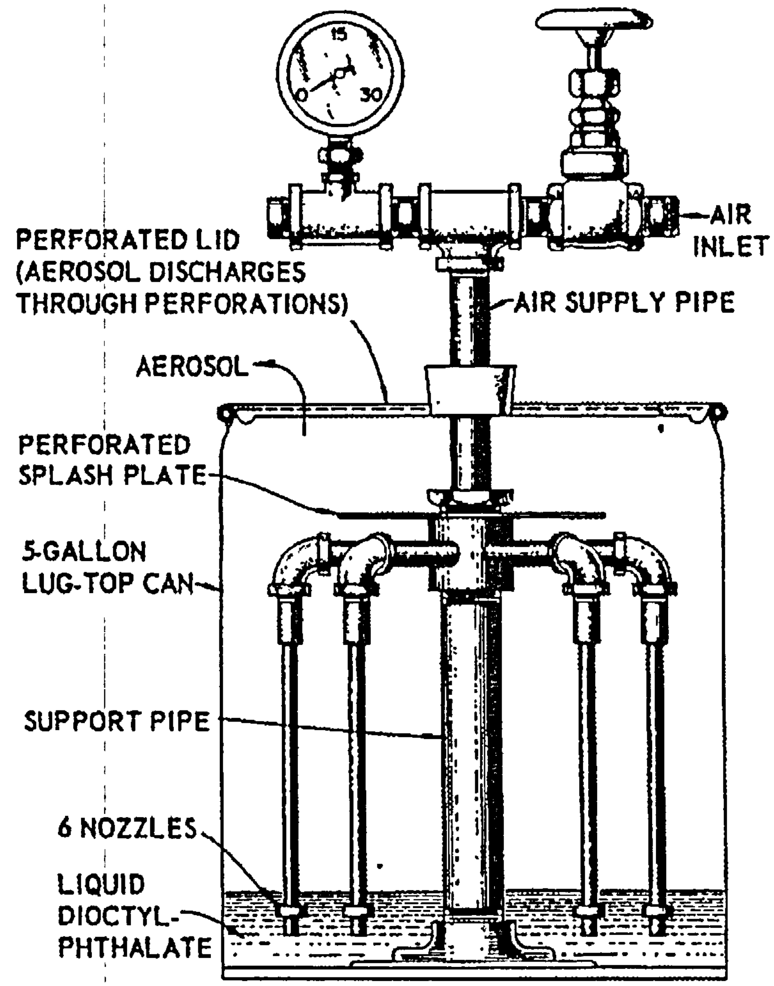
In-place test on single HEPA installation



Laskin nozzel aerosol generator



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HEPA Operation

Impaction

- Particles running into obstructions and adhering
- Larger particles and more particles increase impaction
- Finer meshed filters increase impaction
- Deeper bed filters increase impaction
- Collected particles increases pressure drop and filter efficiency

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HEPA Operation

Diffusion

- Brownian motion redirects particles to collide with filter media
- Smaller particles more affected by Brownian motion
- Impacted by energy of air stream
  - Increased velocity decreases diffusion potential
  - Increased temperature increases diffusion potential
- Collected particles increases pressure drop and filter efficiency

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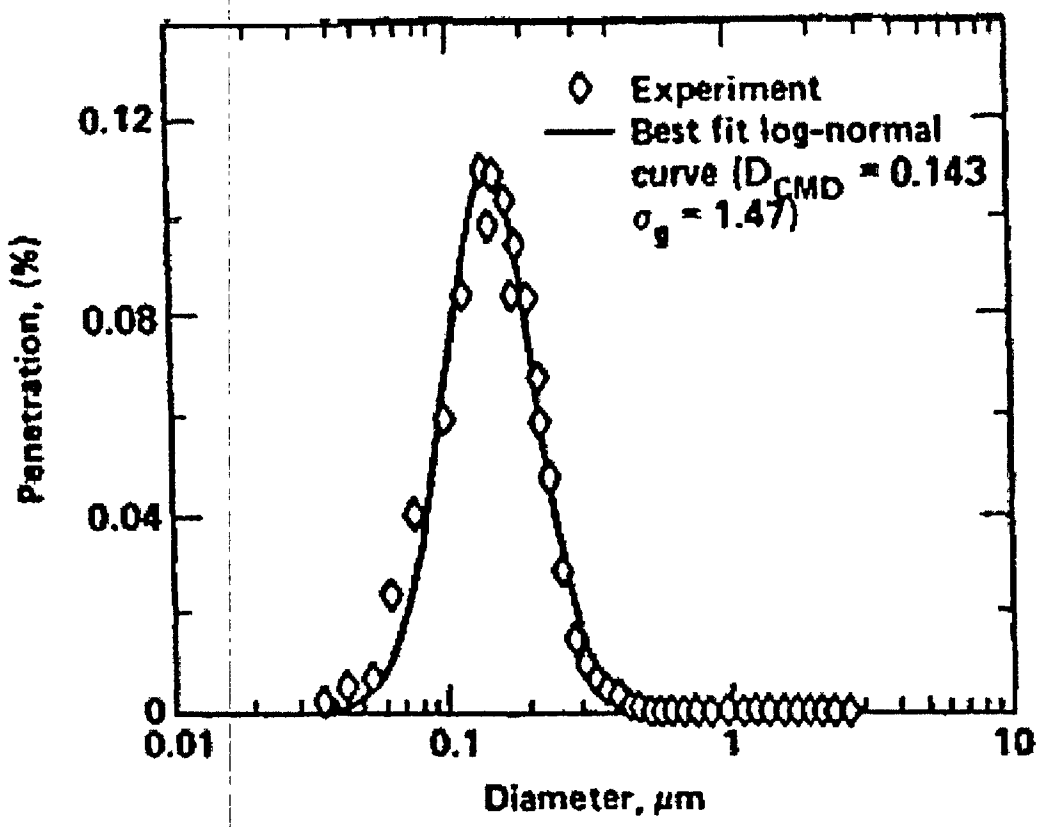
HEPA Operation

Curve of Penetration



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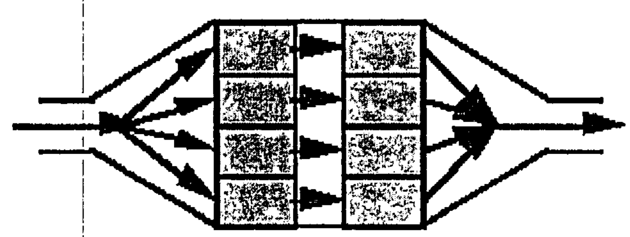
HEPA Operation

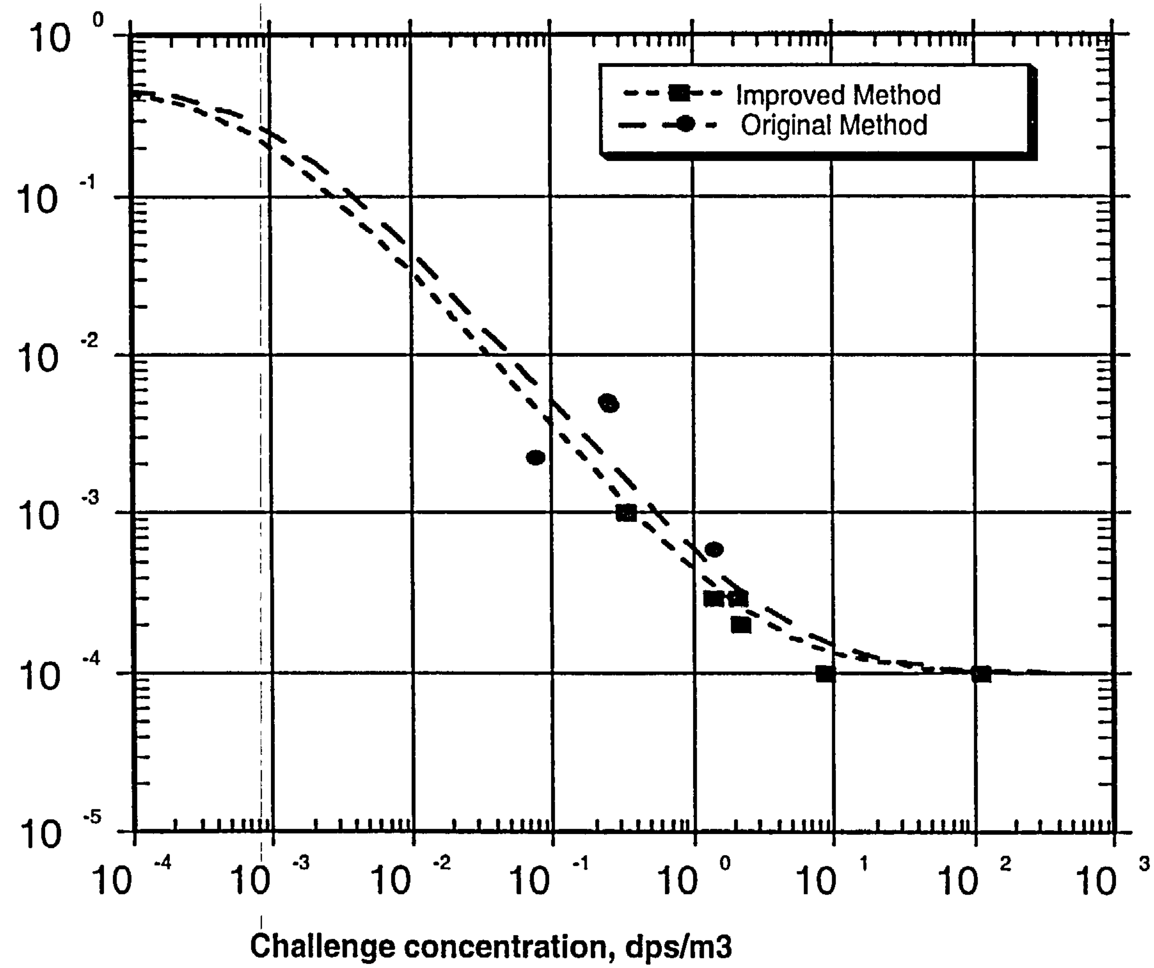
Multiple Filter Stages/ Efficiency

- Filters arranged so air travels through more than one bank of filters before exiting as shown (the shaded cubes represent individual filters):



- Total Penetration is Product of the Penetration of Each of the Individual HEPA Filters in Series
  - Experience (Gonzales, et al)
  - ERDA 76-21
- Efficiency = 1 – Penetration Fraction

Measurements in Support of Multiple HEPA Filters in Series (Large Particle)



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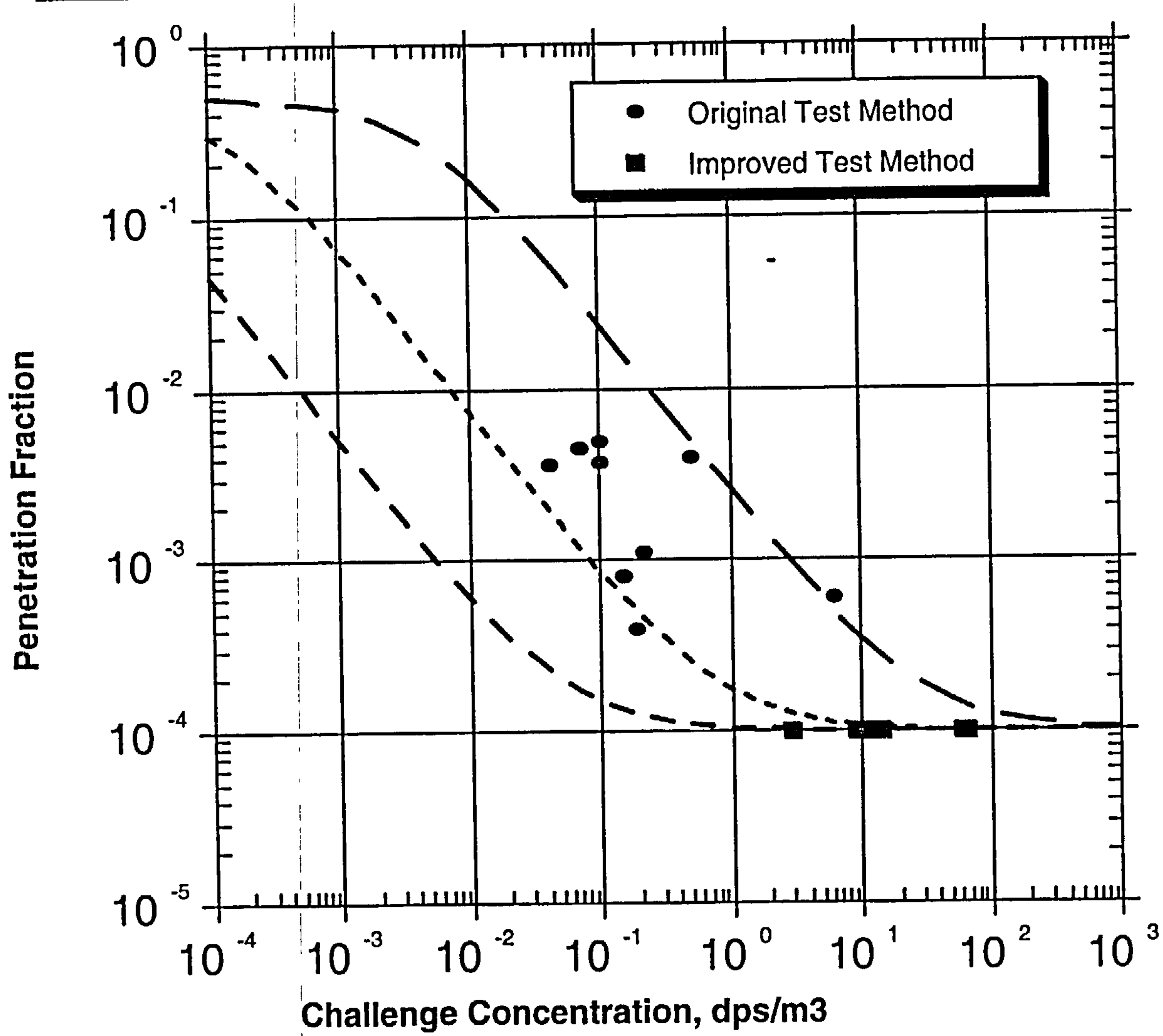
Measurements in Support of Multiple HEPA Filters in Series (Small Particles)



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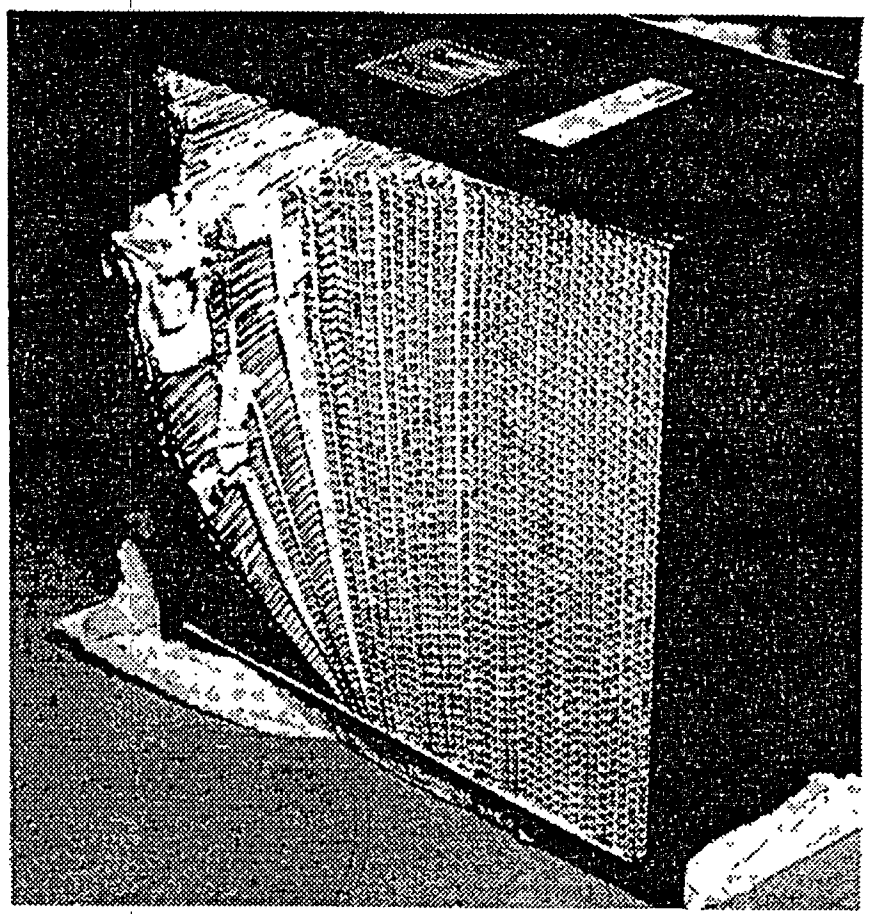
Failure due to moisture exposure

- Ruddinger et al 18th Nuc.Air Clng. Conf.



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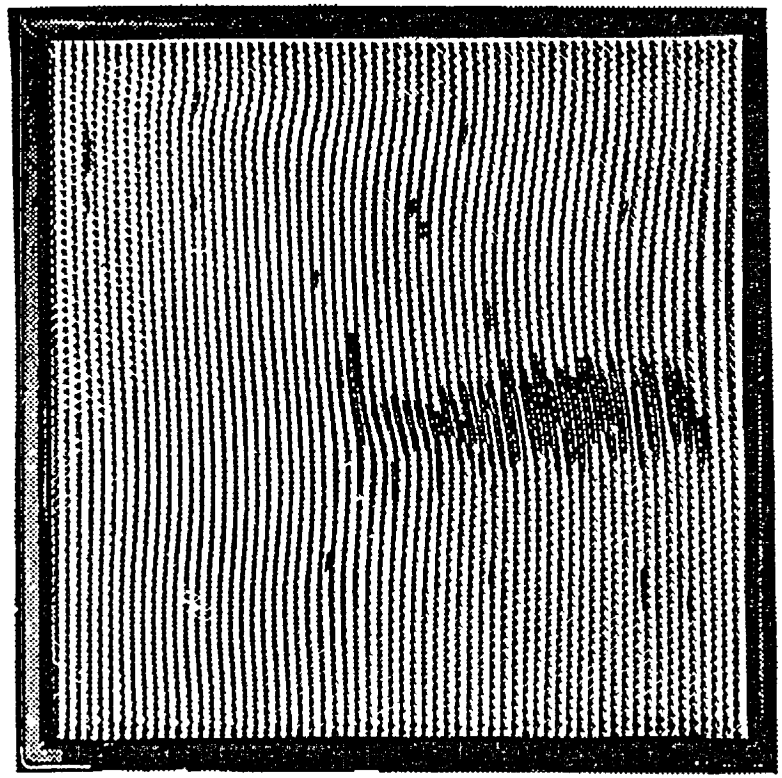
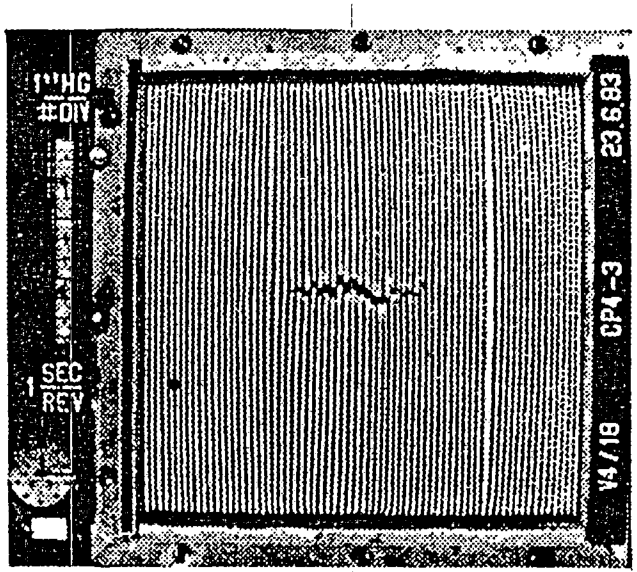
Failure due to moisture exposure

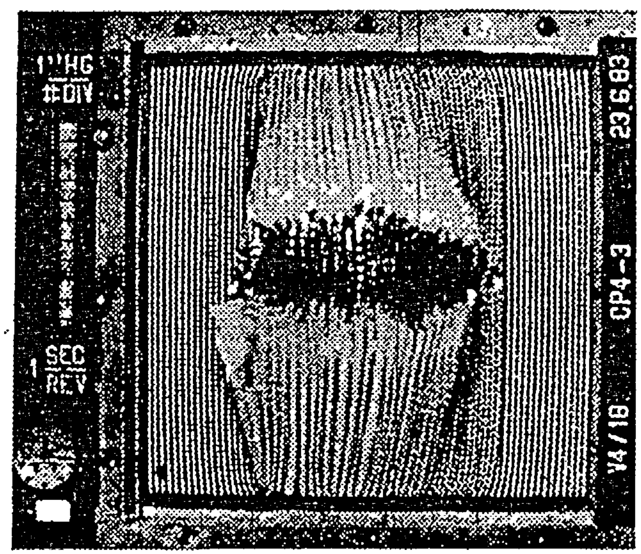
- Ruddinger et al 18th Nuc.Air Clng. Conf.
- Rupture of downstream pleats-std HEPA



High air pulse damage to HEPA filter

- Ruddinger 19th Nuc. Air Clng. Conf.
- Damage on 6" deep filter





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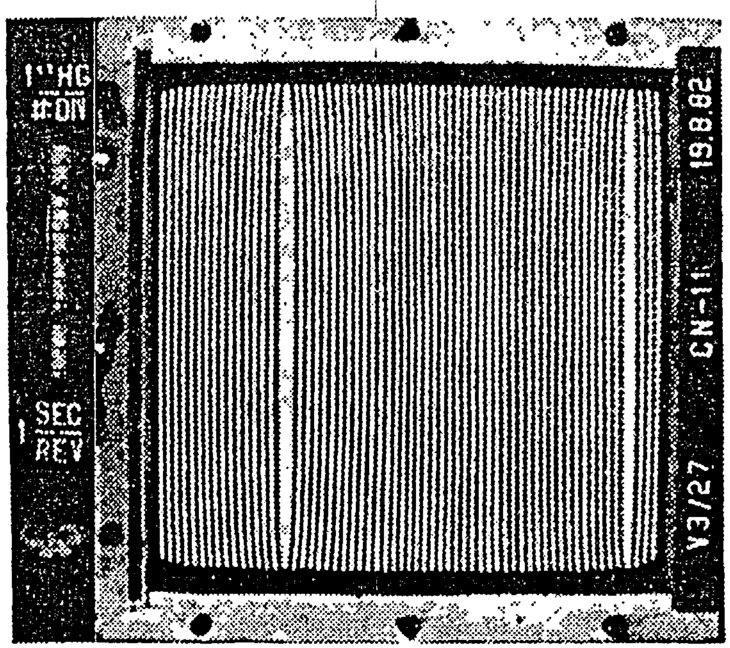
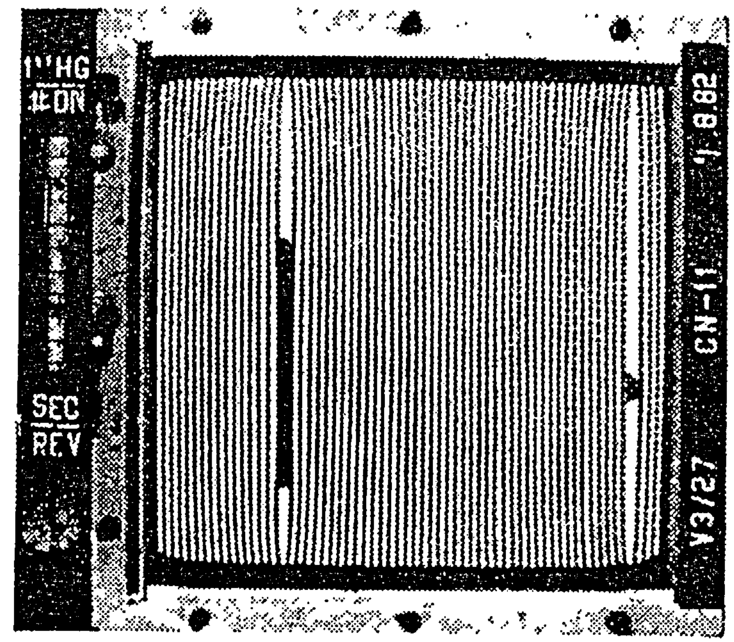
High air pulse damage to HEPA filter

- Ruddinger 19th Nuc. Air Clng. Conf.
- Damage on standard 12” deep filter





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HEPA failure due to overpressure

- Tornadoes and explosions cause this type of failure
- Final blow-out after initial pleats are blown-out.

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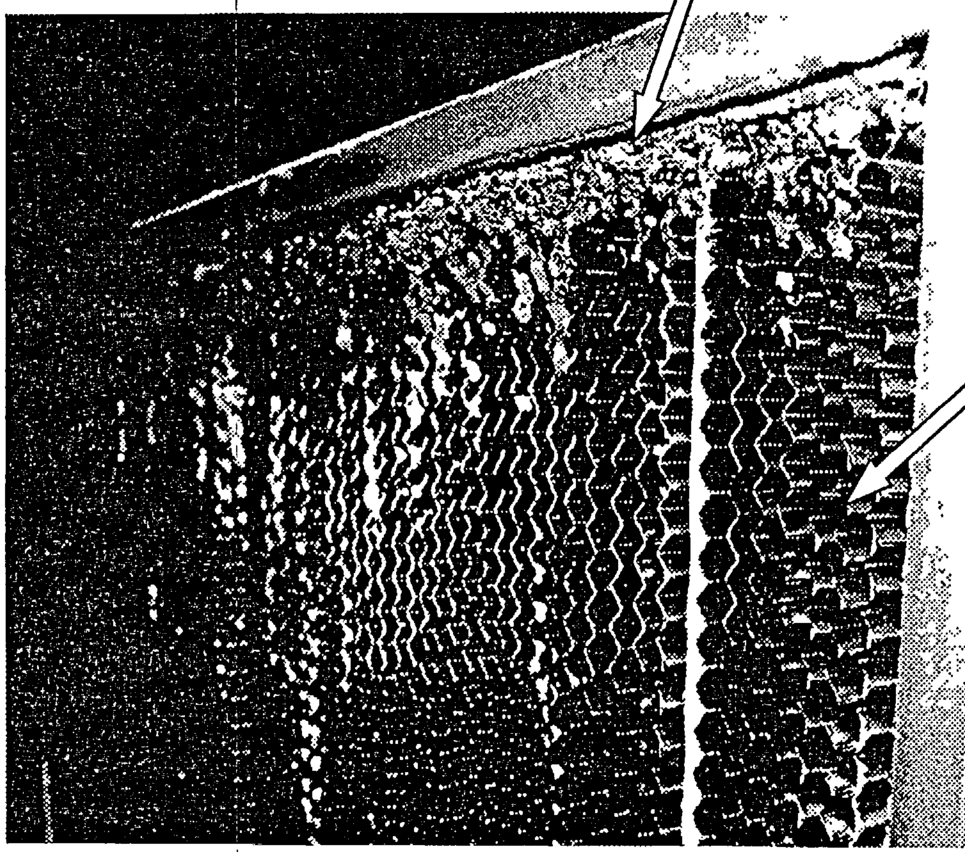
Controlled heat test followed by overpressure test simulates fire

High temperature burns sealant and separates filter pack from frame



Filter pack segment is pushed out following the high pressure test

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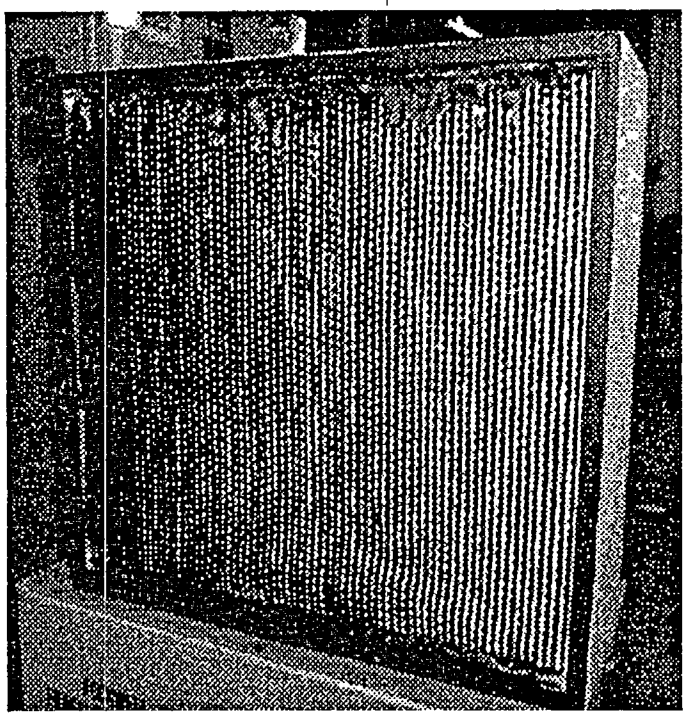
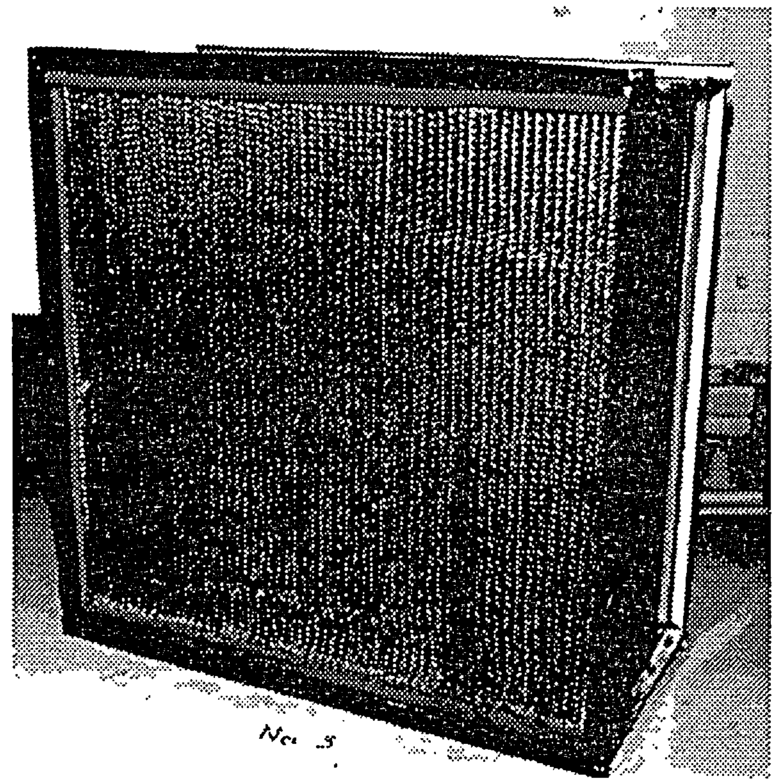
Silicone sealants withstand the high temperature challenge



Urethane sealant



Silicone sealant

PRELIMINARY DATA ON SMOKE CLOGGING

Werner Bergman
7/21/02

Fenton et al Data:

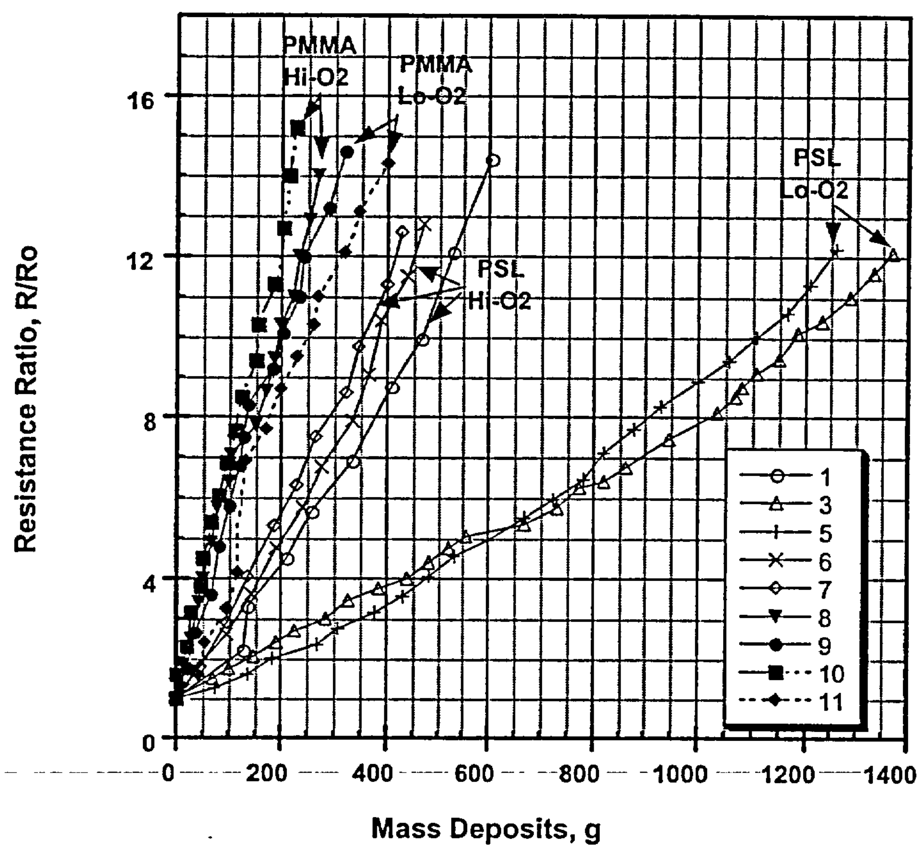


Figure 1 Summary of Fenton et al data on smoke loading using a small scale smoke generator (Battel generator) and full-scale (1,000 cfm) HEPA filter.

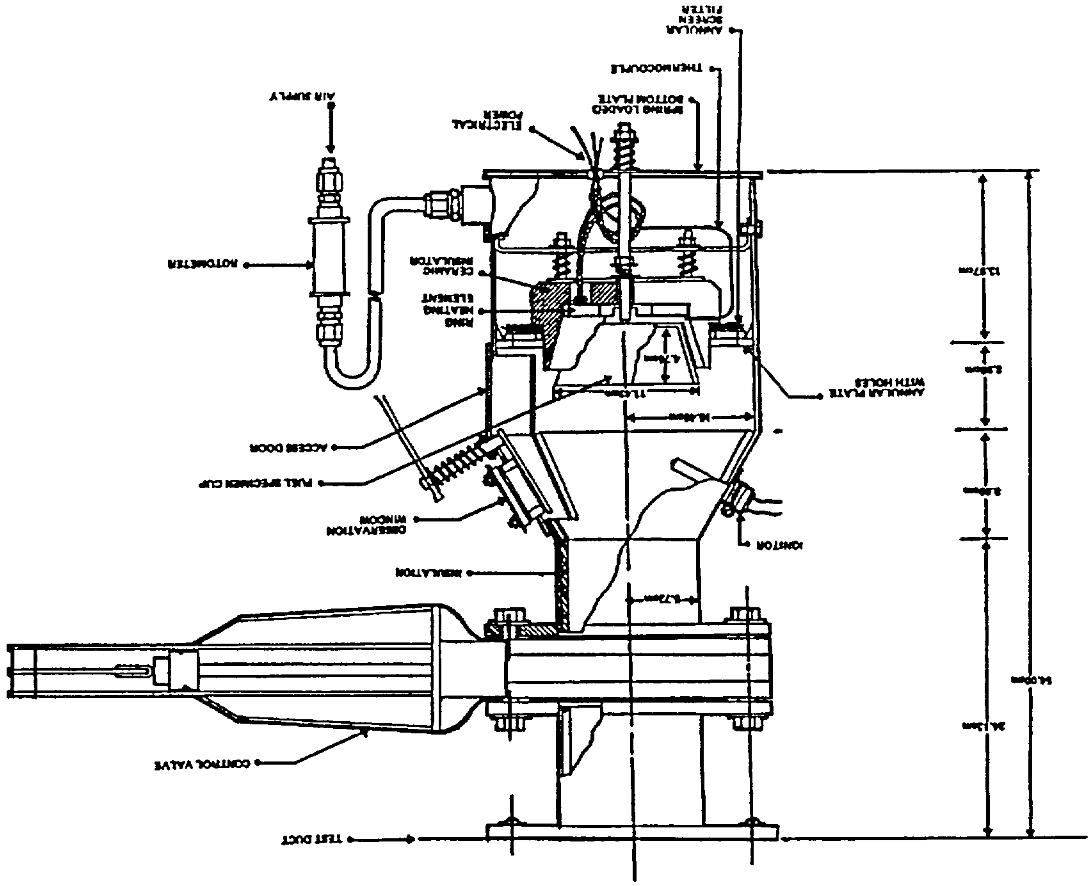


Figure 2 Battell smoke generator

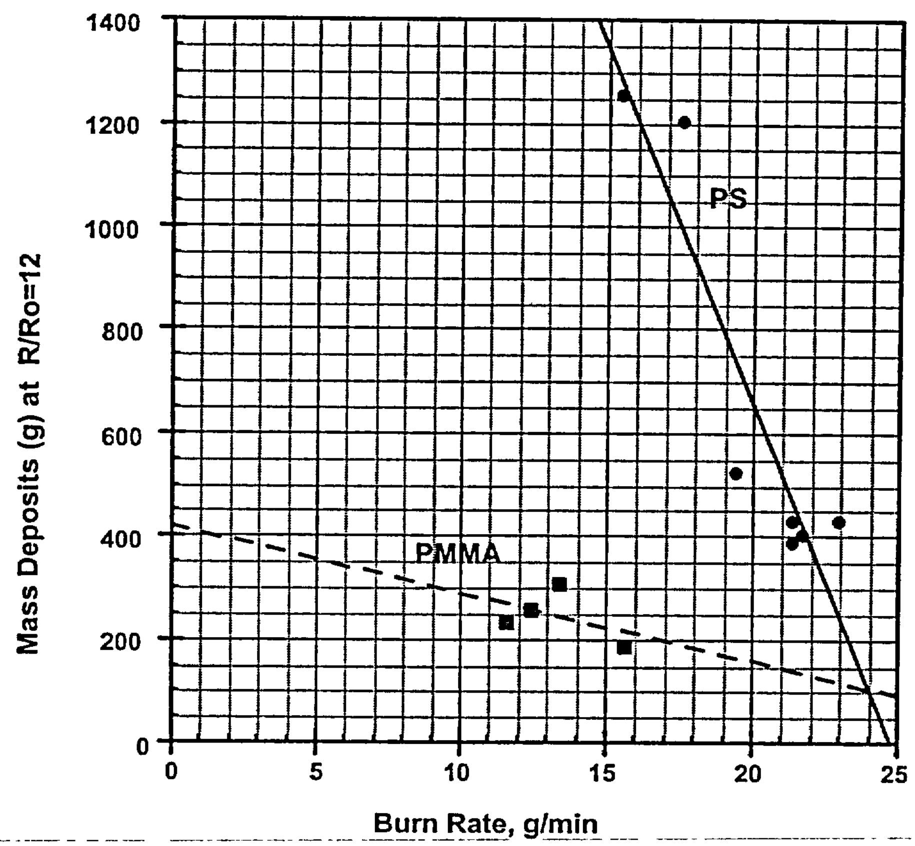


Figure 3. Variation in total smoke deposits at 12 times initial filter pressure as a function of material burn rate. Note combustion becomes more oxygenated with increasing burn rate.

Gaskill Smoke Loading:

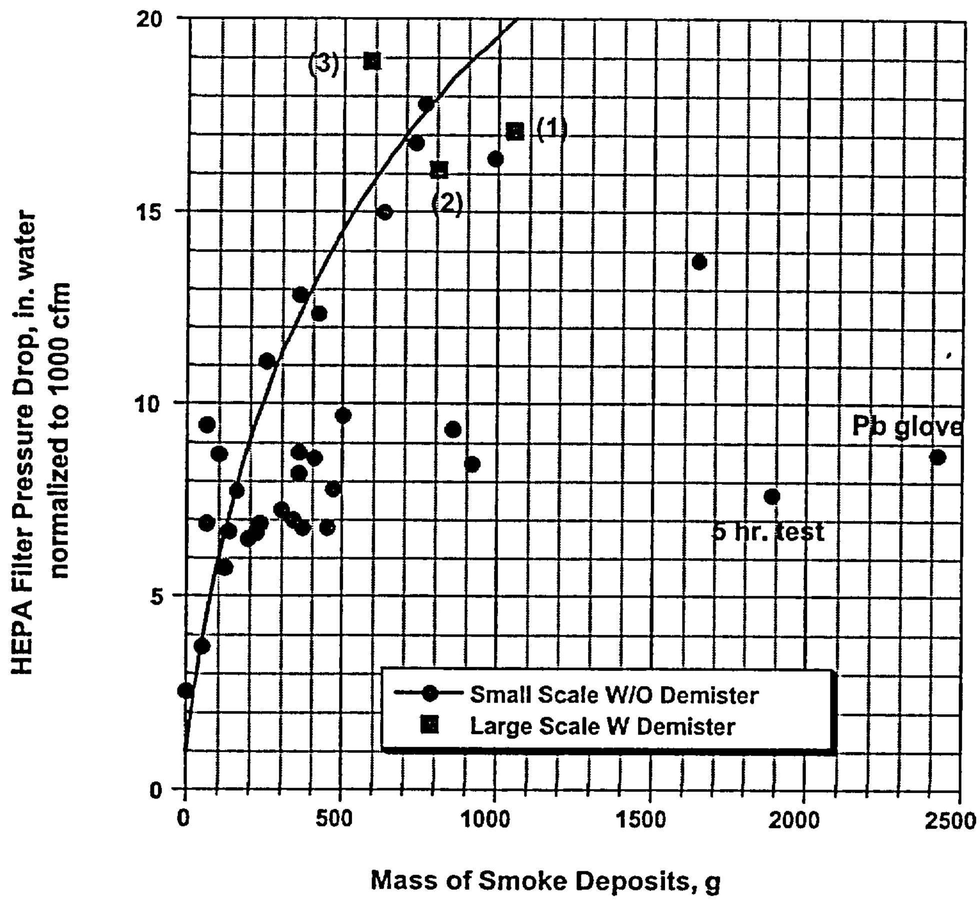


Figure 4. Composite of Gaskill small-scale and large-scale smoke loading tests.

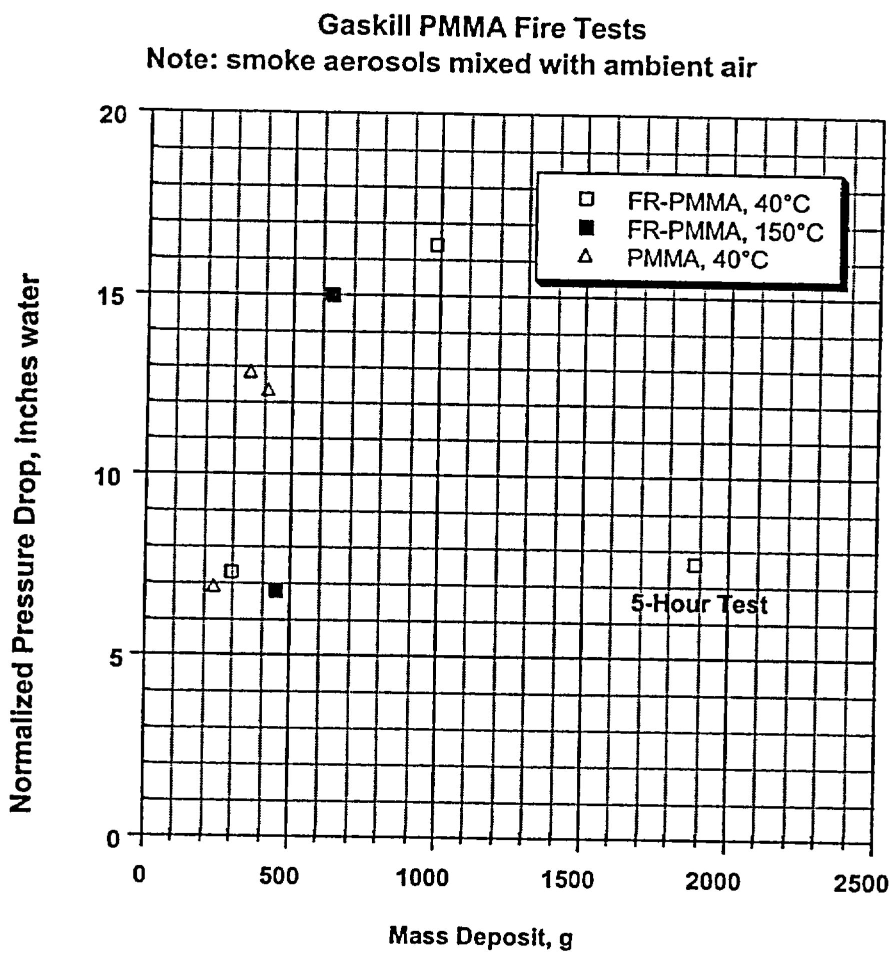


Figure 5. Gaskill small scale tests using PMMA fuel. Data taken from Figure 4.

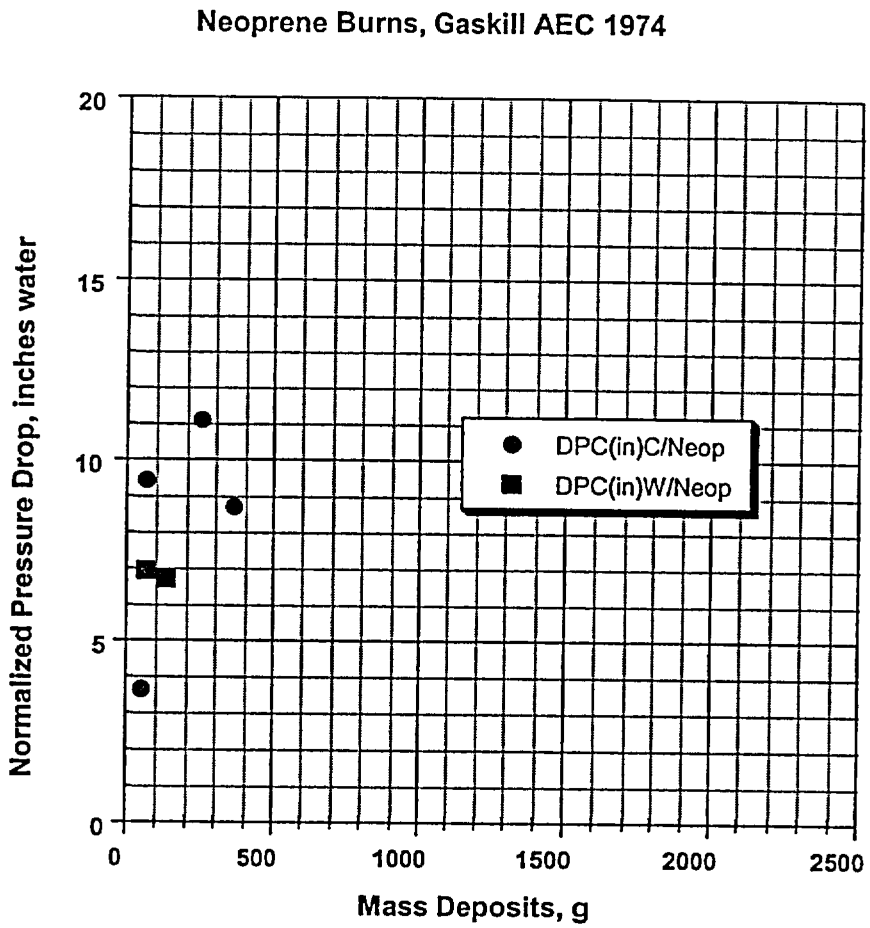


Figure 6. Gaskill small-scale tests with the neoprene data extracted from Figure 4.

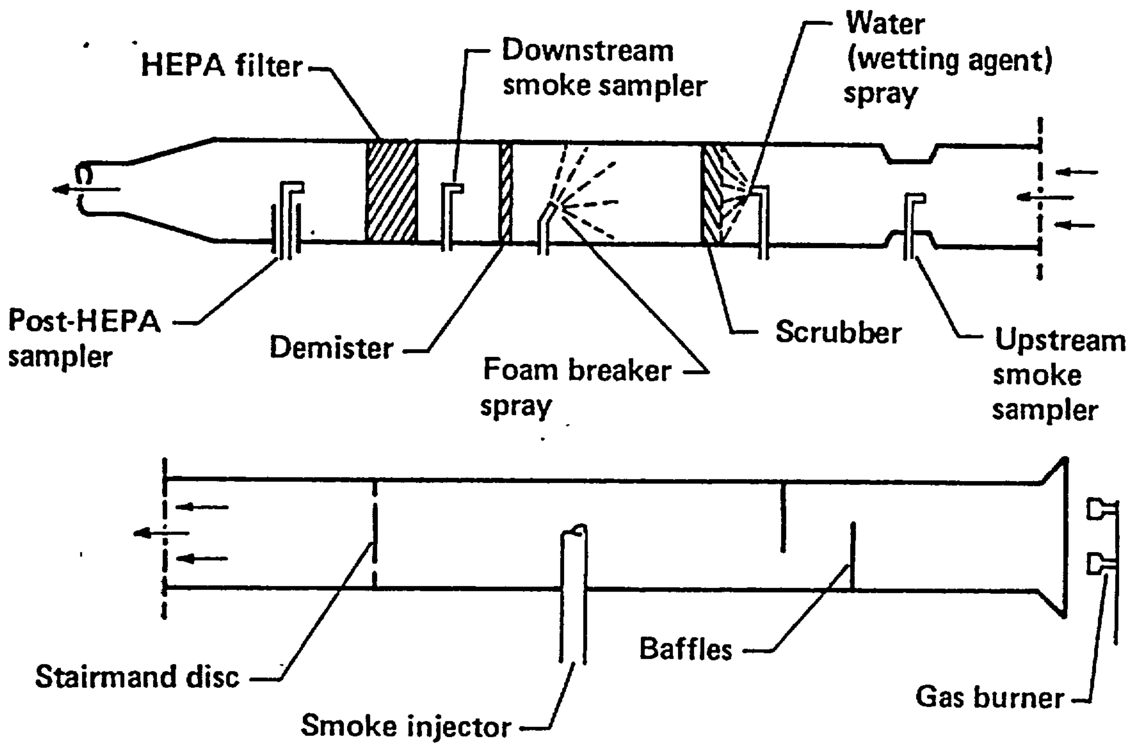


Figure 7. Gaskill small scale smoke loading tests with full-scale (1,000 cfm) HEPA filter. Smoke generated off-line with a Franklin stove.

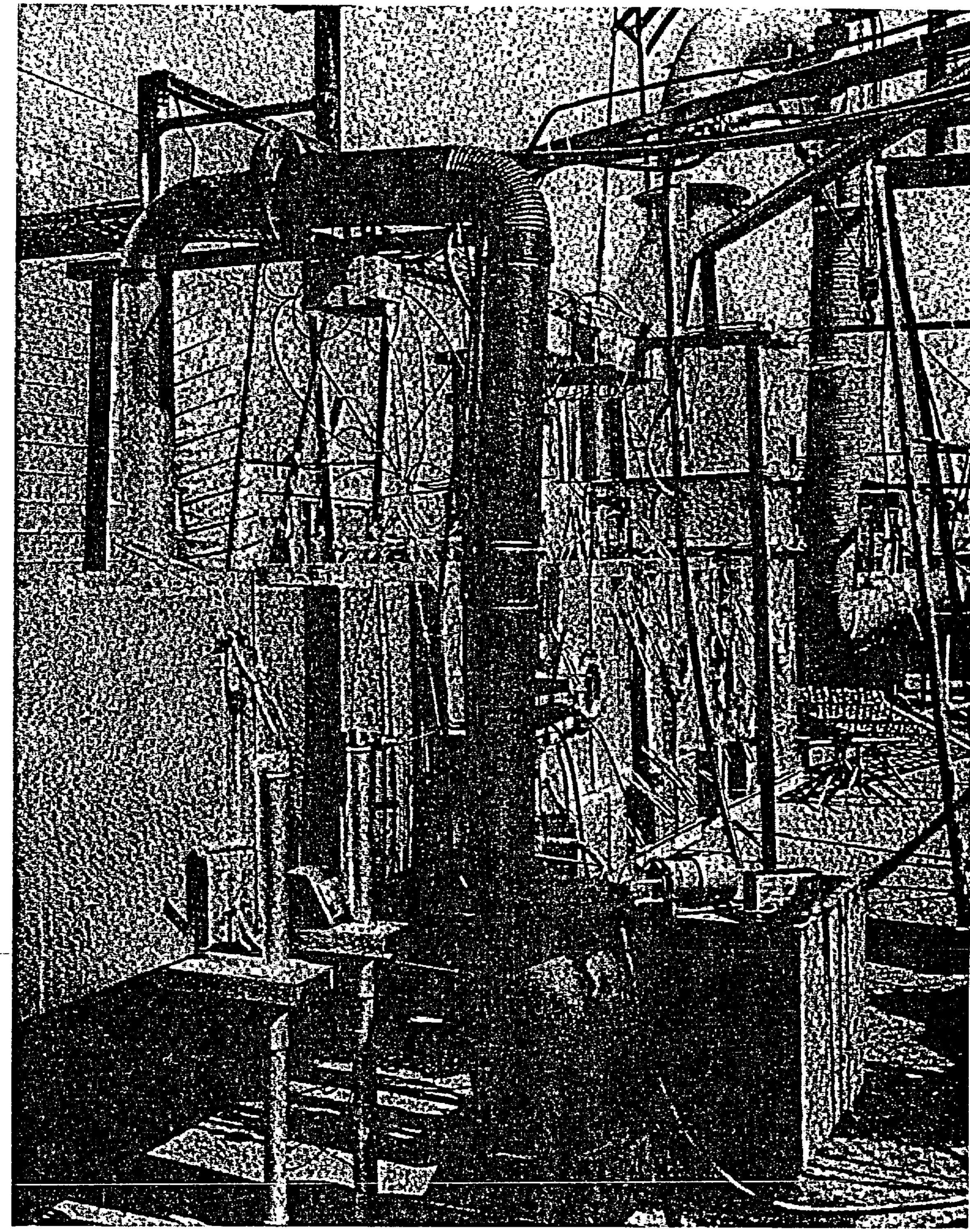


Figure 8. Franklin stove used to generate smoke in small-scale tests.

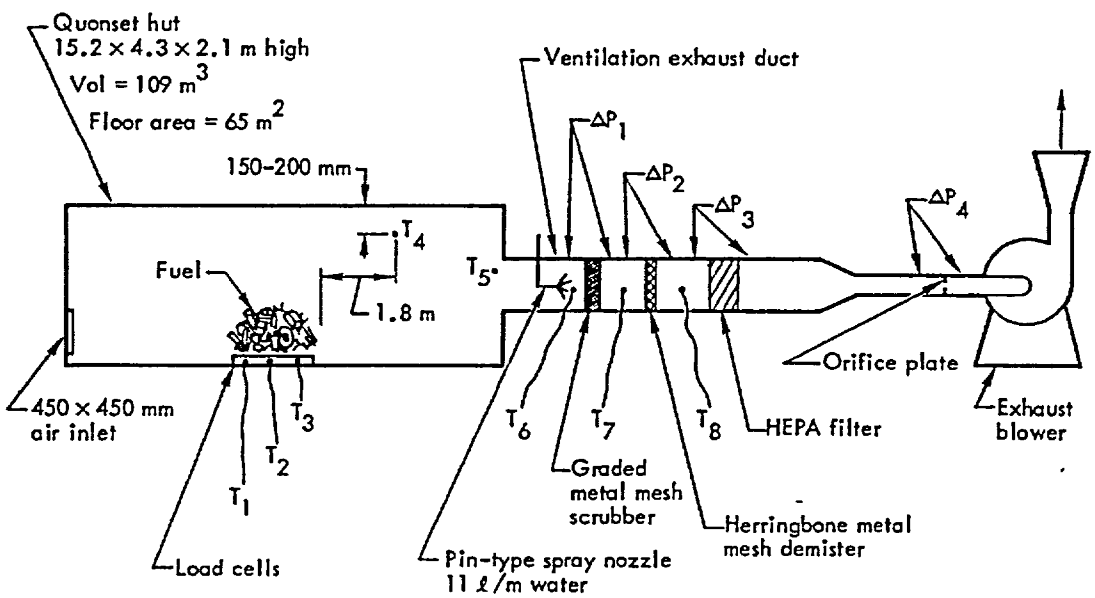


Figure 9. Gaskill large-scale tests with full-scale (1,000 cfm) HEPA filter. Smoke generated inside chamber.

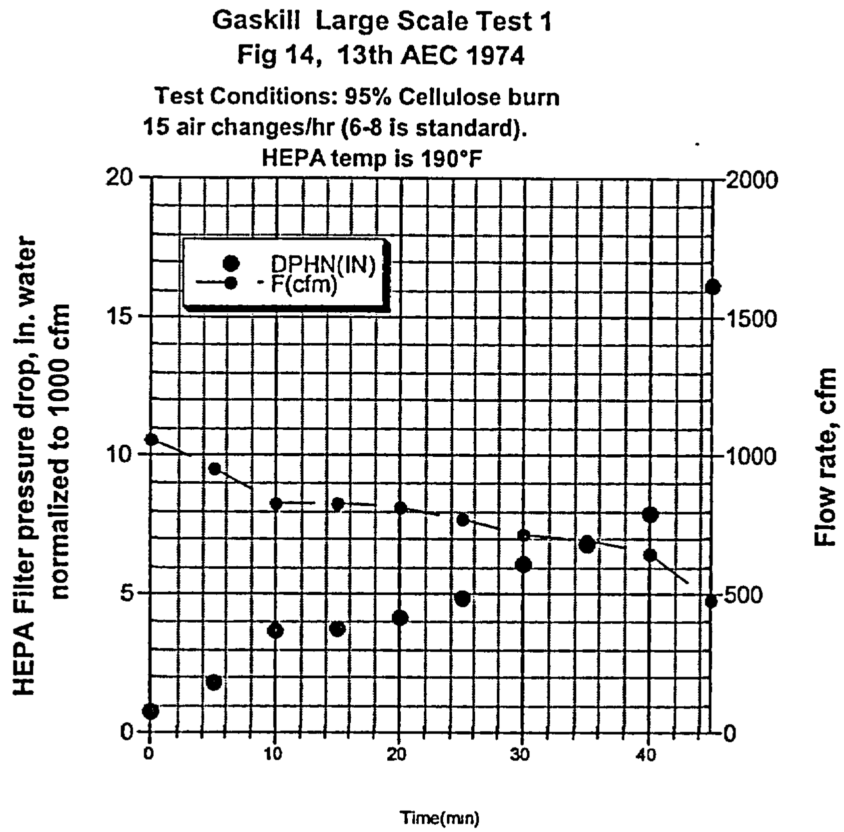


Figure 10. Gaskill large scale test No. 1 with a scrubber (not shown), Note the pressure drop (normalized to 1,000 cfm) across the HEPA filter increases continuously with increasing time. This tests shows the scrubber does not protect the HEPA filter.

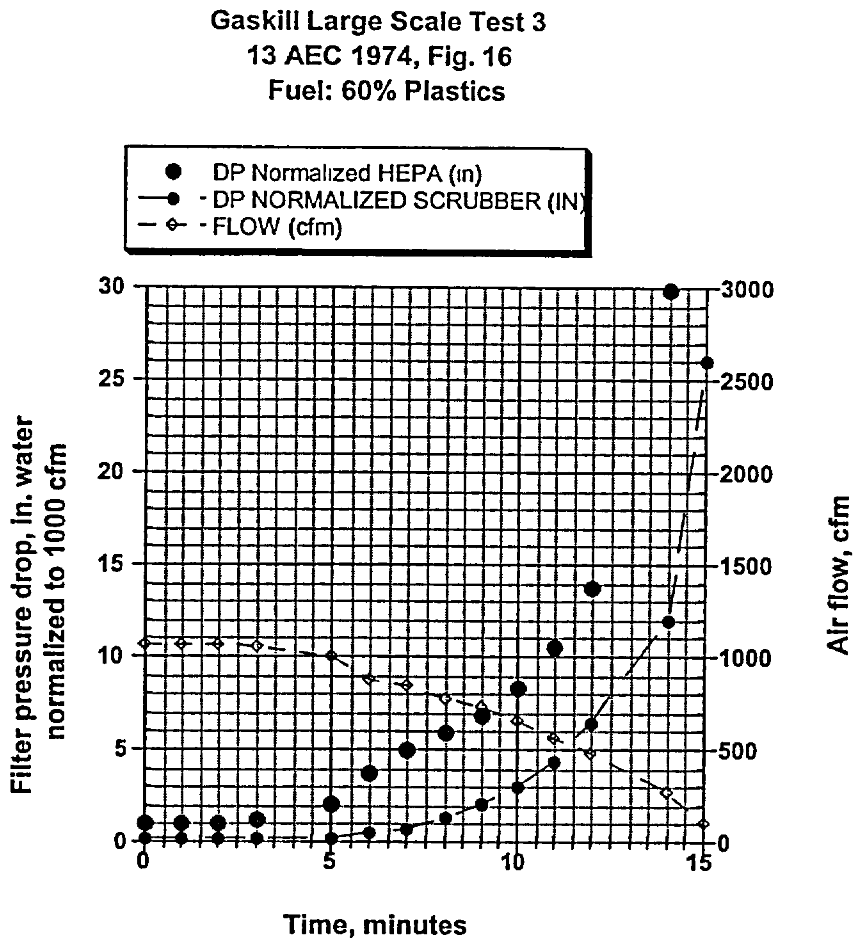


Figure 11. Gaskill large-scale tests with a scrubber shows the HEPA plugs rapidly..

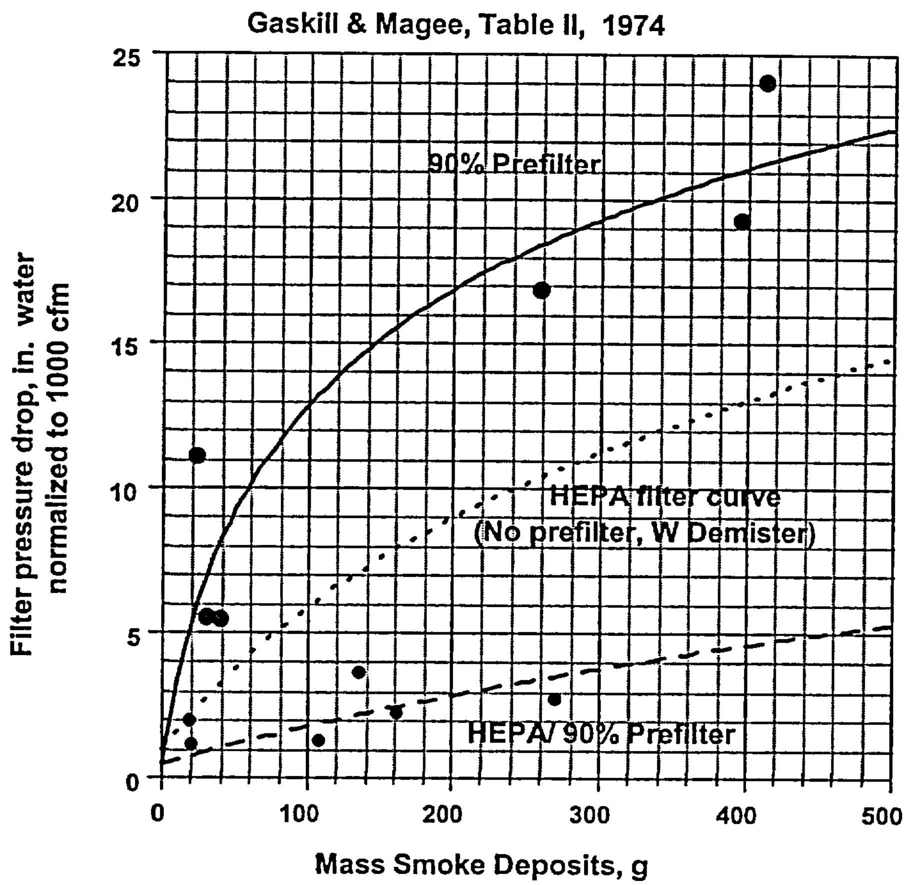


Figure 12. Gaskill large-scale tests shows the 90% prefilter mitigates the smoke clogging, but still causes significant HEPA filter clogging. Note Gaskill did not normalize the HEPA pressure drop for the decrease in air flow.

First Atmospheric Dust Loading:

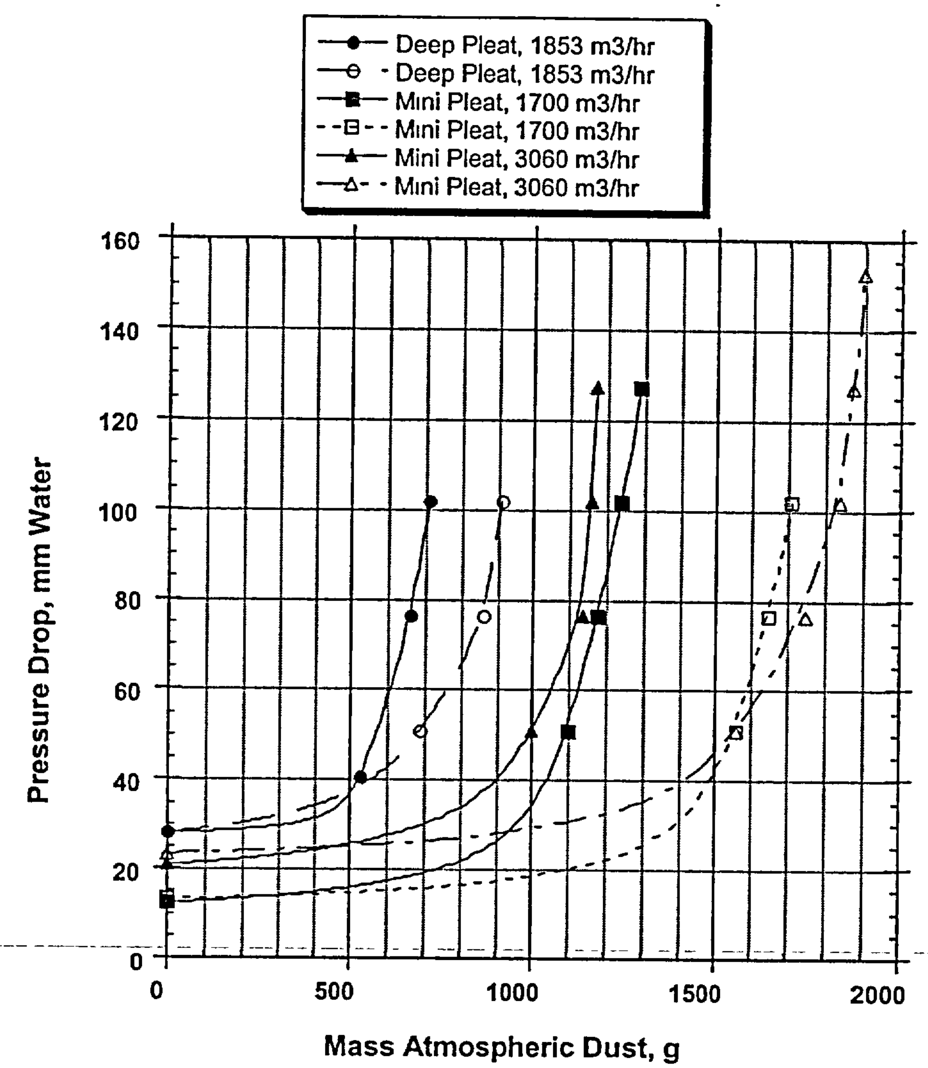


Figure 13. First et al atmospheric dust loading on HEPA filters.

Loughbourough Carbon Black Loading:

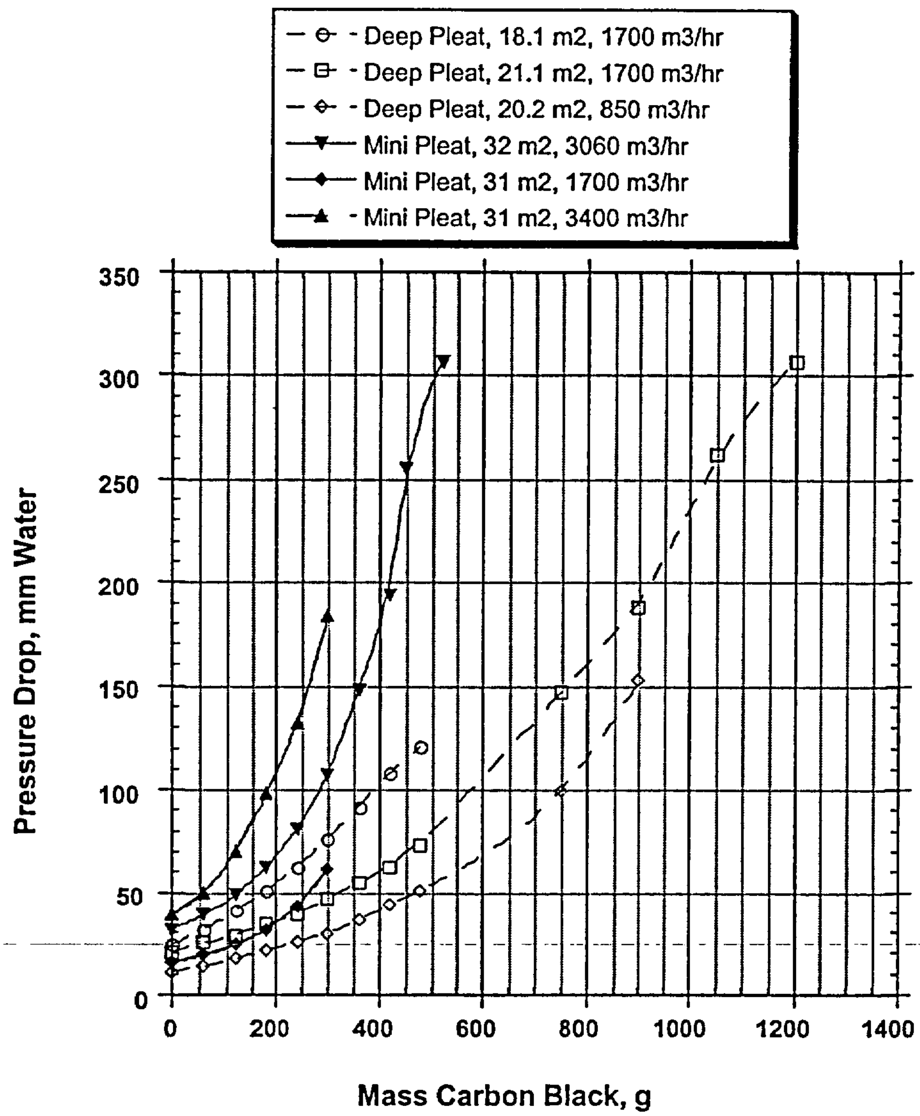


Figure 14. Loughbourough carbon black loading on HEPA filters.

Bergman HEPA HEPA studies:

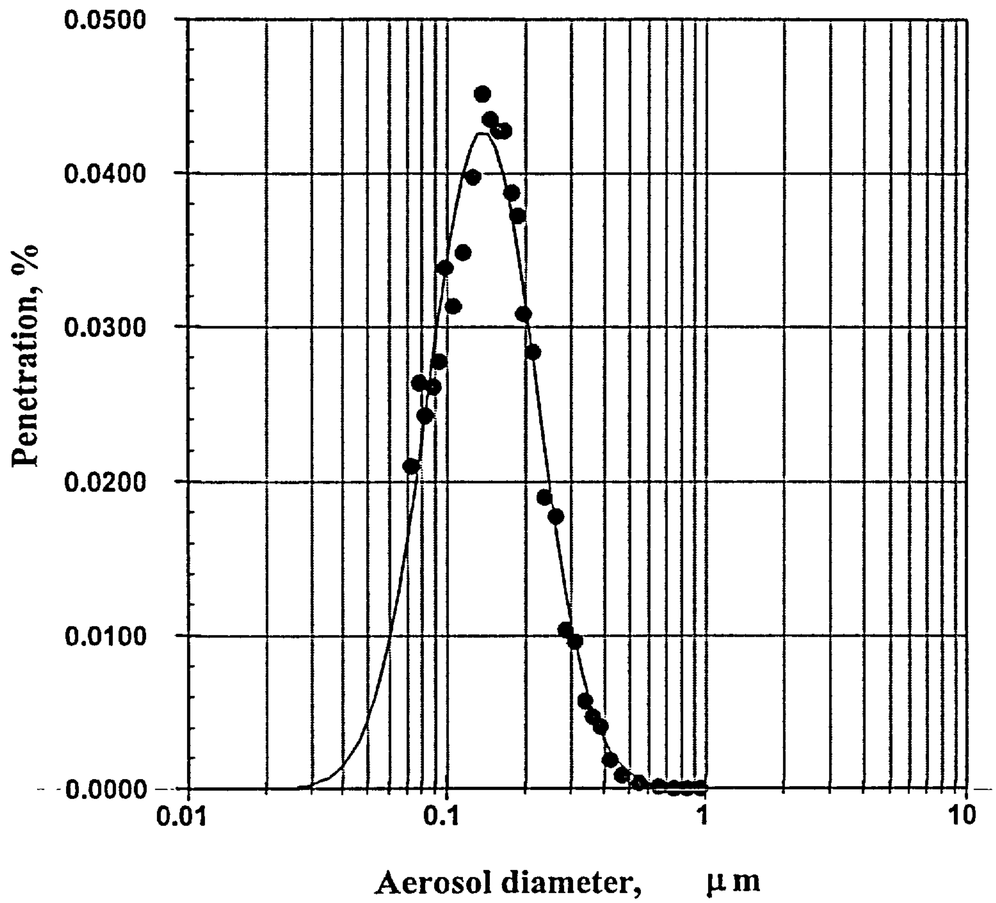


Figure 15. Bergman et al HEPA filter efficiency at 1,000 cfm.

Comparison of Air Dilution V.S. Water Spray for protecting HEPA Filters

	Air Dilution	Water Spray
HIGH Temperature	decrease sufficient	decrease sufficient
Smoke concentratin	decreare sufficient	increase effective conc.
Water concentration	decrease sufficient	greatly increase

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MOX Fuel Fabrication Facility (MFFF) HEPA Filter Efficiency Open Item Resolution

NRC Technical Exchange Meeting
15 January 2003

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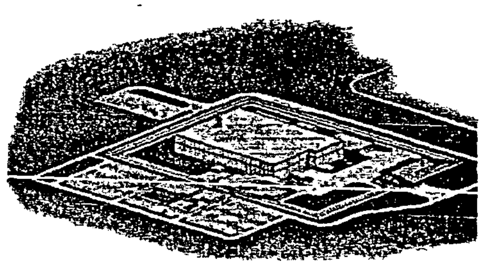
Introduction

Part I—Executive Summary
Part II—Detail Presentation



MOX Fuel Fabrication Facility

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Part II

- Detailed Presentation Material

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Outline of the Presentation

- HEPA Filter Normal Operation (Dr. Bergman)
- HEPA Filter Impacts/ Analysis (Dr. Bergman)
- MFFF HVAC System Description
- MFFF Fire Protection Description
- History of Relevant Fire Events
- Defense-In-Depth Discussion
- Conclusion

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HEPA Filter Normal Operation

Nuclear Air Cleaning Systems in the U.S.

Handouts by Dr. W. Bergman

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HEPA Filter Impacts / Analysis

Presentation of HEPA filter impacts / analysis

HEPA Filter Impacts / Analysis

- HEPA Filter Performance Focus
  - Structural Integrity
  - Efficiency
- Evaluation of Factors Impacting Structural Integrity or Efficiency

HEPA Filter Impacts / Analysis

- Factors That Could Impact Filter Performance
  - Short Term Physical Effects
    - Embers / UO_2 Burnback
    - Smoke/Soot
    - High Temperature
    - Water
    - Airflow
  - Long Term Degradation Effects
    - Aging
    - Chemicals
    - Moisture
    - Radiation
  - Other Factors
    - Manufacturing Defects
    - Installation Errors
    - Inspection Errors

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HEPA Filter Impacts / Analysis

ΔP threshold, inches Avg.	Range	Parameter	Reference
66	(37-81)	Baseline (high air flow)	Gregory et al [25]
57	(38 72)	Baseline (high air flow)	Osaki et al [13]
63	(47-90)	Baseline (high air flow)	Ruedinger et al [27]
52	(29-70)	Explosion shock	Gregory et al [25]
38	(13-78)	Age (15-19 year old filters with Asbestos separators)	Johnson et al [16]
33[1]	(18-40)[1]	Radiation (5 x 10^7 rad)	Jones [28]
X[2]		HNO_3 HF exposure (variable)	Woodard et al [29]
		Temperature	
44[3]	(25-54)[3]	200°C (392°F) 1 hr	Breschi et al [26]
33[4]	(19-41)[4]	300°C (572°F), 10 min.	Hamblin et al [30]
26[5]	(15-32)[5]	400°C (752°F) 1 hr	Breschi et al [26] and Hamblin et al (30)
13[6]	(8 18)[6]	500°C (932°F), 10 min	Pratt et al [31]
	(8-20)	500°C (952°F), 10 min.	Pratt [32]
23	(10-36)	Clean filter, water spray	Ruedinger et al [33]
20	(16-25)	Loaded filter, 100% humidity	Ruedinger et al [33]
18	(7-36)	Clean filter, water spray	Ricketts et al [34]
16	(3 6-25)	Loaded filter 99% RH	Ricketts et al [34]
40[7]	(22-49)[7]	Clean dry filter, prev wet	Ricketts et al [34]

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HEPA Filter Impacts / Analysis

Parameter	ΔP Threshold*, inches w.g.
Baseline (new filter, normal conditions)	37
Age (15 years or older)	13
Radiation (6 x 10^7 Rad)	18
Chemical (HNO_3, HF)	0-37
Temperature	
less than 200°C, (392°F)	37
200-300°C, (192-572°F)	
10 minutes	33
1 hour	30
10 hours	22
300-400°C, (572-752°F)	15
400-500°C, (752-932°F)	10
Moisture	
wet filter, (greater than 95% relative humidity)	10
dry filter, previously wet	22
Air pulse from explosion	29

HEPA Filter Impacts / Analysis

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Parameter	Effect on Filter Penetration	Reference
Baseline	0.1%	Scripsick et al [3]
HF Corrosion		
1,500 ppm-hr	0.1% increase	Brassel et al [35]
Temperature		
increase from 25 to 200 C	decreases penetration from 0.01 to 0.001%	Osaki et al [13]
200°C	.03-0.01%	Pratt et al [31]
240°C for 6 hours	0.01%	Osaki et al [13]
300°C	0.12-0.01%	Pratt et al [31]
350 C	0.4-0.03%	Pratt et al [31]
500°C	0.3-0.2%	Pratt et al [31]
500°C for 10-45 min.	0.3-0.1%	Hackney [36]
538°C	1.2-0.5%	First [37]
Moisture		
Up to 100% RH	Negligible effect	Osaki et al [13]
Water spray loaded to 6 in.	Increase by 10 times	Osaki et al [13]
Filter clogging		
Solid particle loading	Decreases penetration	Bergman [11]
NaCl deposits to 1.9 in.	Decreases penetration from 0.003 to 0.000001%	Osaki et al [13]
Liquid DOP loaded to 4 in.	Penetration increases by factor of 10	Osaki et al [13]
Oil aerosols	Penetration increase is 1.3 P(ΔP/ΔP) increase	Payet et al [12]
Air Flow		
Increasing velocity from 0.5 cm/s to 20 cm/s	Penetration increases from 0.00003% to 0.5%	VanOsdell et al [15]
Increasing air flow by 10 times	Penetration of 0.1 µm particles increases by 100 times	Osaki et al [13]
Air Pulse		
1 psi pulse	Penetration of 0.46 µm latex particles is 0.1%	Gregory et al [25]
Shock tests on filters preloaded with .46 µm latex	Penetration is 0.9%	Gregory et al [25]
Seismic (0.2-0.3 g)	negligible effect	Bergman et al [38]

HEPA Filter Impacts / Analysis

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Embers

- Hot embers are generated during welding operations and fires and consist of relatively large pieces of ash/burning material
- Embers can melt or burn holes in HEPA filter media and ignite combustible material captured on the filters
- Not all embers are carried to the HEPA filter housing
- Energy released by the oxidation of UO_2 is negligible (5W/kg) as compared to energy released by fire
- Damage to HEPAs prevented by spark arrestor and high efficiency high strength stainless steel/glass fiber prefilters

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HEPA Filter Impacts / Analysis

Smoke/Soot

- Smoke particles range in size from .01 to 5 micron. Soot consists of an agglomeration of smoke particles and moisture
- Smoke/Soot can plug HEPA filters causing reduced ventilation flows or increased flow resistance increasing efficiency but potentially resulting in filter rupture
- Water from combustion and fire protection systems exacerbates plugging of HEPA filters by smoke/soot
- DCS has evaluated smoke/soot generation as a result of fire and its affects on ventilation system filters

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MFFF HEPA Filter Analysis

Smoke/Soot (Continued)

- The following important variables were considered in soot analysis:
  - Quantity of combustible material Two consecutive FAs includes area with the largest quantity of combustible material (B-264, Cladding). Also evaluated FA with largest quantity of solvent.
  - Quantity of soot produced Conversion factors from SFPE Handbook.
  - Fire efficiency 100%, produces largest soot quantity.
  - Quantity of soot reaching filter 50% of soot remains in room. Within ducting, thermophoresis credited, gravitational settling not credited.

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MFFF HEPA Filter Analysis

Smoke/Soot (continued)

- The following important variables were considered in soot analysis:
  - Quantity of soot deposited on filter housing components Determined by component efficiencies.
  - Quantity of soot HEPA filters can handle Predicted using simplified Ballinger correlation
- Soot loading on high strength stainless steel roughing filter and high strength stainless steel/glass fiber prefilter to be experimentally verified

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PRELIMINARY DATA ON SMOKE ~~CLOGGING~~

See *Preliminary Data on Smoke Clogging* Handout

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HEPA Filter Impacts / Analysis

High Temperature

- Results in loss of efficiency due to filter damage (media, adhesive) and/or distortion of metal mounting hardware
- DCS has evaluated high temperature as a result of fire

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Room Exhaust Temperature

- The following important variables were considered in dilution analysis:
  - Room exhaust temperature Assume 2300°F. Exhaust ducts located at bottom of room. Expected temperatures 1200 – 1500°F.
  - No heat loss from HVAC ducting
  - Consider several combinations of adjoining fire areas
  - Evaluation criteria of 400°F UL-586 HEPAs designed to withstand 700 – 750°F for 5 minutes. No major decrease in strength below 450°F

Decontamination Factor vs Particle Diameter at Increasing Temperatures

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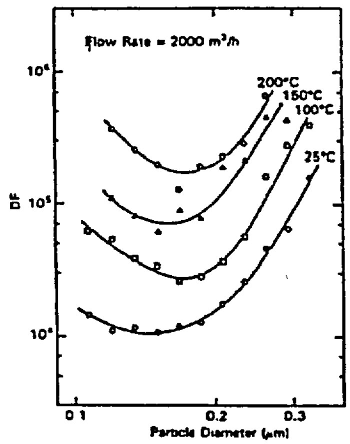

HEPA Filter Impacts / Analysis

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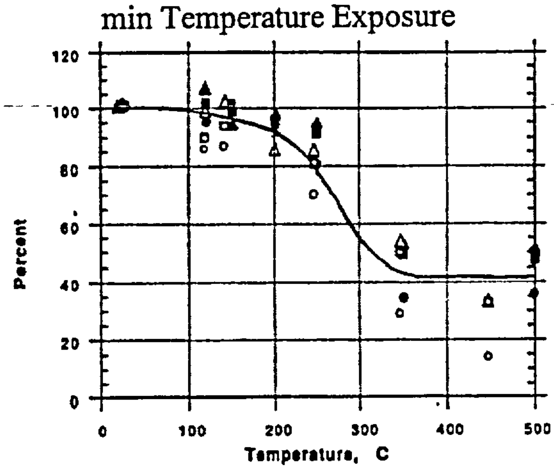
Percent Decrease in HEPA Media Strength Vs 10 min Temperature Exposure



High Temperature (Contd)

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See high temperature effects handout

HEPA Filter Impacts / Analysis

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Moisture

- Exposure of HEPA filters to excessive moisture can result in loss of filter efficiency and loss of filter strength
- The magnitude of effect dependent on factors such as dust loading and age.
- Moisture in the HVAC exhaust can originate from products of combustion due to facility fire, fire suppression systems, and fire fighting activities.

HEPA Filter Impacts / Analysis

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Moisture

- The following MMMF design features minimize the impact of moisture on the facility HEPA filters:
  - Dry agent (proprietary gas mixture) used as fire suppressant in process areas
  - High strength stainless steel/glass fiber prefilters upstream of HEPA filters will act as mist eliminators
  - High strength stainless steel/glass fiber prefilters have been used sucessfully at the SRS and Pantex plants to extend the service life of the downstream HEPA filters
  - HEPA filter housings are not provided with cooling water sprays. Review of past events suggest that sprays have damaged filters to a greater extent than fire itself

HEPA Filter Impacts / Analysis

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See handouts on moisture effects

HEPA Filter Impacts / Analysis

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Aging

- Aging of HEPA filters results in decreased media strength and loss of water repellancy even in storage
- Other factors can contribute to slow degradation of filter strength and efficiency over time including: humidity, wetting, exposure to radiation and chemicals

HEPA Filter Impacts / Analysis

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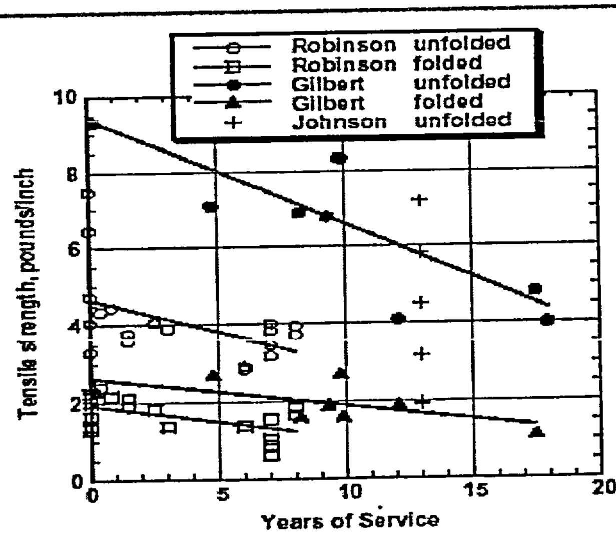

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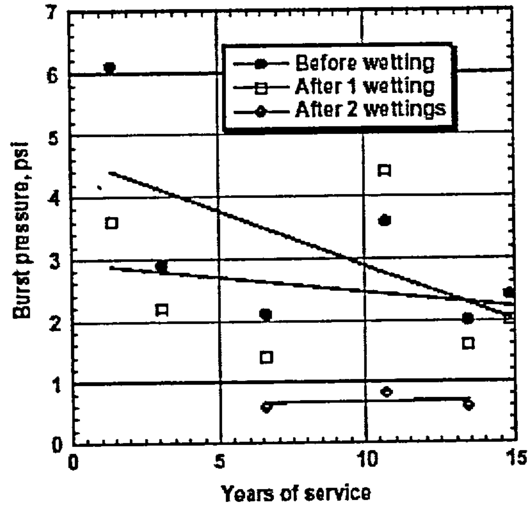
HEPA Filter Impacts / Analysis



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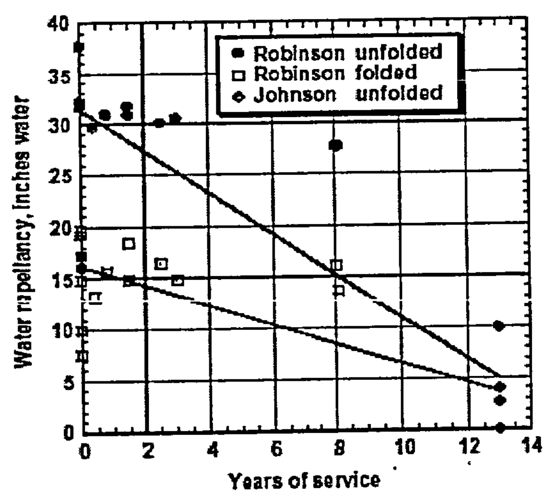
HEPA Filter Impacts / Analysis



HEPA Filter Impacts / Analysis

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Aging

- To prevent these factors from affecting filter ability to perform, MFFF will perform the following:
  - Periodic filter visual inspection and surveillance leak testing in accordance with ASME N510-1989
  - Monitoring of HEPA Delta P and replacement at specified filter differential pressures.
  - Establish filter replacement criteria – Replacement at specified time intervals in accordance with ASME AG-1 or following identified exposures to water or chemicals.

HEPA Filter Impacts / Analysis

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Chemical Exposure

- Chemical exposure can result in the degradation of HEPA filter media efficiency and strength.
- Chemical use is limited in the manufacture of fuel pellets and rods and is not expected to affect MFFF HEPA filters.
- The aqueous polishing process uses an offgas system including scrubber to vent process tanks and vessels.

HEPA Filter Impacts / Analysis

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Radiation Exposure

- Radiation exposure can result in the degradation of HEPA filter media efficiency and strength.
- Local HEPA (glovebox) and intermediate HEPA filters minimize the accumulation of radioactive material on final HEPAs.

HEPA Filter Impacts / Analysis

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Air Flow

- High air flows and resultant differential pressures can result in HEPA filter failure.
- Air flows and filter differential pressures will be controlled and monitored to ensure integrity of final HEPA filters.

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Air Flow

See handout of high airflow effects

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Other Factors

- Manufacturing defects
- Installation errors
- Inspection errors

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Summary of Impacts/Design

Parameter	Design Strategy	HEPA Efficiency Discussion	HEPA Structural Integrity Discussion
Embers	Filtered and/or cooled prior to reaching HEPAs	No Significant Impact	No Significant Impact
Smoke/Soot	Majority is filtered prior to reaching final HEPAs	Efficiency increases with increased loading Fans sized to handle increased filter loading	Rise in ΔP Accounted for in design and monitored Spark arrestors and prefilters designed to handle full ΔP of the fans
High Temperature	Diluted and cooled prior to reaching final HEPAs	Efficiency increases within temperature range	No significant impact within design range ΔP monitored
Moisture from fire	Majority is removed prior to reaching final HEPAs	No Significant Impact	Negligable moisture reaching final HEPAs with minimal increase in ΔP ΔP monitored
Airflow	Varible frequency drive fans control based on ΔP	No significant impact within design range. ΔP and flow monitored	No significant impact within design range. ΔP and flow monitored.
UO2 Burnback	Negligable heating impact	No Significant Impact	No Significant Impact
Moisture from external Water	None	N/A	N/A
Aging	ΔP monitored Filter changeout program.	Efficiency testing at filter changeout	Rise in ΔP Accounted for in design and monitored
Chemicals	Offgas treatment	No Significant Impact	No Significant Impact
Radiation	No high radiation fields expected on final HEPAs	No Significant Impact	No Significant Impact

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HEPA Filter Impacts/Design Synopsis

- Final HEPA filters credited in the safety analysis are designed and tested to be at least 99.97% efficient at 0.3 micrometer diameter particles.
- The filters are periodically inspected and tested in accordance with ASME N510-1995.
- Final HEPA filters are protected from the effects of the fire.

MFFF HVAC System Description

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Presentation of the MFFF HVAC System Description

T. St Louis

HVAC Systems One-line Diagram

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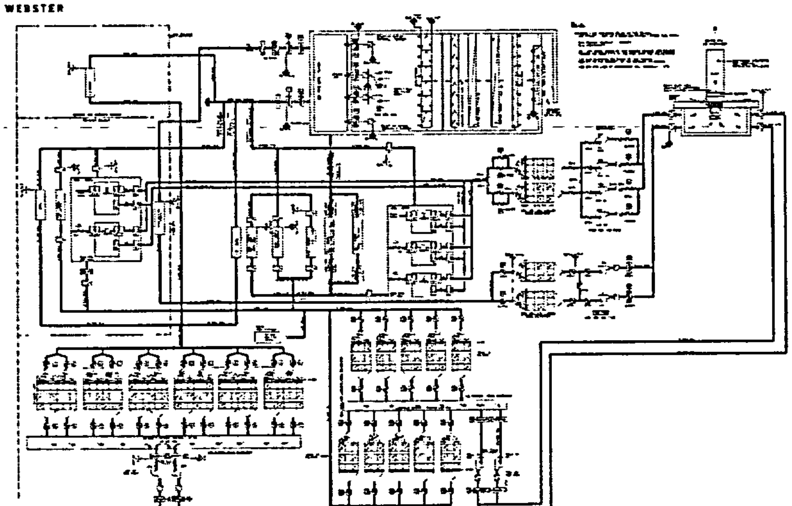

MFFF HVAC System Description

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Very High Depressurization (VHD) Exhaust System

- Functional summary
  - Maintain a negative pressure differential between the C4 (glovebox) and C3 (process room) confinement zones
  - Filter contaminants from glovebox exhaust gases/air prior to discharge through the exhaust stack
- Design parameter Summary
  - Small estimated flow rate capacity of 2,500 to 3,000 cfm
  - Moderate negative pressure at fan inlet of ~1 psig
  - Redundant final filter units (1 per train) consisting of spark arrestor, stainless steel/glass fiber filter, prefilter, and 2-stages of a bank of 4 nuclear grade HEPA filter elements (8 HEPA filter elements)
  - Dual redundant fan trains (2 trains of 2 fans)

MFFF HVAC System Description

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HD Exhaust System

- Functional summary
  - Maintain a negative pressure differential between the C3 (process room) confinement zone and the C2 confinement zone
  - Filter contaminants from the exhausted air prior to discharge through the MOX Fuel Fabrication Building exhaust stack
- Design parameter summary
  - Large estimated flow rate capacity of ~80,000 cfm
  - Moderate negative pressure at fan inlet of ~2 psig
  - Redundant final filter trains (5 filter units per train)
  - Filter units consists of spark arrestor, stainless steel/glass fiber filter, prefilter, and 2-stages of a bank of 6 nuclear grade HEPA filter elements (120 HEPA filter elements)
  - Redundant fans

MFFF HVAC System Description

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Process Cell Exhaust System

- Functional summary
  - Maintain a negative pressure differential between the process cell confinement zone and the C2 confinement zone
  - Filter contaminants from process cell exhaust air prior to discharge through the exhaust stack
- Design parameter Summary
  - Small estimated flow rate capacity of 9,050 cfm
  - Moderate negative pressure at fan inlet of ~1 psig
  - Redundant final filter units (1 per train) consisting of spark arrestor, stainless steel/glass fiber filter, prefilter, and 2-stages of a bank of 9 nuclear grade HEPA filter elements (18 HEPA filter elements)
  - Redundant fan trains

MFFF HVAC System Description

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MD Exhaust System

- Functional summary
  - Maintain a negative pressure differential between the C2 confinement zone and atmosphere
  - Filter contaminants from the exhaust air prior to discharge through the exhaust stack
- Design parameter summary
  - Large estimated flow rate capacity of ~140,000 cfm
  - Moderate negative pressure at fan inlet of ~1 psig
  - Partially redundant filter train (11 operating filter units per train, 1 spare filter unit)
  - Filter units consists of spark arrestor, spark arrestor/prefilter, and 2-stages of a bank of 12 nuclear grade HEPA filter elements (288 HEPA filter elements)
  - Redundant fans

MFFF HVAC System Description

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Offgas Treatment Unit ventilation system

- Functional summary
  - Remove plutonium from offgases collected from AP process units
  - Recombine the nitrous fumes in a specific NOx scrubbing column
  - Clean, by water scrubbing, the offgases collected from all the AP units
  - Treat the offgas flow by HEPA filtration before release to the stack
  - Maintain negative pressure in the tanks and equipment connected to the process ventilation system.
- Design parameter summary
  - Very small estimated flow rate capacity of ~200 cfm
  - Redundant final filter units (1 per train) consisting of spark arrestor, stainless steel/glass fiber filter, prefilter, and 2-stages of a bank of 1 nuclear grade HEPA filter element (2 HEPA filter elements)
  - Redundant fan trains

Simplified Schematic of MP

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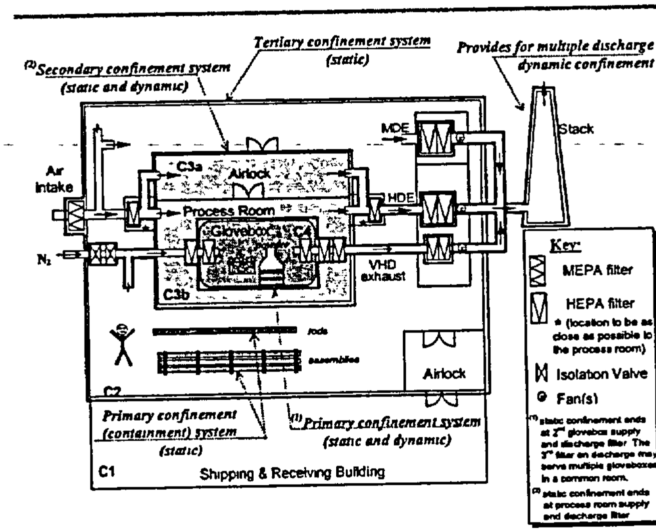

Simplified Schematic of AP

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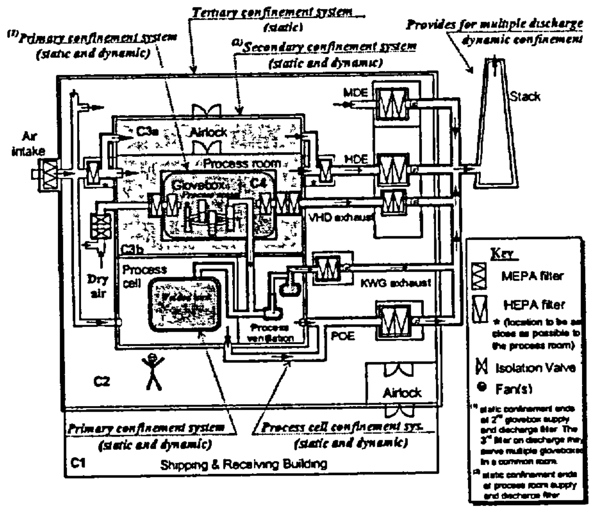

Multiple Fire Areas

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- Limits extent of any individual fire to fire barrier boundaries
- Limits MAR involved in fire
- Analyzed assuming failure of fire suppression systems to ensure that fires are contained

Figure removed under 10 CFR 2.390.

Simplified Schematic of Fire and Confinement Areas

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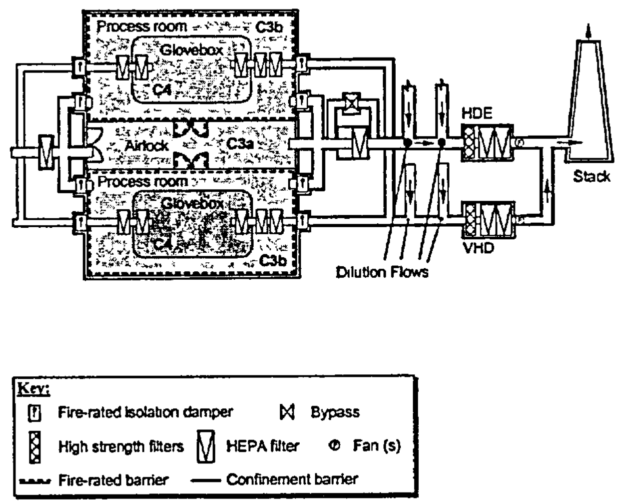

Summary of Dilution Air Flows

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- VHD Exhaust System
  - 240 gloveboxes
  - 61 flow circuits
- HD Exhaust System
  - 203 rooms
  - 14 flow circuits (i.e., intermediate filters)

Room Exhaust Temperature

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- The following important variables were considered in dilution analysis:
  - Room exhaust temperature Assume 2300°F. Exhaust ducts located at bottom of room. Expected temperatures 1200 – 1500°F.
  - No heat loss from HVAC ducting
  - Consider several combinations of adjoining fire areas
  - Evaluation criteria of 400°F UL-586 HEPAs designed to withstand 700 – 750°F for 5 minutes. No major decrease in strength below 450°F

HEPA Filter Housing Design

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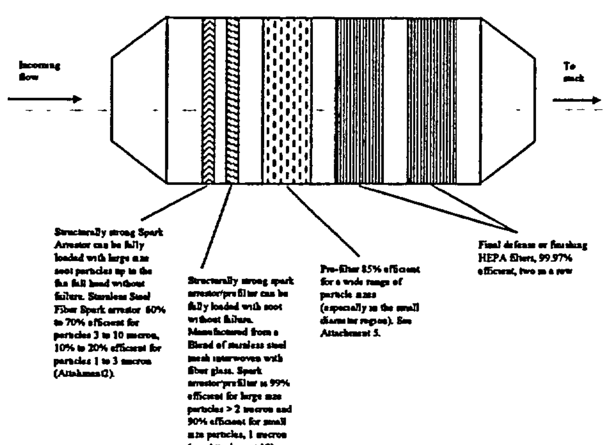

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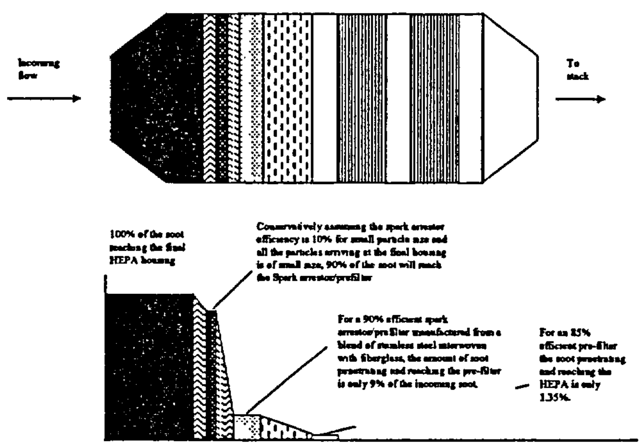
Soot Penetration (Worst Case)



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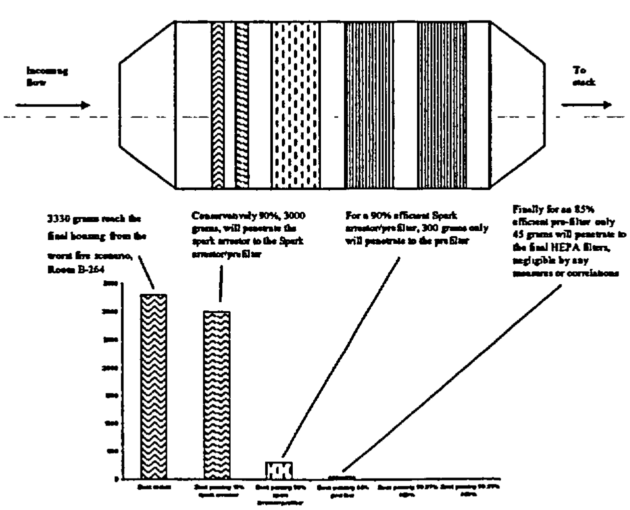
Summary of Estimated Soot Loading



MFFF Fire Protection Features

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Detailed MFFF Fire Protection Features

Discussion of MFFF Fire Protection

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- Multiple layers of protection to reduce challenges to the HEPA filter elements
  - Low combustible loads
  - Seismic isolation valves
  - Control of ignition sources
  - Multiple fire areas
  - Fire detection systems
  - Fire suppression systems
  - Fire brigade
  - Fire protection training

Low combustible loads

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- Combustibles are limited by use of:
  - Noncombustible or nonflammable materials to the maximum reasonable extent for construction and furnishings
  - Thermally stablilized forms of pyrophoric materials (PuO_2, UO_2) or material must be in a form that is essentially noncombustible (e.g., thick titanium plates)
  - Fire retardant electrical insulation (e.g., IEEE 383 rated cable)
  - Glovebox vision panels « Lexan »
  - Minimal glovebox radiation shielding « Kyowaglas » to meet ALARA only
  - Transient combustibles (e.g., cleaning supplies, spare parts, temporary radiation shielding), unless stored in approved containers, are not left unattended

Control of Ignition Sources

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- Ignition sources are controlled by:
  - Restricting use of electrical equipment
  - Grounding of all equipment
  - Hot work permit system (for welding, grinding, flame-cutting, brazing, or soldering activities)

Fire Detection System

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- Fire detectors located:
  - Gloveboxes
  - Rooms
  - Exhaust HVAC plenums of process cells

Fire Suppression System

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- Facility fire suppression systems:
  - Rooms (automatic)
    - Clean agent systems
    - Sprinkler systems
  - Gloveboxes (manual)
    - CO_2 bottles
  - Emergency (manual)
    - Standpipe systems
    - Portable fire extinguishers

Fire Brigade

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- Provides immediate on-site support for fire fighting activities. Fire brigade members are qualifed per NFPA 600 Fire brigade team consists of
  - Leader
    - Qualified as an operator to have sufficient knowledge of plant systems and processes
    - Qualified to be knowledgeable of the effects of fire and fire suppressants on the MFFF
    - Knowledgeable of potential safety consequences and fire suppression notification processes
  - Members
    - Physically qualified yearly
    - Some members trained to understand plant systems and processes and to understand the effects of fire and fire suppressants on the MFFF
  - Training Instructor
    - Knowledgeable, experienced and suitably trained in fighting the types of fires that could occur in the plant and in using the types of equipment available in the MFFF

Fire Protection Training

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- General employee training for fire protection includes:
  - Appropriate actions to take upon discovering a fire, including notification of control room personnel, attempt to extinguish the fire, actuation of local fire suppression systems
  - Actions upon hearing fire alarms
  - Administrative controls on the use of combustibles and ignition sources
  - Actions necessary in the event of a combustible liquid spill or gas release/leak

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History of Relevant Fire Events

- Discussion of Historical Fire Events

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Key Historical Fires

A review of the fires that have occurred in the U S. Nuclear industry showed that, except for the 1957 fire at Rocky Flats, no contamination escaped from the accident sites via the ventilation system Nuclear Air Cleaning Handbook, U.S. DOE

- 1957 Rocky Flats Plant fire
  - Combustible (cellulose based) filters destroyed by fire—resulted in use of noncombustible high-efficiency particulate air (HEPA) filter media
- 1969 Rocky Flats Plant fire
  - Fire originated in an area containing a flammable storage cabinet that housed small, open metal containers of plutonium machine turnings, virtually all processes performed within a single fire area, smoke-plugged filters caused normal air flow reversal within a large interconnected glovebox network, fire spread through glovebox network in direction of air flow, the exhaust systems containing multiple sets of nonflammable HEPA filters were damaged but remained intact—resulted in recommendations to limit combustible materials, reduce fire areas, use fire-wide management system, store pyrophoric materials in approved containers, use noncombustible storage cabinets, provide separation between successive stages of HEPA filters, add water sprays to protect HEPA filters
- 1980 Rocky Flats Plant fire
  - An exothermic reaction between hot nitric acid and urethane seals around HEPA filters may have ignited metallic oxides accidentally deposited on HEPA filters. Water sprays in the HEPA filter housings failed. Hose directed water sprays implicated in damaging 3 out of 4 stages of HEPA—resulted in research which determined that HEPA filter strength is significantly reduced after exposure to water (such as during a test of the water spray system)
- 1992 Siemens Power Corporation Richland
  - Fuel fabrication facility fire which involved a glovebox containing a UO plastic feed hopper which caught on fire as result of a manual bypass of the process equipment. The room single stage HEPA filters were destroyed. The final single stage HEPA filters were protected by dilution of the hot room exhaust by flow in the remaining system and were undamaged.
- 2002 Various
  - Hot embers and slag damaged HEPA filters that were not protected by spark arrestors. In one case the spark arrestor was missing from one train and the type of spark arrestor used did not allow easy verification of presence. In the train with a spark arrestor installed the HEPA filter was not damaged In the other case, no spark arrestor existed in the filter assembly Spark arrestors are shown to be effective in preventing damage to HEPA caused by hot embers/slag.

Matrix—Summary of Features

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Fires/Facilities	Features							
	Fire Areas	Fire Resistant Construction	Fire Resistant HEPA	Protected HEPA	Redundant HEPA Filter Trains	Stabilized metal (PuO_{2}, UO_{2})	Defense in Depth	Other
1957 Rocky Flats Plant-Building 771 Fire	Few	No	No	No	No–Single large building-size bank of filters	No	—	MAR ~28 kg RF $< 2 \times 10^{-3}$
1969 Rocky Flats Plant-Building 776/777 Fire	Few	No	Yes	No	No–Single large building-size bank of filters	No	Fire resistant HEPA filters	MAR >3000 kg RF $< 3 \times 10^{-7}$
1980 Rocky Flats Plant-Waste disposal fire	Few	Yes	Yes	Yes–Sprinkler	No–Single large building-size bank of filters	No	Automatic water sprays installed in filter units	Automatic water sprays inoperable, hose directed water spray damaged 3 out of 4 HEPA filter stages
1992 Siemens Power Corporation Richland	Many	Yes	Yes	Yes–Dilution	Yes–Multiple single-stage primary filters near process rooms separated by large distance from single-stage final filters	No	Final filters not damaged, eventhough primary filters severely damaged	Burnback in over reduced UO_{2} exiting calcining furnace ignited a plastic hopper
Mixed Oxide Fuel Fabrication Facility	Hundreds	Yes	Yes	Yes–Dilution, spark arrestors (ember removal), spark arrestor/prefilter (soot/smoke removal)	Yes–Multiple single-stage intermediate filters near process rooms separated by large distance from two-stage final filters. Final filters composed of many separate individually isolatable filter units with 100% redundant spare capacity	Yes	Facility fire protection (management) system to protect fire barriers. Inert atmosphere in most powder handling gloveboxes	Primary filters in gloveboxes

Major Administrative/Design Features Expected to be Credited

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- High strength stainless steel mesh spark arrestors
- High efficiency high strength stainless steel/glass fiber prefilters
- Protected two-stage final HEPA filters (verified by testing at CETL)
- Multiple redundant ventilation fan systems
- Air flow dilution
- Design ensures < 10 inches water column ΔP across HEPA filter elements
- Clean agent fire suppression systems
- Preventative maintenance to ensure HEPA filter integrity
- Nuclear quality assurance program covers design, procurement, installation, operation and maintenance activities
- Low combustible loads
- Fire areas protected by 2 hr (minimum) rated fire barriers

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DID to Account for Uncertainties Caused by Beyond Design Basis Events

- Control of ignition sources
- Multiple fire areas
- Fire protection training
- Fire detection systems
- Fire brigade/manual fire suppression
- Automatic fire suppression systems
- Parallel filter trains
- Fire-rated isolation dampers
- Monitor ΔP across filter elements
- MDE system

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Significant Changes in CAR Amendment

- Additional PSSCs relied on to protect HEPA filters
  - High efficiency high strength stainless steel/glass fiber prefilters
- Concepts not highlighted in CAR that protect HEPA filters
  - Zoned ventilation exhaust system
  - Differential pressure monitoring across filter elements to ensure < 10 inches water column ΔP

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Conclusions

- Data demonstrates that protected HEPA filters provide $<10^{-4}$ LPF
- MFFF design provides extensive protection of HEPA filters under fire conditions
- MFFF provides multiple layers of defense-in-depth to account for uncertainties caused by beyond design basis events
- Current design evolution significantly enhances surviveability of HEPA filter under severe conditions

NRC Question

What chemical concentration levels will initiate protective actions associated with the emergency control room?

Response

As identified in the CAR, Revision 1, Section 11.4.2.7.4, each emergency control room air intake is continuously monitored for hazardous chemicals. Upon detection of a hazardous chemical above allowable limits, the intake is automatically isolated and switched to the recirculation mode using a filtration unit with HEPA filtration and hazardous gas removal elements. If hazardous chemical concentrations above allowable limits are detected at both intakes, operators will don emergency self-contained breathing apparatuses.

Monitoring will be performed for those chemicals whose unmitigated release could result in control room concentrations above the TEEL-3 limit. The emergency actions described above will be initiated when the chemical concentrations are at or below the TEEL-3 limit for these chemicals. Specific setpoints will be determined during final design.

Initial control room habitability calculations indicate that, of the process chemicals maintained on site (including simple asphyxiants), releases of hydrazine monohydrate or nitrogen tetroxide could result in control room concentrations at or above the TEEL-3 limit. Calculations will be made during final design to verify the list of chemicals to be monitored.

TEEL Values Transition from the Response to RAI 113 to the Updated CAR

	TEELS Rev. 17				TEELS Rev. 17m				TEELS Rev. 18				
Chemical Name / CAS Number	**TEEL-1**	**TEEL-2**	**TEEL-3**	**Units**	**TEEL-1**	**TEEL-2**	**TEEL-3**	**Units**	**TEEL-1**	**TEEL-2**	**TEEL-3**	**Units**	**Explanation for Change from Rev. 17 to Rev. 18**
Chlorine 7782-50-5	1	2.5	20	ppm	3	7.5	60	mg/m^3	3	7.5	60	mg/m^3	Chlorine was introduced to the process due to addition of AFS. Rev. 18 values are ERPG-1, -2, -3
Hydrazine Hydrate (Aqueous Solutions) 10217-52-4	0.0025	0.02	0.02	ppm	0.00325	0.026	0.026	mg/m^3	*0.04*	*0.04*	*0.04*	*mg/m^3*	For the response to the RAI Number 113, TEELS for Hydrazine Hydrate (Aqueous Solutions) were used. The TEEL values for this chemical have only recently been listed.
Hydrazine Monohydrate 7803-57-8	*0.004*	*0.03*	*25*	*ppm*	*0.005*	*0.04*	*35*	*mg/m^3*	0.0075	0.06	50	mg/m^3	For the updated CAR, TEEL values for Hydrazine Monohydrate were used. The TEEL values for this chemical have only recently been listed.
Hydrogen Peroxide 7722-84-1	10	50	100	ppm	12.5	60	125	mg/m^3	12.5	60	125	mg/m^3	Rev. 18 values are ERPG-1, -2, -3
Nitric Acid 7697-37-2	1	5	20	ppm	2.5	12.5	50	mg/m^3	2.5	15	200	mg/m^3	Rev. 18 values are ERPG-1, -2, -3
Nitrogen Dioxide 10102-44-0	2	15	30	ppm	3.5	25	50	mg/m^3	7.5	7.5	35	mg/m^3	All TEEL values were changed for Rev. 18. TEEL values were uncoupled from nitric acid.
Dinitrogen tetroxide 10544-72-6	5	5	20	ppm	9	9	36	mg/m^3	15	15	75	mg/m^3	The TEEL values for this chemical have only recently been listed. RTECS toxicity data was used.

Response to Open Item AP-2 (Part 1)

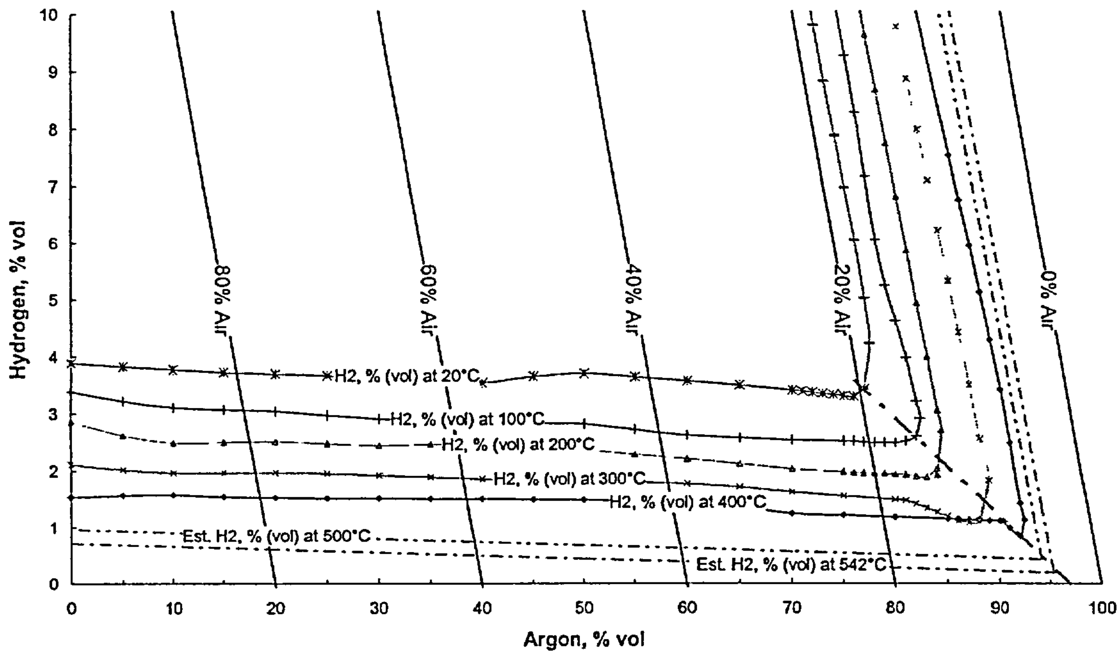
ACTION: DCS will provide description of LFL determination methodology.

To ensure that explosions are prevented within the processing buildings of the Mixed Oxide Fuel Fabrication Facility (MFFF), the facility is designed such that 50% of the lower flammable limit (LFL) for combustible gases used, generated or evolved in the processes is not exceeded outside of the process containment structures. In order to comply with this requirement, the appropriate MFFF systems are designed to dilute the accumulation of combustible gas to ensure that the concentration of combustible gas does not exceed 25% of the LFL or to take action when 25% of the LFL is reached. The safety threshold values of 50% and 25% LFL provide a sufficient margin to account for uncertainties in the actual LFL value and were chosen based on the National Fire Protection Association standards (principally NFPA 801-1998 and NFPA-86C-1995) and NUREG 1718. These values are based on LFL values that have been adjusted to account for changes in temperature, pressure and mixture composition.

An example of how these variations are used when determining an appropriate LFL value will be shown using hydrogen as the combustible gas. Pure hydrogen in air under standard reference conditions is flammable at concentrations between 4% (LFL) and 75% [upper flammable limit (UFL)] by volume. Mixtures that fall below the LFL are too lean to support combustion and mixtures that rise above the UFL are too rich to support combustion. The LFL and UFL values change under different conditions of temperature, pressure and gas composition. Because a higher risk is present when transitioning between lean and rich mixtures, the adopted safety strategy is to remain below the LFL when the combustible gas is outside of the process containment system (by leaks or accident).

Within the MFFF processing buildings, pure hydrogen is not used, so an evaluation of the mixed gas must be performed to determine an appropriate LFL. Instead of pure hydrogen, the MFFF processing buildings use a gas mixture consisting mainly of the inert gas argon with a small percentage of hydrogen. The LFL for hydrogen is not sensitive to changes in pressure below 100 atm, so changes in the LFL due to small changes in the local atmospheric pressure are ignored when determining the LFL. However, the LFL is affected by the addition of argon and changes in temperature. These changes are shown for argon- hydrogen-air mixtures in the following figure.

Flammability Limits of Argon-Hydrogen in Air at 1 bar and temperatures as shown
Data from Chemsafe (C) DECHEMAe V.14 10 2002



The concentration of argon is shown on the abscissa (x-axis). The corresponding hydrogen concentration is the ordinate value at the point that the argon concentration value intersects the flammability limit line. Thus at 0% argon, the figure shows that the LFL for hydrogen at 20°C is 4% by volume (i.e., the standard value). At elevated temperatures such as 120°C, which could be the result of an accident, the LFL could be as low as 3.3% hydrogen by volume, when the gas composition also consists of 75% argon and 21.7% air. Because this scenario represents the worst case credible environmental conditions for a leak of the hydrogen-argon gas into the sintering furnace room, the LFL thresholds for this scenario would be set at 1.6% (50% LFL) and 0.8% (25% LFL).

For diluents other than argon, such as water vapor or steam, the LFL values actually increase with increases in the diluent concentration. For these cases, the conservative assumption would assume the LFL for pure hydrogen in air and the standard value of 4% by volume would be used as the LFL. The thresholds would be 2% (50% LFL) and 1% (25% LFL). This value would be compared against the LFL for any other combustible gas and the lowest value used. The LFL for some vapors (e g., from gasoline) are combustible at concentrations of 1% by volume and lower. The thresholds for these cases would be 0.5% (50% LFL) and 0.25% (25% LFL). Ultimately, justification for the selected thresholds will be demonstrated in the ISA.

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Derivation of Temporary Emergency Exposure Limits (TEELs)

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Key words: chemical safety; hazard assessment; concentration limits; emergency response planning guidelines (ERPGs), temporary limits.

Short-term chemical concentration limits are used in a variety of applications, including emergency planning and response, hazard assessment and safety analysis. Development of emergency response planning guidelines (ERPGs) and acute exposure guidance levels (AEGLs) are predicated on this need. Unfortunately, the development of peer-reviewed community exposure limits for emergency planning cannot be done rapidly (relatively few ERPGs or AEGLs are published each year). To be protective of Department of Energy (DOE) workers, on-site personnel and the adjacent general public, the DOE Subcommittee on Consequence Assessment and Protective Actions (SCAPA) has developed a methodology for deriving temporary emergency exposure limits (TEELs) to serve as *temporary guidance* until ERPGs or AEGLs can be developed. These TEELs are approximations to ERPGs to be used until peer-reviewed toxicology-based ERPGs, AEGL or equivalents can be developed. Originally, the TEEL method used only hierarchies of published concentration limits (e.g. PEL- or TLV-TWAs, -STELs or -Cs, and IDLHs) to provide estimated values approximating ERPGs. Published toxicity data (e.g. LC_{50}, LC_{LO}, LD_{50} and LD_{LO} for TEEL-3, and TC_{LO} and TD_{LO} for TEEL-2) are included in the expanded method for deriving TEELs presented in this paper. The addition here of published toxicity data (in addition to the exposure limit hierarchy) enables TEELs to be developed for a much wider range of chemicals than before. Hierarchy-based values take precedence over toxicity-based values, and human toxicity data are used in preference to animal toxicity data. Subsequently, default assumptions based on statistical correlations of ERPGs at different levels (e.g. ratios of ERPG-3s to ERPG-2s) are used to calculate TEELs where there are gaps in the data. Most required input data are available in the literature and on CD ROMs, so the required TEELs for a new chemical can be developed quickly. The new TEEL hierarchy/toxicity methodology has been used to develop community exposure limits for over 1200 chemicals to date. The new TEEL methodology enables emergency planners to develop useful approximations to peer-reviewed community exposure limits (such as the ERPGs) with a high degree of confidence. For definitions and acronyms, see Appendix.

INTRODUCTION

The Department of Energy (DOE) and its contractor facilities perform emergency planning, including hazard evaluation and consequence analysis. To be protective of DOE facilities, employees, guests and adjacent communities, community exposure limits must be used in the emergency planning process. The DOE uses emergency response planning guidelines (ERPGs) as the community exposure limits of choice.

These ERPGs are developed using original data sources and are published annually in a peer review process conducted by the Emergency Response Planning Committee of the American Industrial Hygiene Association (AIHA).[1] The ERPGs, ERPG Document Sets and 'ERPG/WEEL Handbooks' are available from the AIHA. The ERPGs are developed by the AIHA as guidelines for use in evaluating health effects of accidental chemical releases on the general public. For specific chemicals, ERPGs are estimates of concentration ranges above which acute exposure would be expected to lead to adverse health effects (of increasing severity for concentrations at ERPG-1, ERPG-2 and ERPG-3). The ERPG Document development process results in high-quality community exposure limits that are recognized and used internationally.

The number of approved ERPGs is now ca. 90 The rate of generation of ERPGs is not fast enough to keep up with the immediate need for community exposure limits for emergency planning at DOE facilities. Furthermore, many chemicals may exist at one or two DOE sites in sufficient quantities to require com-

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munity exposure limits for emergency planning; however, these chemicals may be too obscure to ever make it onto a priority list for community exposure limit development. The DOE currently has over 1200 chemicals at its facilities for which community exposure limits have been requested for emergency planning.

Necessary adjuncts to ERPGs

Because many chemicals of interest lack ERPGs, the temporary emergency exposure limit (TEEL) methodology was developed[2] to produce temporary exposure guidance for chemicals of interest until ERPGs are available. The TEEL methodology was originally based on hierarchies of commonly available published and documented concentration-limit parameters (Table 1).

The original TEEL hierarchy methodology was approved by the DOE and has been incorporated into their Emergency Management Guidelines.[3] The TEELs are approximations to ERPGs to be used until peer-reviewed, toxicology-based ERPGs, AEGL or equivalents can be developed. The original TEEL hierarchy method has been expanded to include other published concentration limits, including National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits[4,5] (RELs), AIHA workplace environmental exposure limits[1] (WEELs), German maximum allowable concentrations[5] (MAKs), and others.[6] Because there are no published concentration limits for many chemicals, this methodology was expanded further to include the use of published toxicity parameters (LC_{50}, etc.).

Table 1. Original hierarchy of alternative concentration-limit parameters[a]

Primary guideline	Hierarchy of alternative guidelines	Source of concentration parameter
ERPG-3		AIHA 1999[1]
	EEGL (30-min)	NAS 1985[17]
	IDLH	NIOSH 1997[4]
ERPG-2		AIHA 1999[1]
	EEGL (60-min)	NAS 1985[17]
	LOC	EPA 1987[18]
	PEL-C	CFR 29:1910.1000[19]
	TLV-C	ACGIH 1999[20]
	REL-C[a]	NIOSH 1997[4,5]
	WEEL-C[a]	AIHA 1999[1]
	TLV-TWA × 5	ACGIH 1999[20]
ERPG-1		AIHA 1999[1]
	PEL-STEL	CFR 29:1910.1000[19]
	TLV-STEL	ACGIH 1999[20]
	REL-STEL[a]	NIOSH 1997[4,5]
	WEEL-STEL[a]	AIHA 1999[1]
	OTHER-STEL[a]	e.g. German, Russian[6]
	TLV-TWA × 3	ACGIH 1999[20]
PEL-TWA		CFR 29: 1910.1000[19]
	TLV-TWA	ACGIH 1999[20]
	REL-TWA[a]	NIOSH 1997[4,5]
	WEEL-TWA[a]	AIHA 1999[1]
	MAK-TWA[a]	Germany 1999[5]
	OTHER-TWA[a]	e.g. Russian[6]
	CEGL	NAS 1985[17]

[a]Parameters added since initial publication of the hierarchy methodology.[2]

Expanding the TEEL database

Emergency planners and others required community exposure limits for many chemicals without alternative published exposure limits. Because there are no published concentration limits for many chemicals (i.e. TLVs, PELs, MAKs), the original TEEL methodology was expanded further to include the use of published toxicity parameters.[7–9] The TC_{LO} and TD_{LO} values can be used to estimate TEEL-2, and LC_{50}, LC_{LO}, LD_{50} and LD_{LO} can be used (in order of availability) to estimate TEEL-3.

In using toxicity data to determine TEELs, human data are given primary consideration over animal data, and rat data are preferred over those for other species. Inhalation data are preferred over data from other routes of uptake. This hierarchy is similar to that developed by the US Department of Transportation (DOT) and other agencies in establishing protective action distances for 'the Orange Book' (properly named the 1996 North American Guide Book).[10–12]

Previous authors have developed hierarchies of exposure limits and toxicity data to be used as less precise alternatives when ERPGs do not exist.[11] The use of human equivalent concentrations has been hinted at for emergency planning by some sources.[10,11] In the absence of peer-reviewed ERPG values, the DOE SCAPA Committee on TEELs decided that the human equivalent concentration method was a useful methodology to pursue for developing TEELs.

Relationship between ERPGs and toxicity parameters

To identify a relationship between ERPGs and toxicity parameters, data were extracted for all chemicals for which ERPGs were available (77 on 31 December 1997).[13] Regressions were carried out for two sets of data:

(i) lethality data (LD_{50}, LC_{50}, LD_{LO} and LC_{LO}) and ERPG-3s;
(ii) toxicity data (TD_{LO} and TC_{LO}) and ERPG-2s.

These analyses were done for all values ($N = 77$) and then for restricted ranges of ratios ($n < 77$, to eliminate ratios considered to be outliers in the sense that they distorted the means and standard deviations of most of the data). The resulting mean ratios were rounded and applied to lethality and toxicity data for new chemicals. Ultimately, the relationship between ERPG-2 and -3 and the toxicity data allowed TEEL-3s and TEEL-2s to be calculated from the available lethality and toxicity data for chemicals lacking official ERPG values.

METHODS

Data input

For new chemicals requiring TEELs, the following data input sequence is used.

(i) The name of the chemical compound is entered on the first worksheet of the Excel workbook,[14] along with its CAS number, SAX number,[7] molecular weight (MW) and the primary units (ppm or mg m^{-3}) of available concentration limits (e.g. PELs, TLVs, ERPGs, etc.).
(ii) For each chemical, LD_{50}, LD_{LO}, TD_{LO}, LC_{50}, LC_{LO} and TC_{LO} data from SAX, RTECS or HSDB[7–9] are entered. These data include dose (mg kg^{-1}), animal species and route of administration (Rte). The lowest reported dose or concentration reported for a given parameter (e.g. TC_{LO}) is used. For TD_{LO}, gender and nature of test and the number of exposure days are entered as well.
(iii) For inhalation exposures, exposure time and whether toxic effects of the chemical are concentration dependent are also entered. When data for more than one species are available, the priority for use is human data, followed by rat, mouse and other species in that order.
(iv) The lowest reported dose or concentration reported for a given parameter (e.g. TD_{LO}) is used.
(v) Default values for mean body weight (BW in kg) and breathing rate (ABR in m^3 day^{-1}) in species tested and an adjustment factor for route of administration (RAF) are included in two separate worksheets as look-up tables (Tables 2 and 3). These RAFs are somewhat arbitrary, and are under investigation.

Table 2. Default mean body weight and breathing rate values for different species[a]

Species	Abbreviation for species (Sp)	Mean BW (kg)	Mean ABR (m^3 day^{-1})
Bird	brd	0.5	0 525
Bird—tns	brd-t	1	1.05
Bird—wild	brd-w	0 04	0 42
Child	chd	20	8 64
Chicken	ckn	0 8	0 85
Cat	ct	2	1 25
Dog	dg	10	3 66
Duck	dck	2.5	2.625
Frog	frg	0 033	1.51
Guinea pig	gp	0 5	0 283
Hamster	ham	0 125	0.1
Human/man	hmn	70	20
Infant	inf	5	2 5
Monkey	mo	5	3.94
Mouse	mu	0.025	0 035
Pig	pg	60	20
Quail	quail	1	1 05
Rat	r	0.2	0 153
Rabbit	rb	2	1 3
Women	wmn	50	16

[a]The default body weight (BW) data are from SAX.[7] The daily inhalation rates (ABR) are commonly used values for human males, females, children and infants, and laboratory animals. Similar sets of default values, for a more limited list of species, are presented by Calabrese[21] and Hayes.[22]

Table 3. Adjustment factors used for different routes of administration[a]

Route of administration	Abbreviation (Rte)	RAF
Eye	eye	0.20
Implant	imp	0.25
Inhalation	ih	0.50
Inhalation—gas/vapor	ih-g	0.50
Inhalation—particles	ih-p	0.25
Intracerebral	ice	0.50
Intradermal	idr	0.10
Intramuscular	im	0.25
Intraperitoneal	ip	0.75
Intrapleural	ipl	0.50
Intratesticular	itt	0.25
Intratracheal	it	0.25
Intravaginal	ivg	0.25
Intravenous	iv	1.00
Oral	os	0.25
Skin	sk	0.10
Skin—insoluble	sk-i	0.10
Skin—soluble	sk-s	0.20
Subcutaneous	sc	0.10
Unknown	uk	0.25

[a]The route of administration adjustment factors (RAF) presented are rough estimates used to account partially for the differences between administered dose and absorbed dose. In practice, these values would be expected to vary from chemical to chemical, depending upon solubility in body fluids, metabolic changes and other factors The RAFs for inhaled material are used only when data are given in dose units (mg kg^{-1}).

Calculations

All subsequent Excel worksheets to calculate TEELs based on toxicity data are linked to the data entered (above) on the first worksheet. The TEELs are established as follows:

(i) If possible, hierarchy-based TEELs are first calculated by direct application of the hierarchy methodology[2] to the chemicals for which concentration limits are required (when the hierarchy method can be applied, i.e. alternative exposure limits exist).
(ii) Minimum values (i.e. hierarchy-based values below which subsequently calculated toxicity-based TEEL-2s or TEEL-3s must not fall) are calculated because it would be inappropriate for TEEL-2, for example, to be less than TEEL-1. Factors used to convert ppm units to mg m^{-3} at 25°C and 760 mmHg for use in subsequent worksheets are computed next, followed by toxicity-based TEELs.
(iii) Dose data (in mg kg^{-1}) are first converted to concentrations (in mg m^{-3}) by applying simple mean body weight and breathing rate (Table 2) and route of intake adjustment factors (Table 3) to account for differences in uptake from different routes of exposure.
(iv) For repeated TD_{LO} dose data, the published mg kg^{-1} dose is divided by the number of exposure days before conversion to a human-equivalent concentration.

(v) Concentration data from these calculations, or from inhalation exposure data, LC_{50}, LC_{LO} or TC_{LO} if available, are converted to human-equivalent LC_{50}, LC_{LO} and TC_{LO} values[14] in mg m^{-3}.

(vi) No route of administration adjustment is used when input data are in concentration units (i e. ppm or mg m^{-3}).

(vii) A judgement must be made as to whether toxic consequences of exposure to a particular chemical are concentration dependent (Y) or exclusively dose dependent (N). Any chemicals for which there are short-term concentration limits similar to PEL-STEL, TLV-STEL, PEL-C or TLV-C are assumed to have concentration-dependent toxic consequences. When repeated TC_{LO} inhalation exposure data are used, the daily exposure concentration is used. All toxic concentration data are reduced to a 15-min exposure time. If the exposure time is not given, 15 min is assumed for concentration-dependent chemicals and 60 min is assumed for dose-dependent chemicals.[14] The concentration adjustment is made as follows:

$$C_{adj} = C \times (t_{exp}/t)^n$$

where C = reported or calculated concentration for the specific endpoint (e.g LC_{50}, LC_{LO}, TC_{LO}, etc.), t_{exp} = reported exposure time, t = 15 min and n = 0.5 for concentration-dependent chemicals (Y) and 1.0 for exclusively dose-dependent chemicals (N).

(viii) Toxicity-based TEEL-2s are calculated using mean ratios of the human-equivalent concentrations for TC_{LO} and TD_{LO} data (in order of availability) to ERPG-2s.

(ix) Toxicity-based TEEL-3s are calculated using mean ratios of the human-equivalent concentrations for LC_{50}, LC_{LO}, LD_{50} and LD_{LO} data (in order of availability) to ERPG-3s (Table 4).

The mean ratios were calculated between matched pairs of toxicity and ERPG data, resulting in correlations for all chemicals having official ERPGs. These correlations were calculated for matched pairs of ERPG values and the following toxicity parameters:

(i) All LC_{50}, LD_{50} and TD_{LO} data and corresponding rat-only data.

(ii) All LC_{LO}, LD_{LO} and TC_{LO} data and corresponding human-only data

Correlations were conducted on all matched pairs and then repeated for pairs within arbitrarily selected ratio ranges to eliminate outliers. A trial-and-error procedure was used to maximize the number of data pairs and to minimize the coefficient of variation of the mean ratios in restricting the ratio ranges.

For some chemicals, data are not available to develop a full set of TEEL values. For these cases, default ratios are used to estimate the 'missing' TEEL value from the existing TEELs above or below it. The default ratios were derived as follows. Ratios of all existing ERPG-2 to ERPG-1 values, and ERPG-3 to ERPG-2 values, were calculated. The means, standard deviations and coefficients of variation of these ratios were calculated. This analysis was conducted for all available ratios (N), and then repeated after eliminating some extreme outlier ratios (n, where $n < N$). The mean ratio of ERPG-2 to ERPG-1 was used to estimate TEEL-1s from TEEL-2s if no hierarchy-based TEEL-1 was available. The mean ratio of ERPG-3 to ERPG-2 was used to estimate TEEL-2s from TEEL-3s, or vice versa, if there were neither hierarchy-based nor toxicity-based TEEL-2 or TEEL-3 values.

Procedure-based TEELs result from selection of hierarchy-based values first, followed by toxicity-based TEEL-2 and TEEL-3 values, followed by default values in the absence of either hierarchy-or toxicity-based TEELs. Procedure-derived TEELs at all levels (i.e. TEEL-0, TEEL-1, TEEL-2 and TEEL-3) are calculated next. The raw numbers are rounded down to factors of ten of 1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 3 5, 4.0, 5.0, 6.0 and 7.5, unless the value is within 5% of the next highest value, in which case it is rounded up (e.g. 290 would become 300, not 250). Procedure-based TEELs are adjusted to recommended TEELs to ensure that there are no blanks, and that all TEELs are at least equal to the previously calculated minimum hierarchy-based values, i.e.

$$\text{TEEL-3} \geq \text{TEEL-2} \geq \text{TEEL-1} \geq \text{TEEL-0}$$

It also reduces all TEEL values for materials in aerosol form (mg m^{-3} units) to a maximum of 500 mg m^{-3}.

RESULTS

The mean ratio of ERPG-2 to ERPG-1 was determined to be ca. 7. This ratio is used to estimate TEEL-1s from TEEL-2s when no hierarchy-based TEEL-1 is available. The mean ratio of ERPG-3 to ERPG-2 was determined to be ca. 5; this ratio is similarly used to estimate TEEL-2s from TEEL-3s, or vice versa, if there are neither hierarchy-based nor toxicity-based TEEL-2 or TEEL-3 values.

The TEEL rounding protocol is similar to that used by others (OSHA, ACGIH and AIHA). The maximum TEEL value of 500 mg m^{-3} is the upper limit of stability for an aerosol.

Results of statistical analysis of the available toxicity and ERPGs are presented in Table 4. All available LC_{50} data are plotted against ERPG-3s for these chemicals in Fig. 1. Using only the restricted-range data, mean ratios of TC_{LO} to ERPG-2s were ca. 15 for all the data and 10 for the human data only. Mean ratios of TD_{LO} to ERPG-2s were ca. 1.5 for all the data and ca. 1 for rat data only. The results were rounded and used to estimate TEEL-2 values.

Mean ratios of LC_{50} to ERPG-3s were ca. 100 for all the data and for rat data. Mean ratios of LC_{LO} to ERPG-3s were ca. 100 for all the data and 50 for the human data. Mean ratios of LD_{50} to ERPG-3 for all the data and for rat data were both <2, whereas mean ratios of LD_{LO} to ERPG-3s for all data and for human data were both close to unity. The results were rounded and used to estimate TEEL-3 values.

The rounded mean ratios of human-equivalent toxicity parameters to ERPG-2s (toxicity) and to ERPG-3s (lethality) are summarized in Table 5. A sample of

Table 4. Results of statistical correlations between human-equivalent toxicity parameters and ERPGs[a]

Regression parameters		$n = N$ (data from all matched pairs)				$n < N$ (restricted ratio range data)			
Limit	Toxicity	Data	N	Mean	r	Range	n	Mean	r
ERPG-3	LD_{50}	All	55	19.4	0.41	10–0.01	43	1.32	0.74
	LD_{50}	Rat	48	21.7	0.41	10–0.01	37	1.30	0.74
	Log LD_{50}	All	55		0.53	10–0.01	43		0.77
	Log LD_{50}	Rat	48		0.51	10–0.01	37		0.74
ERPG-3	LD_{LO}	All	40	29.7	0.05	5–0.005	35	0.771	0.69
	LD_{LO}	Human	18	1.82	0.84	5–0.005	16	0.570	0.89
	Log LD_{LO}	All	40		0.36	5–0.005	35		0.59
	Log LD_{LO}	Human	18		0.53	5–0.005	16		0.68
ERPG-3	LC_{50}	All	67	666	0.72	500–5	55	109	0.84
	LC_{50}	Rat	55	747	0.72	500–5	46	107	0.84
	Log LC_{50}	All	67		0.79	500–5	55		0.93
	Log LC_{50}	Rat	55		0.81	500–5	46		0.94
ERPG-3	LC_{LO}	All	39	302	0.35	250–2.5	28	68.0	0.71
	LC_{LO}	Human	18	79.0	−0.02	250–2.5	13	43.6	0.75
	Log LC_{LO}	All	39		0.70	250–2.5	28		0.90
	Log LC_{LO}	Human	18		0.72	250–2.5	13		0.84
ERPG-2	TD_{LO}	All	31	17.9	0.37	15–0.15	20	1.49	0.46
	TD_{LO}	Rat	16	30.4	−0.05	15–0.15	8	0.700	0.35
	Log TD_{LO}	All	31		0.56	15–0.15	20		0.86
	Log TD_{LO}	Rat	16		0.24	15–0.15	8		0.83
ERPG-2	TC_{LO}	All	36	1431	0.02	150–0.15	26	16.0	0.12
	TC_{LO}	Human	30	1696	0.01	150–0.15	22	6.05	0.25
	Log TC_{LO}	All	36		0.38	150–0.15	26		0.80
	Log TC_{LO}	Human	30		0.36	150–0.15	22		0.88

[a] N = total number of data points for the parameter of interest; n = number of data points within the stated range (this was obtained by eliminating a few ratios judged to be outliers, in the sense that these data points grossly distorted the mean of the majority of the data); r = correlation coefficient for $Y = mX + b$, where X = ERPG-2, ERPG-3, log ERPG-2, or log ERPG-3, Y = stated toxicity parameter or log of toxicity parameter and $b = 0$

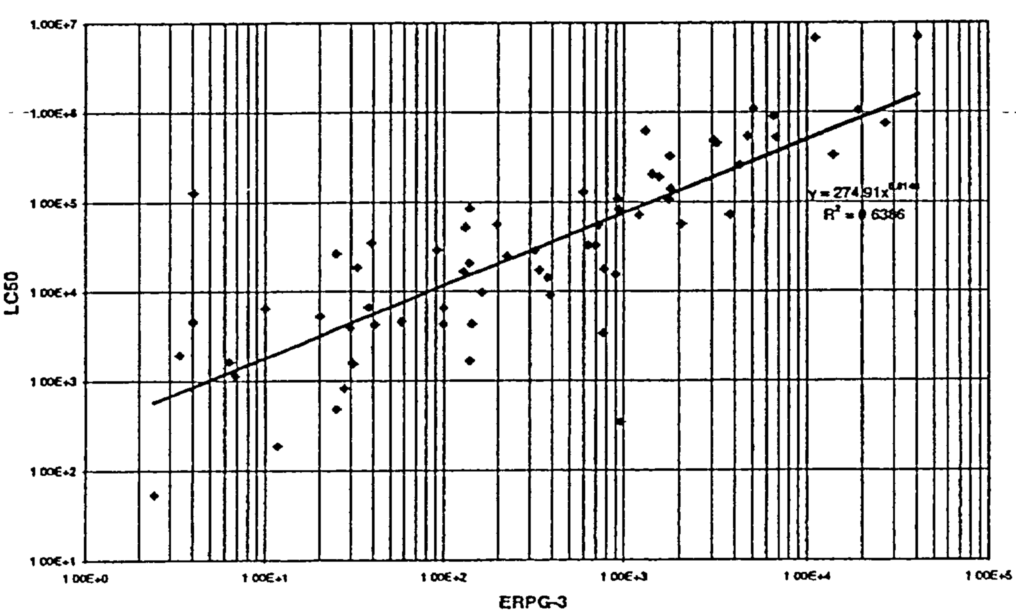

Figure 1. The LC_{50} data versus ERPG-3.

Table 5. Adjustment factors to derive toxicity-based TEELs from human-equivalent toxicity concentration values

Species	ERPG-3				ERPG-2	
	LC_{50}	LC_{LO}	LD_{50}	LD_{LO}	TC_{LO}	TD_{LO}
Human only	—	50	—	1	10	—
Rat only	100	—	2	—	—	1
All data	100	100	2	1	15	15

the input and output for five chemicals for which differing input data are available is included in Tables 6 and 7, respectively.

The TEELs for 1251 chemicals, including 77 for which 'official' ERPGs had been published,[1] are included in the document WSMS-SAE-99-0001, dated 4 January 1999. This document is available on the DOE (Department of Environment, Safety and Health) Chemical Safety home page, *http://tis-hq.eh.gov/web/chem_safety/*, under 'Documents'. The methodology described above was applied to develop TEELs for all these chemicals.

DISCUSSION

The published[2] hierarchy methodology for deriving TEELs is in use and is included in the United States Department of Energy Emergency Management Guidelines.[3] The toxicity-based procedure described was developed because of the lack of existing concentration limits for many of the chemicals for which acute exposure limits are required. Further default procedures, such as the determination of ratios of ERPG and TEEL levels, were developed to fill in the remaining gaps in the recommended TEELs.

Regarding data selection, if there are data for the same parameter (e.g. LC_{LO}) for more than one species, human data are used first, followed by rat data, mouse data and data for other species in order. The reason for this choice is that there is far more rat and mouse toxicity data than are available for other animal species.

The selection of route adjustment factors (RAFs) is based on professional judgement. For example, intravenous (i.v.) administration has been assumed to have an RAF of 1.00, because the material is injected directly into the bloodstream, whereas oral administration (o.s.) has been assigned an arbitrary RAF value of 0.25 (Table 3).

It is recognized that the conversion of animal toxicity data to human-equivalent concentrations is controversial. Mean ratios of animal-equivalent concentrations for LD_{50}, LD_{LO} and TD_{LO} data (or animal concentration data for LC_{50}, LC_{LO} and TC_{LO}) could have been computed instead. This would actually simplify the computation slightly, but should not affect significantly the toxicity-based TEELs. Because the TEEL procedure is based on the computed mean ratios of human-equivalent concentrations to existing ERPGs it does not really matter.

The treatment of exposure time in the development of TEELs bears further explanation. Consideration must be given to whether the toxic consequences of exposure to a chemical may be concentration dependent (e.g. hydrogen sulfide), dose dependent (e.g. quartz) or both (e.g. benzene). In effect, the procedure described in this paper uses Haber's Law[15] ($C \times t = K$, where C is concentration, t is exposure time and K is a constant) for all chemicals for which toxic consequences are *exclusively* dose dependent.

For all other chemicals, rather than use the ten Berge[16] equation ($C^n \times t = K$, where n is a chemical-dependent exponent that lies in the approximate range 0.8–4), a decision was made to reduce the influence of exposure time t for concentration-dependent chemicals. Besides the fact that the exponent n would not be known for virtually all the chemicals to which the TEEL methodology would be applied, it is felt that for those chemicals for which toxic effects are concentration dependent it is the influence of time, not concentration, that needs to be adjusted.

CONCLUSIONS

The TEEL determination process (for TEEL-2 and TEEL-3) selects hierarchy-based values first, if available (e.g. TLV, PEL, etc.), followed by toxicity-based values (e.g. TC_{LO} and TD_{LO} for TEEL-2, or LC_{50}, LC_{LO}, LD_{50} and LD_{LO} for TEEL-3). However, human toxicity data take precedence over animal data, overriding the order of toxicity-parameter selection. The inhalation data cover a range of exposure times. Although acute exposure data (i.e. exposure times up to 4 h) are preferred, longer term exposure data are used if there are no acute exposure data. The TEEL hierarchy and toxicity methodology is listed in Table 8.

The software program described above calculates TEELs from these data and the default ERPG ratios. This methodology has been applied successfully to nearly 1200 chemicals lacking ERPGs. Most of the required input data parameters are already available on CD-ROMs. Application of the methodology to develop temporary emergency exposure limits requires only that data be entered on the first worksheet of the Excel workbook. These data are used to produce procedure-derived TEELs.

The work described greatly expands the number of chemicals for which TEELs can be derived, and its application will ensure consistency of TEEL values from one DOE site to another. It should be emphasized that TEELs are default, temporary, emergency exposure limits. They are derived using the methodology summarized in this paper, and are intended for use only until official acute exposure guidance levels are provided by the EPA, or ERPGs are published by the AIHA. Although TEEL-1, TEEL-2 and TEEL-3 have the same definitions as ERPG-1, ERPG-2 and ERPG-3, TEELs are not equivalent to ERPGs but are approximations. The latest revision of the recommended TEEL list is available on the DOE (Department of Environment, Safety and Health) Chemical Safety home page: *http://tis-hq.eh.gov/web/chem_safety/*, under 'Documents'.

Table 6. Input data for the calculation of TEELs[a]

No	Chemical compound	CAS no.	SAX no	MW	Units of limits
1	Chemical with ERPGs	00107-13-1	ADX500	53 07	ppm
2	Chemical with toxicity data only	00105-60-2	CBF700	115.18	mg m^{-3}
3	Chemical with HT-3, toxicity data, no HT-2	00140-88-5	EFT000	100.13	ppm
4	Chemical with no HTs and only LC_{50} data	28182-81-2	HEG300		mg m^{-3}
5	Chemical with HT-2 and some toxicity data	01310-65-2	LHI100	23.95	mg m^{-3}

	TEEL-0						TEEL-1						
	Time-weighted average concentration (TWA)							Short-term exposure limit (STEL)					3 × TLV
	PEL	TLV	REL	WEEL	Other	Note	ERPG-1	PEL	TLV	REL	WEEL	Other	TWA
1 ERPGs	2	2	1				10						
2 Tox data only		1	1		5	MAK			3	3			
3 HT-1, -3, tox data	25	5			5	MAK			15				
4 No HTs, LC_{50}													
5 HT-2, some tox													

	TEEL-2								TEEL-3		
	ERPG–2	EEGL	EPA	15-min celing concentration				5 × TLV	ERPG-3	EEGL	
		60 min	LOC	PEL	TVL	REL	WEEL	TWA		30 min	IDLH
1 ERPGs	35		50	10					75		85
2 Tox data only											
3 HT-1, -3, tox data											300
4 No HTs, LC_{50}											
5 HT-2, some tox							1				

	LD_{50}			LD_{LO}			TD_{LO}				
	Dose (mg kg^{-1})	Spec	Rte	Dose (mg kg^{-1})	Spec	Rte	Dose	Spec	Rte	Gender, exp. type	Days
1 ERPGs	78	r	os	2015	chd	sk	650	r	os	f, post	10
2 Tox data only	930	r	os	800	r	Ip					
3 HT-1, -3, tox data	800	r	os	1800	r	sk	51500	r	os	2yr-I	260
4 No Hts, LC_{50}											
5 HT-2, some tox				200	mu	os					

	LC_{50}				LC_{LO}			
	Dose (ppm)	Dose (mg m^{-3})	Spec	Exp. T (min)	Dose (ppm)	Dose (mg m^{-3})	Spec	Exp T (min)
1 ERPGs	425		r	240		1000	hmn	60
2 Tox data only		300	r	120				
3 HT-1, -3, tox data	2180		r	240	1204		rb	420
4 No Hts, LC_{50}		18500	r	60				
5 HT-2, some tox		960	r	240				

	TC_{LO}								Toxicity is concentration-dependent
	Dose (ppm)	Dose (mg m^{-3})	Spec	Exposure regimen: Year	Week	Day	min	Exp. T (min)	
1 ERPGs	16		hmn				20	20	Y
2 Tox data only		212	hmn					15	Y
3 HT-1, -3, tox data	50		hmn					15	Y
4 No Hts, LC_{50}									Y
5 HT-2, some tox									Y

[a]HT = hierarchy-based TEEL.
2yr-I, I = intermittent

Table 7. The TEELs calculated from the input data in Table 6[a]

No	Chemical	CAS no.	Recommended TEELs				Units of original limits
			TEEL-0	TEEL-1	TEEL-2	TEEL-3	
1	ERPGs	00107-13-1	2	10	35	75	ppm
2	Tox data only	00105-60-2	1	3	3	20	mg m^{-3}
3	HT-1, -3, tox data	00140-88-5	15	15	15	300	ppm
4	No Hts, LC_{50}	28182-81-2	7.5	25	200	500	mg m^{-3}
5	HT-2, some tox	01310-65-2	0 05	0 15	1	100	mg m^{-3}

[a]HT = hierarchy-based TEEL.

Table 8. The TEEL hierarchy and toxicity methodology[a]

Primary guideline	Hierarchy of alternative guidelines	Source of concentration parameter
ERPG-3		AIHA 1999[1]
	EEGL (30-min)	NAS 1985[17]
	IDLH	NIOSH 1997[4]
	LC_{50}	a
	LC_{LO}	a
	LD_{50}	a
	LD_{LO}	a
ERPG-2		AIHA 1999[1]
	EEGL (60-min)	NAS 1985[17]
	LOC	EPA 1987[18]
	PEL-C	CFR 29:1910 1000[19]
	TLV-C	ACGIH 1999[20]
	REL-C[b]	NIOSH 1997[4,5]
	WEEL-C[b]	AIHA 1999[1]
	TLV-TWA × 5	ACGIH 1999[20]
	TC_{LO}	a
	TD_{LO}	a
ERPG-1		AIHA 1999[1]
	PEL-STEL	CFR 29 1910 1000[19]
	TLV-STEL	ACGIH 1999[20]
	REL-STEL[b]	NIOSH 1997[4,5]
	WEEL-STEL[b]	AIHA 1999[1]
	OTHER-STEL[b]	e g. German, Russian[6]
	TLV-TWA × 3	ACGIH 1999[20]
PEL-TWA		CFR 29:1910 1000[19]
	TLV-TWA	ACGIH 1999[20]
	REL-TWA[b]	NIOSH 1997[4,5]
	WEEL-TWA[b]	AIHA 1999[1]
	MAK-TWA[b]	Germany[5]
	OTHER-TWA[b]	e g. Russian[6]
	CEGL	NAS 1985[17]

[a]See complete discussion in text regarding the use of toxicity parameters for deriving TEELs
[b]Hierarchy parameters added since publication of the original hierarchy methodology [2]

Further technical reports and applications literature describing this methodology[8] are available on the DOE SCAPA Home Page: *http://www.scapa.bnl.gov.*

APPENDIX

Definitions

Definitions for the different temporary emergency exposure limits (TEELs) are based on those for emergency response planning guidelines (ERPGs).

ERPG-1. The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2. The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3. The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing life-threatening health effects.

TEEL-0. The threshold concentration below which most people will experience no appreciable risk of health effects.

TEEL-1. The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

TEEL-2. The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3. The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

Exposure time. It is recommended that, for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-min time-weighted average concentration. It should be emphasized that TEELs are default values, following the published methodology explicitly. The only judgement involved is that exercised in the extraction of data used to calculate the recommended TEELs.

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
BW	body weight of exposed species (kg)
BR	breathing rate of exposed species (m^3 day^{-1})
C	ceiling limit
CAS	Chemical Abstract Services registry number
CEGL	NAS continuous exposure guidance level
CFR	US Code of Federal Regulations
DOE	US Department of Energy
EEGL	NAS emergency exposure guidance level
EPA	US Environmental Protection Agency
ERPG	AIHA emergency response planning guideline
HT	hierarchy-based TEEL
HT-2	hierarchy-based TEEL-2
HT-3	hierarchy-based TEEL-3
IDLH	NIOSH immediately dangerous to life or health
LOC	EPA level of concern
LD_{50}	lethal dose to 50% of the exposed population (in mg kg^{-1} body weight)
LD_{LO}	lowest dose at which mortality is observed in exposed population (mg kg^{-1})
TD_{LO}	lowest dose at which toxicity is observed in exposed population (mg kg^{-1})
LC_{50}	lethal concentration to 50% of the exposed population (in mg m^{-3} or ppm)
TC_{LO}	lowest concentration at which mortality is observed in exposed population (mg m^{-3} or ppm)
LC_{LO}	lowest concentration at which toxicity is observed in exposed population (mg m^{-3} or ppm)
MAK	Germany maximum allowable concentration
NAS	US National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
OSHA	US Occupational Safety and Health Administration
PEL	OSHA permissible exposure limit
RAF	route adjustment factor
REL	NIOSH recommended exposure limit
SAX	Name of reference book 'SAX's Dangerous Properties of Industrial Materials'[7]
SCAPA	US DOE Subcommittee on Consequence Assessment and Protective Actions
STEL	short-term exposure limit
TEEL	SCAPA temporary emergency exposure limit
TLV	ACGIH threshold limit value
TWA	time-weighted average
WEEL	AIHA workplace environmental exposure limit

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No ERPG? Use a TEEL!
TEELs Provide Guidance When ERPGs Unavailable

Community exposure limits are essential components of emergency planning and emergency management for accidental releases of chemicals.

Emergency Response Planning Guidelines (ERPGs) are the most widely used and accepted community exposure limits at this time. ERPGs are developed through a peer-review process established by the American Industrial Hygiene Association (AIHA), and this review process has been validated by outside scientific agencies.

Unfortunately, many emergency planners have to perform hazard and consequence assessments for chemicals without ERPGs. For considering these chemicals in emergency planning at its sites, the DOE Emergency Management Advisory Committee's Subcommittee on Consequence Assessment and Protective Action (SCAPA) has developed Temporary Emergency Exposure Limits (TEELs). SCAPA was established to assist DOE's Director of Emergency Management by providing technical recommendations (radiological and nonradiological) in areas related to the health and safety of workers and the public.

Why TEELs Were Developed

To establish a system for conducting consistent emergency planning for chemicals at DOE facilities whether or not ERPGs are available, SCAPA developed the TEELs as an interim method. TEELs allow for the preliminary identification of hazardous or potentially hazardous situations for emergency planning.

The DOE Emergency Management Guide (EMG) calls for the use of TEELs when ERPGs are not available. Figure 1 shows the relationship of ERPGs and TEELs to the process for developing emergency management programs. The EMG is available on-line at http://www.explorer.doe.gov:1776/htmls/directives.html.

SCAPA recognizes the validity (and preferability) of peer-reviewed ERPG values, and TEELs are only used when ERPGs do not exist. Simply put, TEELs represent a linear regression best-fit hierarchy of alternatives to

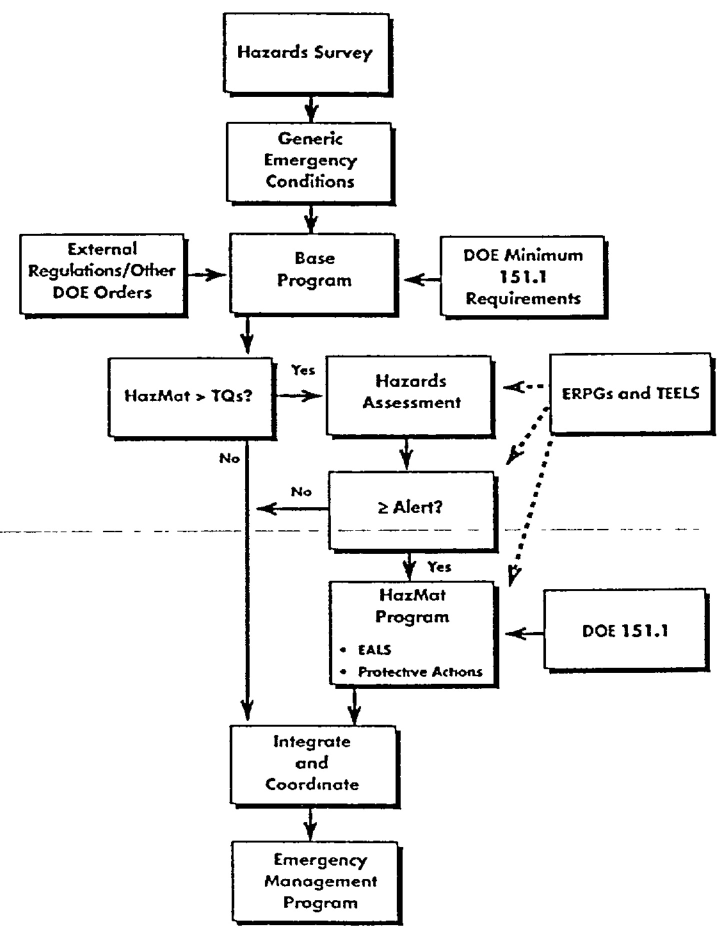

Figure 1. DOE Emergency Planning: ERPGs and TEELS

Please fax comments, suggestions, or questions regarding On Track *or* Clear Signals *to Tom Tuccinardi at 301-903-5114.*

ERPGs. The TEEL hierarchy uses occupational exposure limits (PELs, TLVs, etc.) and toxicity-based data (for example, TD_{LO}, TC_{LO}, LD_{50}, LC_{50}, LD_{LO}, and LC_{LO}) to derive TEELs. (Acronyms are listed at the end of this article.)

The TEEL: A Temporary Guideline

Whenever an ERPG is developed for a new chemical, the ERPG replaces the TEEL in emergency planning for that chemical because TEELs are subordinate to ERPGs. TEELs allow emergency planners to perform consequence assessments for chemicals for which there may never be ERPGs (i.e., for chemicals that may not be in wide enough use to be reviewed by the American Industrial Hygiene Association Emergency Response Planning Committee).

Using TEELs

The Environmental Protection Agency has recently published its Risk Management Program (RMP), which provides guidance to the public with respect to planning for emergency releases. This guidance, like the DOE EMG, mandates the use of ERPGs when available. TEELs are a temporary solution for the compliance process when ERPGs do not exist.

Advantages and Disadvantages

There are advantages and disadvantages in using TEELs. The main disadvantage in using a TEEL for emergency exposure planning is that the TEEL is a formulaic derivation of an ERPG value rather than a peer-reviewed, chemical-specific, community exposure limit value that includes the toxicological nuances of the chemical in question. The TEEL is an interim parameter meant to approximate an ERPG so that emergency planning and preparedness activities can be conducted.

The main advantage of using TEELs is that they allow the emergency planner to perform emergency planning within reasonable limits for the many chemicals not having ERPGs.

How to Get TEELs

To get more information on ERPGs, SCAPA, or TEELs, call Doan Hansen at 516-344-7535 or e-mail doan@bnl.gov. To get the comprehensive manuscript deriving TEELs, go to the SCAPA Web page at http://www.sep.bnl.gov/scapa.

To get detailed information on TEELs, including the current list of TEELs, call Doug Craig at 803-502-9640, e-mail doug.craig@wxsms.com, or go to http://tis- hq.eh.doe.gov/web/chem_safety/.

Acronyms

LC_{LO}	Lowest lethal concentration
LC_{50}	Concentration lethal to 50% of test animals
LD_{LO}	Lowest lethal dose
LD_{50}	Dose lethal to 50% of test animals
PEL	Permissible Exposure Limit
TC_{LO}	Lowest toxic concentration
TD_{LO}	Lowest toxic dose
TEEL	Temporary Emergency Exposure Limit
TLV	Threshold Limit Value

Quick Reference: Web Pages

DOE EMGs:
http://www.explorer.doe.gov:1776/htmls/directives.html

DOE SCAPA:
http://www.sep.bnl.gov/scapa

DOE SCAPA TEELs:
http://tis-hq.eh.doe.gov/web/chem_safety/

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DCS-NRC MEETING ON CRITICALITY SAFETY DSER OPEN ITEMS

16 Jan 2003
NRC Offices

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Agenda

- DSER Criticality Safety Open Items
  - NCS-1:Pu/MOX Experience
  - NCS-2:Auxiliary Systems
  - NCS-3:Bounding Densities
  - NCS-4:USL, Admin Margins, Validation Reports
  - NCS-5:Definition of Highly Unlikely
  - NCS-6:ANS-8.1,Meaning of "Other justification"
  - NCS-7:Closed
  - NCS-8:ANS-8.17,Meaning of "Other justification"
- NRC questions on revised CAR

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NCS-1 (1 of 2)

- **"The need for specific Pu/MOX experience for NCS staff involved in the design phase"**
- DCS team includes COGEMA and subsidiary SGN
  - Over 20 years Pu and MOX experience
  - Senior DCS/SGN personnel have over 5 years Pu/MOX experience including experience at LaHague and MELOX facilities
- US team includes individuals with over 3 years Pu/MOX experience as a result of the MFFF project as well as many years of criticality safety experience in LEU and HEU facilities
- There is no fundamental difference in neutron physics or evaluation techniques between Pu/MOX and LEU/HEU. Small differences are more than accounted for, given the DCS COGEMA and SGN resources.

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NCS-1 (2 of 2)

- 10 CFR 70 is silent on the specific need for criticality safety personnel with specific Pu/MOX experience
- NUREG-1718 (SRP) and applicable guidance (ANS-8.x series) does not specifically contain such requirements
- Accordingly, consistent with applicable regulation and available guidance and precedent, DCS has not identified a specific commitment to isotope-specific experience.
- DCS has committed extensively in the CAR to criticality safety experience as required in regulations and guidance.
- These commitments, coupled with the extensive experience of personnel performing the DCS criticality safety function, should support a favorable NRC Staff conclusion regarding NCS qualification and experience.

NCS-2

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- **"Definition of NCS design basis controlled parameters for AP and MP process auxiliary systems (specifically including process ventilation, isotopic dilution, and high-alpha waste)"**
- Tables 6-1 and 6-2 are preliminary design details information for principle units. All applicable units to be evaluated in NCSEs.
- However, Tables 6-1 and 6-2 have been updated in the revised CAR to provide more detail, to clarify isotopic dilution (i.e., to show the units where isotopic dilution occurs), and to add discussion of the high-alpha waste auxiliary systems.
- The ventilation system will be included in a facility-wide auxiliary system NCSE and is therefore not listed as a principle unit.
- Other systems such as chemical and water additions will be treated also in the auxiliary systems NCSE and are not listed as principle units.

NCS-3 (1 of 2)

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- **"Justification for the bounding density values assumed in Tables 6-1 and 6-2"**
- Tables 6-1 and 6-2 are preliminary design details information for principle units. All applicable units to be evaluated in NCSEs.
- However, CAR has been revised to incorporate justification in Table 6-1 footnote ([10])
- In AP units (Table 6-1), lead-in units are evaluated at maximum theoretical density (11.46 g/cc).
- AP units shown with lower densities (e.g., 7 g/cc) take advantage of upstream direct measurements of density.
- AP units shown with lower densities (e.g. 3.5 g/cc) have been shown to be conservative for identical operations at the Cogema La Hague facility; these values will be confirmed during startup testing.
- Final AP densities will be confirmed by measurements.

NCS-3 (2 of 2)

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- For MP process units (Table 6-2), CAR has also been revised to incorporate justification in Table 6-2 footnote ([6]).
- As noted on previous slide, the incoming MP density is controlled to a maximum value of 3.5 g/cc.
- MP densities downstream of the incoming MP material have been shown to be bounding by direct measurement in a sampling program of identical operations in the MELOX facility.
- These values will also be confirmed during MFFF startup testing program.

NCS-4 (1 of 4)

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- **"Determination of Design Basis USLs for each process type, and justification for the administrative margin; description of sensitivity methods to be provided in Part III of the Validation Report"**
- Validation reports present "Justification of Administrative Margin" for using admin margin of 0.05.
- The justification is based on a comparison against administrative margin practices at both NRC and DOE facilities, past NRC guidance and practice, and substantiated by a statistical analysis of the benchmark validation results.
- NRC has requested DCS provide justification why the proposed margin is acceptable for normal conditions, or why it is appropriate to base a single k_{eff} limit on the limit for abnormal conditions. Further, NRC has requested DCS describe which other NRC-regulated facilities are most similar to the MFFF for the purpose of setting subcritical margin and justify why.

NCS-4 (2 of 4)

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- The purpose of a minimum subcritical margin is to ensure that calculated keff values are adequately subcritical based on the validation of the code to applications within one or more specific areas of applicability.
- Per NUREG/CR-6698, "...the subcritical margin is not intended to account for process upset conditions or for uncertainties associated with a process."
- Design uncertainties, operational concerns, and the ability to control the criticality controlled parameters below the subcritical limits are all part of the accident evaluation for all credible criticality event sequences considered for double contingency and highly unlikely determination.
- The criticality event sequence analyses inherently consider operating margin for determining highly unlikely.

NCS-4 (3 of 4)

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- For instance, if a subcritical mass value is calculated for a system, and compliance with that mass limit is controlled by less than a "highly unlikely to fail" set of controls, additional operating margin in the mass parameter would be necessary to ensure that multiple failures are necessary to ensure that a criticality is highly unlikely.
- Conversely, if the set of controls used to limit the mass parameter value are highly unlikely to fail, then additional safety margin is not necessary.
- The determination of the criticality controlled parameter limits for normal operation are based on the amount of operating margin necessary to demonstrate highly unlikely and not based on an arbitrary additional k_{eff} margin.
- For the MFFF, double contingency, in most cases, is based on 2 controls or barriers to prevent a change in one controlled parameter. A loss of one of these controls or barriers does not cause a change in the controlled parameter and therefore does not change the k_{eff} value.

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NCS-4 (4 of 4)

- DCS is only similar to other fuel licensees (BWXT and NFS) when comparing types of material processed (high enriched U vs. Pu and MOX). DCS does not have sufficient insight into other licensees manufacturing processes to do a meaningful comparison of operating margin.
- The MFFF uses highly reliable, automated manufacturing processes with limited human interaction thereby minimizing the potential for a process upset leading to an accidental criticality. Regardless of the type of process used, all credible accident sequences will be considered for all manufacturing processes and will be shown to have DCP and be highly unlikely to occur.
- Therefore, a subcritical margin of 0.05 can be used to show that all processes used in the MFFF will remain sufficiently subcritical during normal operations and credible abnormal conditions. An evaluation of all credible accident sequences will demonstrate that it is highly unlikely to have a criticality in the MFFF because appropriate controls and barriers (maintained as IROFS) are in place and functional.

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NCS-5 (1 of 4)

- **"The definition of 'highly unlikely' for criticality hazards"**
- Section 5.4.3 was updated to reflect the additional details discussed above, and to be consistent with the Staff agreements surrounding the response to RAI 39.
  - Application of the single failure criterion or double contingency principle
  - Application of 10 CFR 50 Appendix B, NQA-1
  - Application of codes and standards
  - Management measures including IROFS failure detection
- Analyses conducted as part of the ISA process, which will demonstrate that the application of DCS' commitments provide for effective qualitative demonstration of meeting the highly unlikely threshold.
- The analyses
  - Verify that the double contingency principle is effectively applied,
  - Verify that there are no common mode failures,
  - Verify that the IROFS will be effective in performing their intended safety function,
  - Verify that the conditions that the IROFS will be subjected to will not diminish the reliability of the IROFS, and
  - also identify and verify appropriate IROFS failure detection methods
- Specifically, NCSEs will contain the following:

NCS-5 (2 of 4)

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Item 1. For each event for which a potential criticality is credible, the following will be described and analyzed to demonstrate adherence to the DCP:

a) Description of the potential event
b) Control challenge
c) Methods of prevention
d) Listing of potential initiating event
e) At least two independent IROFS controls to prevent the event including the safety functions of the controls
f) Description of redundancy and diversity
g) Description of safety margin involved
h) Description of failure mode, detection of failure, and surveillance methods

NCS-5 (3 of 4)

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Item 2: For each IROFS control identified in item 1 above, the following will be described :

a) Description of the IROFS control
b) Listing of the safety functions for the control
c) Quality classification (e.g., QL-1a or QL-1b)
d) Process Operating Range and Limits
e) Emergency Capabilities
f) Testing and Maintenance
g) Environmental Design Factors, as applicable.
h) Natural Phenomena Response
i) Instrumentation and Controls required
j) Applicable Codes and Standards

The NCSEs will reference/summarize analyses, as necessary, that demonstrate that the IROFS are effective and perform the intended function

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NCS-5 (4 of 4)

Item 3. For each event for which a potential criticality is credible as described in item 1, the event will be shown to be highly unlikely as follows:

a) Cross correlation with the events as described in item 1 including description of the initiating event,

b) Summary description of each of the IROFS controls with cross reference to the IROFS information (item 2 above),

c) Description and justification of the un-likeliness of failure of each of the IROFS,

d) Description of failure detection or safety margin involved providing justification that the potential event is highly unlikely to occur.

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NCS-6

- **"For ANSI/ANS-8.1-1983 (R1988): What is meant by 'other justification' in the means for extending the code's area(s) of applicability beyond experimental data"**
- CAR section 6.4 has been revised to indicate (with respect to section 4.3.2 of this standard) that, in cases where an extension in the area(s) of applicability of a NCS analysis methodology is required, the method will be supplemented by other methods to provide a better estimate of bias in the extended area(s). As an alternative, the extension in the area(s) of applicability may be addressed through an increased margin of subcriticality.
- To clarify this, the sentence will be revised to say "...other calculational methods."

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NCS-7

- **"For ANSI/ANS-8.15-1981: The applicability of ANSI/ANS-8.1 limits to mixtures involving special actinide elements at the MFFF"**
- This item has been closed.

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NCS-8

- **"For ANSI/ANS-8.17-1984: What is meant by 'other justification' in the means for extending the code's area(s) of applicability beyond experimental data"**
- CAR section 6.4 has been revised to indicate (with respect to section 5.1 of this standard) that, in cases where an extension in the area(s) of applicability of a NCS analysis methodology is required, the method will be supplemented by other methods to provide a better estimate of bias in the extended area(s). As an alternative, the extension in the area(s) of applicability may be addressed through an increased margin of subcriticality.
- To clarify this, the sentence will be revised to say "...other calculational methods."

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Q1

- **"CAR Section 6.3.4.3.2.4 says 'all other impurities' are within the margin. Is this still valid for AFS ?"**
- Yes, it is still bounding.
- Preliminary calculations have shown that use of the assumption that the ^{239}Pu isotope is 96% rather than the specification value of 95% bounds the influence of the other impurities and isotopes.
- Besides ^{239}Pu, the main other isotope is ^{241}Pu, which is specified to be less than 1%.

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Q2

- **"Even though there is no revision bar in the revised CAR (page 6-26), the fraction of ^{235}U has been changed from 100% to 1%. Why? Is this correct?"**
- The omission of the change bar was an oversight.
- ^{235}U enrichment occurs in the AP process at an assumed three different bounding values.
  - First, the incoming ^{235}U enrichment is assumed to be a bounding 100%.
  - Second, after the dissolution of the powder (by the dissolution unit), the solution is mixed with depleted Uranyl nitrate such that the enrichment is about 30%. The criticality calculations assume a bounding 35%.
  - Finally, at the end of the purification step, when the Uranium is extracted and prior to being sent to the waste stream, an additional dilution occurs with depleted Uranyl nitrate such that the enrichment is less than 1%.
- To clarify the situation, the sentence ending in "the following bounding assumption is made:" will be changed to read "the following bounding assumption is made for the incoming feed material:" and the fraction of ^{235}U will be changed back to 100%.

Q3

- **"Table 6-1, pg 6-53. For the row for Dechlorination Columns, both the density and concentration are marked 'YES.' Is this correct? Usually one does not control density for liquid systems such as this."**
- Correct. The primary means of control is concentration control to ensure that the concentration in these columns is low.
- However, still further upstream of the point of concentration control, the density of the incoming feed material is controlled to ensure that it is below the indicated value. Consistent with previous NRC request, upstream parameter control is indicated as such in the table.
- In fact, at this unit, there is no direct density control.

Q4

- **"In Section 6.4, ANSI/ANS Standards, NRC did not understand the change in wording from the previous response (RAI-90) from 'MFFF operations will comply with the requirements and implement the recommendations of ANSI/ANS-8...' to 'MFFF operations will comply with the <u>guidance</u> and implement the recommendations of ANSI/ANS-8...' Is this a change in DCS commitment?"**
- No, there is no change in DCS commitment.
- This change in wording was meant to more accurately portray the ANS standards and did not indicate any reduction in commitment to the information in the standards.
- The revised CAR will be changed to "MFFF operations will comply with the guidance <u>(shall statements)</u> and implement the recommendations <u>(should statements)</u> of ANSI/ANS-8...'

Q5

- **"Section 6.1.1, page 6-1. and 6.1.2, page 6-2. Comparison indicates differences, including omissions of functions: e.g.,**
  - **Establishing procedures and training**
  - **Review and approval of operating procedures"**
- The differences are due to the activities in "design phase" (pg 6-1) and "operation phase" (pg 6-2)
- Activities shown in the "operations phase" and not shown in the "design phase" do not occur in design phase.

Q6

- **"CAR Section 6.1.1, page 6-1. The paragraph following the bulleted list is inconsistent with the previous DCS response on qualification of criticality manager. There is a missing sentence: "Have a familiarity with NCS programs at similar facilities". This is from DCS-NRC-00085 (08 Mar 2002 clarification letter). Restore the sentence."**
- The sentence in the CAR will be restored.

Q7

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- **"CAR 6.3.3.2.4 pg 6-13 says analysis will demonstrate that for our isotopic 241Pu can be neglected. Discrepancy between RAI 79 (bounding nature will be demonstrated in crit calcs to be referenced in NCSEs) and what's in revised CAR on pg 6-13 ("demonstrated by analysis")"**
- The sentence will be revised in the CAR: … in crit calcs in NCSE …
- Justification will be provided in NCSEs and ISA summary.

Q8

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- **"CAR Section 6.3.2, pg 6-7. The second paragraph ends with the following: "Specific areas qualifying for exemption from criticality accident monitoring requirements will be identified in the LA and the ISA. The basis for such exemptions shall be provided in the ISA." This is different that that previously provided by DCS in RAI response #74 which was the following: "Specific areas (if any) requiring exemption from criticality accident monitoring requirements will be identified in the LA. The basis for such exemptions will be provided." NRC disagrees with the new text and requests the text previously proposed by DCS be used (i,e., NRC approval for CAAS exemptions) "**
- The text will be revised in the CAR: … justification will be required for the LA or in a separate exemption request …

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Q9

- **"CAR Section 6.4, ANSI/ANS-8.7, -10, and -12. The way DCS is using the wording in reference to these standards is confusing to NRC. It is also changed from the previous response to NRC. We now say "This standard may be part of the design basis…" Please clarify whether these are or not part of the design basis."**
- The text will be clarified to state that these standards are not part of the design basis.

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Q10

- **"CAR Section 6.4, ANSI/ANS-8.23. DCS changed the wording of this standard from "This standard is referenced as a basis for the design of MFFF processes and fissile material handling and storage areas. The standard provides guidance for minimizing risks to personnel during emergency response to a nuclear criticality accident outside reactors."**
  Criticality accident emergency planning and response, while an important programmatic element, is not part of the safety basis." This seemed confusing to NRC".
- As described in chapter 14, NRC approval is not required for the Emergency Plan .
- Nevertheless, DCS commits to comply with the recommendations without exception .

MEETING ATTENDEES

NAME	AFFILIATION
January 15, 2003	
Andrew Persinko	Nuclear Regulatory Commission (NRC)
Tim Johnson	NRC
Mike Lamastra	NRC
Alex Murray	NRC
David Brown	NRC
Melvyn Leach	NRC
Rex Wescott	NRC
Bill Troskoski	NRC
Norma Garcia Santos	NRC
Ken Ashe	Duke Cogema Stone & Webster
Steve Kimura	DCS
Gary Kaplan	DCS
Werner Bergman	DCS/consultant
Lindell Sunde	DCS
Tom St. Louis	DCS
David Alberstein	Department Of Energy/NNSA
Lane Hay	SERCH Bechtel
Tom Clements	Greenpeace International
Herb Massie	Defense Nuclear Facilities Safety Board (DNFSB)
Joe Roarty	DNFSB
Faris Badwan	LANL
Geoff Kaiser	SAIC
Steven Dolley	Nuclear Control Institute (NCI)
Junichi Kurakami	JNC
January 16, 2003	
Andrew Persinko	Nuclear Regulatory Commission (NRC)
David Brown	NRC
Melvyn Leach	NRC
Rex Wescott	NRC
Norma Garcia Santos	NRC
Wilkins Smith	NRC
Muffet Chatterton	NRC
Christopher Tripp	NRC
Ken Ashe	Duke Cogema Stone & Webster (DCS)
Bill Newmyer	DCS
Bob Foster	DCS
Bill Hennessy	DCS

MEETING ATTENDEES (CONTINUED)

David Alberstein	Department Of Energy/NNSA
Lane Hay	SERCH Bechtel
Tom Clements	Greenpeace International
Herb Massie	DNFSB
Joe Roarty	DNFSB
Kevin Kamps	Nuclear Information and Resource Service (NIRS)
Mary Olson (by telephone)	NIRS