HEPA SERVICE LIFE TESTS-EFFECTS-RECOMMENDATIONS AT DEPARTMENT OF ENERGY ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

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I. Abstract

HEPA filters dating from the 1960's are in use in supply and exhaust systems at Rocky Flats Environmental Technology Site . In July 1997 tests of 140 HEPA filters that varied in age, usage, and manufacture were completed. The tests were conducted to determine the effects of aging on expected filter performance. From the results of the tests expected and unexpected conclusions were drawn..

II. Introduction

High Efficiency Particulate Air (HEPA) filters provide the final barrier to release of nuclear material to the environment and public. HEPA filters are specifically credited in the authorization basis for mitigating the consequences of operational accidents and natural phenomena hazards.

Nuclear facility operations have historically been authorized by Final Safety Analysis Reports (FSAR) with specific requirements for operations contained in the Operational Safety Requirements (OSR) section.

In 1994, the Site contractor declared an Unreviewed Safety Question (USQ) as a result of the discovery issue of testing only the final stage of a multi stage credited HEPA filtration bank. As a part of this USQ, filter service life was identified as an issue. To resolve the issue, a HEPA filter service life study was performed to determine significant effects of aging on expected filter performance.

Based on the conclusions and recommendations of the study, the following position documents and operational changes were initiated: A Subject Matter Expert (SME) Team review/impact study with recommendations, an Engineering Operability Evaluation

(EOE) of the Filter Plenum Fire System/Procedures, an Unresolved Safety Question Determination (USQD) on moisture impact on HEPA filters, and an Implementation Plan to change procedures, evaluate filter change and investigate alternate test methods.

III. Service Life Testing

While conducting Unreviewed Safety Question Determination (USQD), questions were raised concerning the maximum service life criteria for HEPA filters.

RFETS committed to perform a service life study to determine the effects of aging on HEPA filters. The study proposal involved obtaining HEPA filter media test samples of various ages from filters used in facilities under a variety of service conditions, and subjecting these samples to tests of tensile strength and water repellency.

HEPA filters procured for use in nuclear facilities were manufactured to Mil-Spec requirements for HEPA filters (MIL-F-51068F and MIL-F-51079D), and were qualified to the Mil-Spec requirements.

The study did not attempt to analyze aged HEPA filters under accident conditions. The study was intended to provide data on observed age-related filter media degradation and water exposure affecting media service life, which could be used to determine service life criteria for HEPA filters used in RFETS facilities. The results may have application at other DOE facilities where HEPA filter system are used for radiological confinement.

The current RFETS criteria for replacement of in-service HEPA filters is based on 1) pressure drop, 2) visible filter degradation, 3) stack emissions sampling results, and 4) failed diotcylphthalate (DOP) aerosol efficiency testing. These criteria do not identify filters that have degraded structural strength, and can allow filters to remain in place for practically an unlimited time. Most of the plena at RFETS have filters that have been in service greater than ten years.

The Test Plan was performed as follows:

Phase I sampling was conducted on eighty-five filters removed from radiological operations areas. The filters ranged in age from six years to twenty-five years.

Phase II sampling and testing was conducted on fifty-five filters removed from non-radiological areas and stock storage. The filters ranged in age from one year to twenty-one years.

Tests performed on the filter media were drawn from Mil-Spec MIL-F-51079D for HEPA filters manufactured for use in nuclear facilities. The tests were:

- Tensile strength of the media in the machine direction
- Tensile strength of the media in the cross direction
- Thickness
- Water repellency

Humphrey Gilbert, DOE Consultant, and Werner Bergman, Lawrence Livermore National Laboratory, (recognized experts in the field of HEPA filters) were consulted as to what additional tests should be performed. The following tests were added to the test plan, based on filter failure mechanisms observed in the field:

- Tensile strength of the media in the machine direction across the fold
- Tensile strength of the media in the cross direction across the fold
- Burst pressure on the media flat
- Burst pressure on the media fold
- Water degradation tests:
  - Wetted & dried media tensile strength in the machine direction
  - Wetted & dried media tensile strength in the cross direction
  - Wet tensile strength in the machine direction
  - Wet tensile strength in the machine direction across the fold

The test data was sorted into five groups, based on relevancy to operational failure and service life analysis: Water Repellency; Water Degradation, Tensile Strength - Machine Direction; Burst Pressure, and Manufacturer Variances. (Fig.1)

Water Repellency:	A minimum of 18 inches water column.
Water Degradation:	Exposure of filter media to water will potentially degrade the media tensile strength.
Tensile Strength:	Minimum tensile strength of 2.5 pounds per inch width in the Machine Direction.
Burst Pressure:	HEPA filters to withstand a pressure differential of 10.0 inches water column (water gauge).
Manufacturer Variances:	Three Manufacturers account for more than 80% of all HEPA filters installed at RFETS. The remaining 20% is distributed among four other manufacturers.

Specific test results for Water Repellency, and Water Degradation are discussed below.

	Manufactured	Age (Years)	Thickness (Mils)	Burst (PSI)	Burst Across Fold (PSI)	Tensile - Machine Direction (lb/in.-width)	Tensile - Machine Direction Across Fold (lb/in.-width)	Tensile - Cross Direction (lb/in.-width)	Tensile - Cross Direction Across Fold (lb/in.-width)	Water Repellency (Inches Water)
A	Feb-72	25	16.0	3.1		3.8	0.4	1.8		
A	Aug-72	25	19.0	1.6	0.8	1.0	0.1	1.0		
A	Oct-72	25	17.0	3.1	1.8	6.0	1.2	2.1		
B	Sep-73	24	22.0	3.0	0.8	3.7	0.6	2.3		
A	Jan-74	23	17.0	3.2	2.0	4.6	0.8	1.9		
A	Jan-74	23	16.0	1.2	1.2	3.8	1.0	1.4		
A	Jan-74	23	16.0	1.8	1.0	4.1	0.1	1.8		
A	Jan-74	23	24.0	3.0	2.0	5.3	0.6	5.1		
A	Jan-74	23	17.0	1.8	1.0	3.6	0.7	2.7		
A	Jan-74	23	17.0	2.2	1.0	3.6	1.0	1.5		
C	Jan-76	21	17.7	1.2	0.4	1.9	0.8	1.9	1.6	36.8
D	Dec-77	20	17.2	1.2	0.4	2.9	0.9	2.6	2.2	30.0
D	Aug-80	17	17.7	4.7	1.2	3.6	2.0	3.4	2.5	42.0
E	Dec-80	17	18.0	8.8	4.0	4.7	3.8	5.7		
E	Jan-81	16	18.0	7.8	1.6	6.5	0.6	4.8		
B	Mar-81	16	20.0	2.8	1.5	4.8		3.3	0.8	21.5
B	Mar-81	16	20.0	7.0	2.2	7.0		3.4	3.4	20.0
B	Mar-81	16	20.0	3.8	1.5	5.2	1.3	3.8	2.6	25.0
B	Apr-81	16	21.0	2.0	1.5	2.4	0.7	1.0	1.4	19.0
B	May-81	16	24.0	15.0+	14.8+	11.0	10.2	5.4	2.8	15.5
B	Jul-81	16	21.0	3.0	1.6	7.1	2.1	3.6		
B	Aug-81	16	21.0	2.8	1.6	5.4	0.4	3.1	2.3	29.0
B	Aug-81	16	19.0	4.0	1.0	5.2	0.7	4.0	2.3	18.0
A	Jan-82	15	20.0	2.4	2.2	2.9	0.7	2.0	1.5	23.0
D	Mar-82	15	17.8	3.7	2.1	3.7	3.3	2.6	2.7	24.8
E	Aug-82	15	20.7	2.5	1.3	2.9	1.7	2.3	1.8	17.1
E	Aug-82	15	19.8	3.6	1.7	3.6	2.4	2.9	2.8	36.3
E	Aug-82	15	18.9	2.4	1.4	3.3	2.1	2.5	2.8	42.0
E	Aug-82	15	19.8	2.6	1.2	3.1	2.0	2.1	2.1	30.8
E	Aug-82	15	19.6	2.6	1.6	3.2	2.3	2.6	2.6	35.0
B	Aug-82	15	19.0	4.0	1.5	3.7	2.1	6.0	4.0	30.0
D	Feb-83	14	17.4	4.2	1.6	2.5	2.2	2.6	2.5	42.0
D	Apr-83	14	17.4	4.6	2.8	3.8	3.2	3.0	2.5	26.0
F	Jun-83	14	14.0	6.2	2.5	2.5	0.7	3.8	2.1	6.0
D	Jul-83	14	18.0	7.8	2.0	5.3	0.3	3.9		
G	Aug-83	14	17.9	2.1	1.0	3.0	1.8	1.8	1.7	42.0
G	Aug-83	14	18.0	7.8	4.6	7.0	2.2	4.7	4.5	41.0
G	Aug-83	14	19.0	6.8	3.8	7.2	1.8	5.4	5.0	42.0
B	Aug-83	14	21.0	5.0	1.7	4.7	0.3	3.3	1.9	17.5
D	Aug-83	14	18.0	8.8	4.0	5.7	1.1	4.1	3.0	19.0
D	Aug-83	14	19.0	5.2	3.2	5.2	2.2	4.5	3.8	25.0
B	Aug-83	14	20.0	2.0	1.0	2.4	0.3	2.7		
B	Aug-83	14	22.0	2.3	1.0	4.3	0.4	2.8		
B	Aug-83	14	21.0	1.8	0.8	2.1		1.3		
B	Aug-83	14	20.0	2.0	0.8	1.1	0.1	0.6		
B	Sep-83	14	20.4	1.8	0.3	3.1	1.1	2.4	1.7	12.3
B	Sep-83	14	22.2	2.1	0.7	3.5	1.2	2.8	1.9	12.5
G	Sep-83	14	20.0	5.8	2.6	4.3	1.6	4.7		
G	Sep-83	14	18.0	5.2	3.2	3.5	0.5	3.5		
G	Sep-83	14	20.0	3.2		5.2	1.6	4.6		
G	Sep-83	14	19.0	6.4	3.2	5.3	0.3	5.4		
G	Sep-83	14	18.0	8.0	3.0	5.1	0.6	3.2		
G	Sep-83	14	17.0	4.6	1.6	5.4	0.4	2.8		
G	Oct-83	14	18.0	9.2	2.6	5.4	3.2	3.9	3.0	19.5
B	Oct-83	14	19.0	2.0	2.0	3.0	0.1	1.6		
G	Jan-84	13	18.0	5.8	2.0	3.9	1.6	3.4		18.5
G	Jan-84	13	19.0	7.8	3.2	8.0	3.0	4.3	1.1	36.0
G	Jan-84	13	20.0	8.5	3.8	5.7	2.0	4.9	4.8	31.0
G	Jan-84	13	19.0	8.2	4.0	7.2	3.6	6.2	5.1	38.0
G	Mar-84	13	19.0	6.0	2.5	3.6	1.1	4.1	2.5	28.0
G	Mar-84	13	19.0	6.0	3.2	4.0	1.7	4.7	4.1	24.0
G	Apr-84	13	21.0	6.0	1.6	6.7	0.3	4.8		
G	Apr-84	13	21.0	4.6	2.2	6.2	0.5	5.1		
B	Apr-84	13	20.0	5.0	1.0	2.8	0.4	0.6		
B	Jul-84	13	17.0	1.6	1.2	1.4	0.4	1.3		
B	Jul-84	13	21.0	4.0	1.4	5.4	0.1	2.8		
B	Nov-84	13	19.0	2.0	0.4	4.7	1.1	3.4	2.3	11.8

Figure 1. Filter Test Results pg. 1

	Manufactured	Age (Years)	Thickness (Mils)	Burst (PSI)	Burst Across Fold (PSI)	Tensile - Machine Direction (lb/in.-width)	Tensile - Machine Direction Across Fold (lb/in.-width)	Tensile - Cross Direction (lb/in.-width)	Tensile - Cross Direction Across Fold (lb/in.-width)	Water Repellency (Inches Water)
G	Feb-85	12	21.0	4.2	1.8	5.6	0.1	4.0		
G	Jun-85	12	21.0	3.6	3.8	4.5	0.1	2.3		
G	Jun-85	12	22.0	4.2	1.6	7.6	0.1	5.6		
G	Jun-85	12	21.0	7.2	4.0	2.1	2.1	4.8		
G	Jul-85	12	21.0	3.8	3.0	6.3	0.9	3.9		
G	Jul-85	12	23.0	5.0	3.0	2.2	0.4	1.6		
G	Jan-86	11	19.0	6.8	3.8	5.8	2.4	5.7	4.5	41.0
D	Jun-86	11	18.8	5.7	1.5	4.9	2.3	3.0	2.7	42.0
B	Jul-86	11	24.0	3.2	0.8	4.4	1.3	5.6		
B	Sep-86	11	19.0	2.5	0.6	3.1	1.1	2.4	1.8	20.7
B	Sep-86	11		2.7	1.3	2.2	0.8	1.7	1.6	
B	Oct-86	11	20.1	2.9	1.0	4.2	1.7	3.6	3.4	14.0
B	Oct-86	11	19.6	1.6	0.7	2.6	1.1	3.0	2.1	16.1
B	Oct-86	11	18.6	2.8	1.2	4.6	2.3	3.7	2.3	19.5
B	Oct-86	11	20.3	3.6	1.0	5.1	2.9	3.9	3.2	31.8
B	Jun-87	10	20.4	3.5	1.5	4.4	2.2	3.2	2.1	23.9
D	Jun-87	10	19.8	7.1	2.0	4.3	1.4	3.0	2.3	15.5
B	Oct-87	10	21.0	3.0	1.2	4.5	0.1	3.4		
D	Dec-87	10	18.0	5.8	1.8	6.0	1.7	4.6		
B	Jan-88	9	21.0	4.0	1.2	2.2	1.2	2.2		
B	Jan-88	9	23.0	2.4	1.8	3.2	0.1	3.8		
D	Jun-88	9	17.4	7.1	2.2	4.8	2.1	3.5	3.0	41.8
B	Jun-88	9	22.0	2.1	1.8	6.1	0.4	5.4		
B	Jun-88	9	20.0	3.0	2.0	7.2	0.1	5.0		
D	Aug-88	9	18.0	3.9	1.4	3.5	1.2	2.6	2.2	42.0
D	Aug-88	9	17.9	6.7	1.8	3.6	2.3	2.7	2.7	39.8
D	Sep-88	9	19.0	6.2	3.2	5.0	0.7	5.0		
D	Sep-88	9	19.0	3.5	0.2	4.0	0.4	3.0		
B	Feb-89	8	20.8	2.1	0.8	3.1	1.5	2.1	2.2	42.0
B	Feb-89	8	16.1	1.9	0.5	2.5	0.7	1.9	1.9	42.0
B	Feb-89	8	19.2	1.3	0.6	2.3	1.0	1.8	1.1	20.5
D	Feb-89	8	17.0	6.8	2.4	5.2	0.7	3.7		
D	Jul-89	8	18.0	3.8	2.8	7.4	0.6	3.9		
D	Aug-89	8	19.0	6.0	3.0	4.6	1.4	3.7		
D	Aug-89	8	19.0	5.8	1.6	4.5	0.3	3.5		
D	Sep-89	8	19.0	5.6	2.2	3.5	0.4	3.7		
D	Oct-89	8	17.0	7.0	4.0	5.0	0.7	4.3	3.4	39.0
B	Nov-89	8	23.0	2.0	0.2	3.6	0.7	1.0		
B	Dec-89	8	17.2	1.4	0.6	2.4	1.0	2.2	1.7	15.0
B	Dec-89	8	19.6	2.3	0.4	3.6	0.9	2.6	2.3	13.5
B	Dec-89	8	19.6	2.4	0.9	2.6	1.6	2.9	2.2	7.8
B	Dec-89	8	19.0	1.6	1.4	3.6	0.4	4.4		
B	Jan-90	7	18.5	2.5	1.0	3.9	1.4	3.0	2.4	11.5
B	Jan-90	7	20.3	2.1	0.6	3.8	1.2	2.7	2.3	13.0
B	Jan-90	7	20.8	2.1	0.6	3.3	1.1	2.3	1.9	16.5
B	Jan-90	7	19.5	2.2	1.3	3.9	2.1	3.0	2.5	18.0
B	Jan-90	7	19.6	2.1	0.6	3.3	1.0	2.6	1.7	9.6
B	Jan-90	7	19.4	1.7	0.8	3.6	2.0	2.5	2.0	6.5
B	Jan-90	7	18.5	1.7	0.4	2.9	1.0	1.8	1.5	11.5
B	Feb-90	7	19.0	2.0	2.0	5.6	0.5	7.0		
B	Apr-90	7	15.9	0.8	0.4	1.5	0.9	1.6	1.2	29.0
B	May-90	7	17.2	2.0	0.4	2.6	0.6	1.9	1.5	5.0
B	Aug-90	7	18.0	2.0	1.1	3.0	0.1	1.7		
B	Oct-90	7	17.0	1.4	0.8	1.2	0.1	1.3		
B	Nov-90	7	17.0	2.2	1.0	1.7	0.1	1.5		
B	Nov-90	7	16.0	2.0	0.2	2.5	0.1	2.0		
B	Nov-90	7	19.0	0.2	0.2	1.3	0.1	1.8		
B	Apr-91	6	18.0	2.2	1.0	4.4	0.4	3.5		
B	Apr-91	6	20.0	2.0	1.0	1.3	0.1	1.6		
B	Sep-91	6	21.0	4.2	1.8	3.2	0.2	2.3		
H	Dec-92	5	18.6	6.1	1.2	4.8	2.1	3.2	2.7	42.0
C	Feb-94	3	17.1	3.1	1.6	3.9	2.8	3.0	2.8	36.0
C	Mar-94	3	16.7	5.9	1.3	4.9	3.3	2.7	2.3	42.0
B	May-94	3	22.1	2.9	1.2	4.9	2.4	3.3	2.8	37.0
B	May-94	3	22.7	3.9	0.7	4.1	1.5	3.4	2.8	34.5
B	Sep-94	3	21.8	1.9	0.8	2.8	1.2	2.5	1.6	12.5
B	Apr-95	2	24.0	4.5	1.8	4.6	1.3	3.8	3.6	17.8
H	Sep-95	2	15.7	4.4	0.9	3.3	2.6	2.9	2.5	15.4
C	Dec-95	2	15.0	4.5	1.5	5.0	2.8	2.7	2.2	27.1
H	Jan-96	1	16.6	6.1	1.2	4.9	1.9	4.9	2.1	15.5
H	Jul-96	1	13.4	3.2	0.5	3.4	1.8	2.0	1.7	13.0

Figure 1. Filter Test Results pg. 2

Water Exposure Data

Filter Sample				Burst (PSI)		Tensile - Machine Direction (lb/in.-width)		Tensile - Cross Direction (lb/in.-width)		Wet Tensile-Machine Direction (lb/in.-width)	Wet Tensile - Machine Direction Across Fold (lb/in.-width)
Sheet No.	Date Manufactured	Age (Years)	Thickness (Mils)	Before	After H2O	Before	After H2O	Before	After H2O		
9	Sep-83	14	20.4	1.8	0.4	3.1	1.1	2.4	1.5	1.2	0.4
12	Sep-83	14	22.2	2.1	0.4	3.5	2.0	2.4	1.8	1.4	0.4
41	Sep-86	11	19.0	2.5	0.6	3.1	3.3	2.4	2.7	2.1	0.9
13	Oct-86	11	20.1	2.9	0.8	4.2	3.7	3.6	2.7	2.0	0.6
15	Oct-86	11	19.6	1.6	0.6	2.6	3.2	2.1	1.4	1.9	0.6
27	Oct-86	11	18.6	2.8	1.0	4.6	3.3	3.7	2.9	2.5	1.0
34	Dec-89	8	19.6	2.3	0.6	3.6	3.1	2.6	2.2	2.5	0.3
39	Dec-89	8	17.2	1.4	0.2	2.4	2.4	2.2	2.2	1.5	0.4
21	Jan-90	7	18.5	2.5	0.6	3.9	2.8	3.0	2.4	1.4	0.5
29	Jan-90	7	20.8	2.1	0.4	3.3	2.6	2.3	1.5	1.4	0.3
30	Jan-90	7	19.5	2.2	0.8	3.9	3.7	3.0	1.5	2.5	0.7
31	Jan-90	7	19.6	2.1	0.4	3.3	2.3	2.6	1.5	1.4	0.4
32	Jan-90	7	19.4	1.7	1.0	3.6	2.3	2.5	1.3	1.4	0.4
33	Jan-90	7	18.5	1.7	0.4	2.9	2.7	1.8	2.4	1.6	0.3
7	Apr-95	2	24.0	4.5	1.0	4.6	5.3	3.8	3.9	2.3	0.8

Figure 2.

Water Data - Multiple Exposures

Filter Sample				Burst (PSI)			Tensile - Machine Direction (lb/in.-width)			Tensile - Cross Direction (lb/in.-width)		
Sheet No.	Date Manufactured	Age (Years)	Thickness (Mils)	Initial	1st H2O	2nd H20	Initial	1st H2O	2nd H20	Initial	1st H2O	2nd H20
10 (Unused)	Aug-82	15	18.9	2.4	2.0		3.3	2.1		2.5	2.0	
11 (Dust Loaded)	Nov-84	13	19.0	2.0	1.6	0.6	4.7	1.7	2.8	3.4	1.4	1.0
28 (Dust Loaded)	Oct-86	11	20.3	3.6	4.4	0.8	5.1	3.7	3.5	3.9	2.4	2.5
22 (Dust Loaded)	Jan-90	7	20.3	2.1	1.4	0.6	3.8	3.1	2.5	2.7	2.1	1.6
19 (Unused)	May-94	3	22.1	2.9	2.2		4.9	2.1		3.3	1.9	
20 (Unused)	Jan-96	1	15.6	6.1	3.6		4.9	3.2		4.9	1.6	

Figure 3.

Water Repellency Tests

1. Testing of Unused Filters: Twenty-nine (29) filters of various ages from various manufacturers were tested. Four (4) samples (14%) did not meet the minimum required standard of 20 inches water column.
2. Testing of Dust Loaded Filters: Twenty-four (24) filters of various ages from various manufacturers were tested. Twenty (20) samples (83%) did not meet the minimum required standard.
3. Testing of Used Clean Filters: Twenty-four (24) filters of various ages from various manufacturers were tested. Four (4) samples (17%) did not meet the minimum required standard.

Water Degradation Tests (Fig.2&3)

1. Testing of Unused and Dust Loaded Filters - Tensile Strength: Three (3) unused filters and three (3) used filters of various ages from various manufacturers were tested by wetting (soaking in water for 15 minutes), allowing them to dry for 24 hours, and then measuring tensile strength in the Machine Direction. The three (3) unused filter samples showed a reduction in tensile strength from 30% to 60%.

   The three (3) dust loaded filters were tested twice. After the first test, the dust loaded samples showed a reduction in tensile strength in the Machine Direction from 20% to 60%. After the second test, two (2) of the samples showed a further reduction in tensile strength between 5% and 10%.

2. Testing of Dust Loaded Filters - Tensile Strength: Fifteen (15) filters of various ages from various manufacturers were tested by wetting, drying, and then measuring tensile strength in the Machine Direction. Eleven (11) samples (73%) showed a reduction in tensile strength, and five (5) of these samples (33%) did not meet the minimum required standard. The reduction in strength ranged from 5% to 60%.

3. Testing of Dust Loaded Filters Wet Tensile Strength: Fifteen (15) filters of various ages were tested for tensile strength in the Machine Direction while wet. All fifteen (15) samples (100%) exceeded the minimum wet tensile strength specification of 1.0 lb/in-width.

   Samples from these fifteen (15) filters were also wetted and tested for tensile strength in the Machine Direction across the fold while wet. Note that the Machine Direction across the fold is the weakest configuration and that the fold is the most common failure point on the filter. Fourteen (14) samples (93%) were less than 1.0 lb/in-width while wet.

General Conclusions:

- The wide variability of measured filter parameters between and within manufacturers generally conceals the effects of age-related degradation.
- A filter exposed to water can be weakened, even after it dries. The test data shows a reduction in tensile strength of up to 60%.
- Measured filter parameters (water repellency, tensile strength, burst pressure) vary significantly by batch within the same manufacturer. For example, measured tensile strength - machine direction (Mil-Spec criteria - 2.5 lb/inch-width) on a set of five filters from the same manufacturer yielded the following results, expressed as Year Manufactured vs. lb/inch-width:

  1973: 3.7   1981: 7.1   1983: 2.1   1986: 4.4   1991: 2.2

Water Repellency Conclusions:

- Exposure of first stage filters to water during OSR required plenum deluge system surveillance tests can reduce the tensile strength of filters to less than Mil-Spec levels.

Water Degradation Conclusions:

- Significant loss of tensile strength was observed after filters were exposed to water and allowed to dry. Further water exposures resulted in additional loss of tensile strength on clean filters.

Age Related Degradation Conclusions:

- The data from this report, which is based on 140 filters, does not support replacement based solely on age.

The Recommendations From The Report Are As Follows:

- The data does not support the replacement of HEPA filters based solely on age or the development/establishment of age specific service life criteria.
- The wide variation of measured filter parameters between and within manufacturers demonstrates the need for reevaluation of minimum filter specifications.
- A strong QC/QA policy must be adopted and applied at the time of filter manufacture as well as at the 5 year qualification.
- Significant loss of tensile strength was observed after filters were exposed to water and allowed to dry. Subsequent water exposures resulted in additional loss of tensile strength.

- Filters routinely exposed to water from deluge system surveillance tests should be given priority for replacement.

- Alternate deluge system test methodologies should be developed to protect filters from water-exposure degradation resulting from surveillance tests.

IV. Team SME Review

In September, 1997, a multi-disciplined team of site subject matter experts was convened to consider the potential impacts of the study results on the Site's current strategies for ventilation and plenum deluge system operation during fires. The team's charter included the development of consensus recommendations for changing Site practices, if needed, in order to minimize environmental and public consequences resulting from fire in nuclear facilities. The team focused on specific circumstances at Rocky Flats, including the facility hardware configurations and the short remaining mission of the Site. The ensuing recommendations may or may not be appropriate for other sites in the DOE complex.

In addition to the conclusions of the HEPA filter service life study, the team sought to understand lessons learned from previous fires at RFETS that involved HEPA filters, plenum configurations, surveillance's, and current fire fighting strategy. Pertinent information in each area is summarized below.

Three fires have occurred at RFETS that affected HEPA filters. The first occurred in 1957 in Building 771 (Fig. 4), the second in 1969 in Building 776 (Fig. 5), and the last in 1980, also in Building 771 (Fig. 6).

These three fires provide several lessons learned that still apply today.

- Explosions, including rapid deflagrations, can occur. An explosion in the plenum would be expected to physically damage the HEPA filters.
- Back to back filter stage configurations create the potential for cascading damage to follow on stages should the first stage mechanically fail.
- Direct water spray damages filters. While it may be necessary to extinguish a fire, water sprayed from either the deluge system heads or a hose line will weaken and damage the filter media.
- Filtered particulate may accumulate on the filter and then ignite.

Nine issues were evaluated:

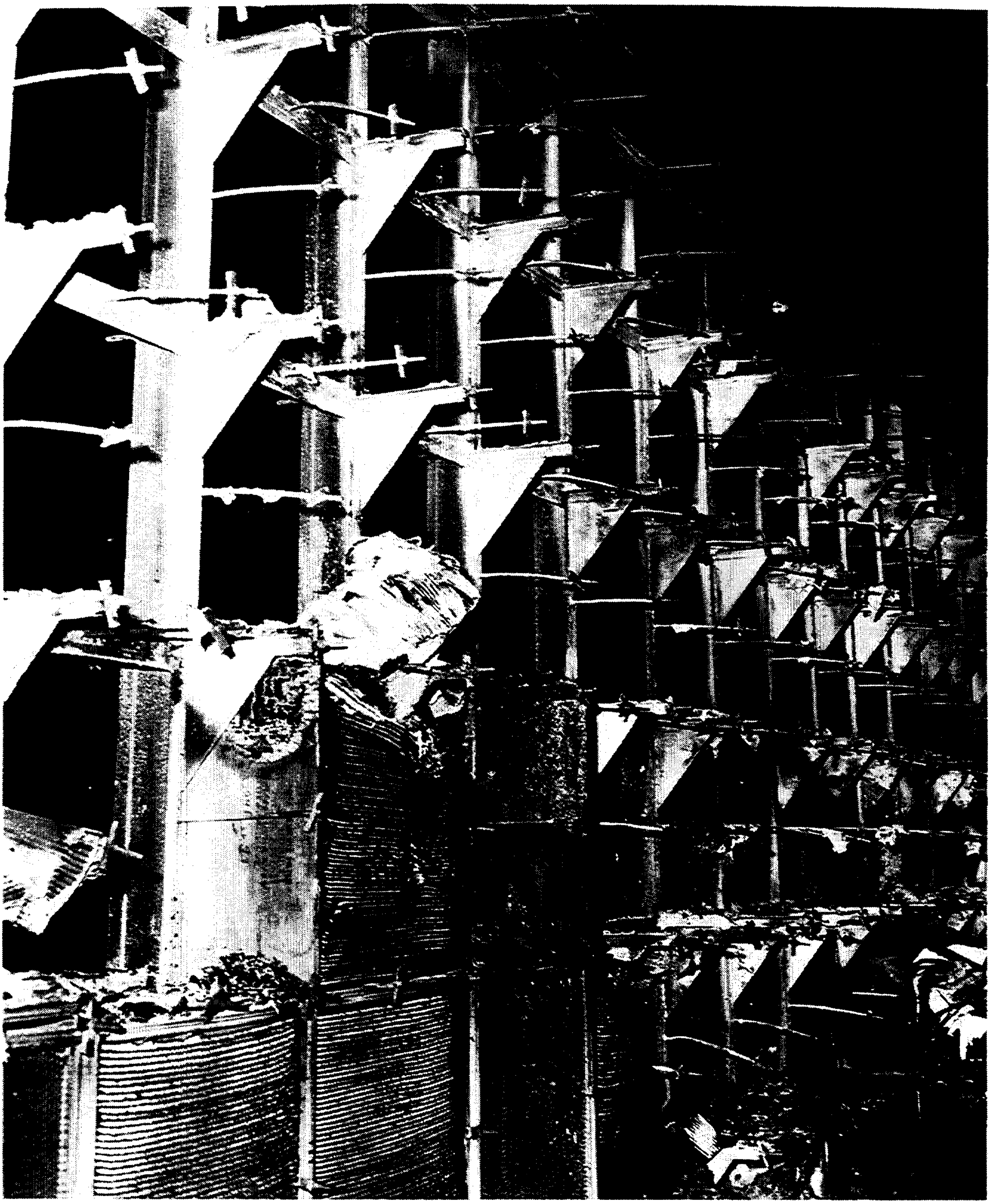

Figure 4. 1957 Filter Plenum Fire

Figure 5. 1969 Filter Plenum Fire

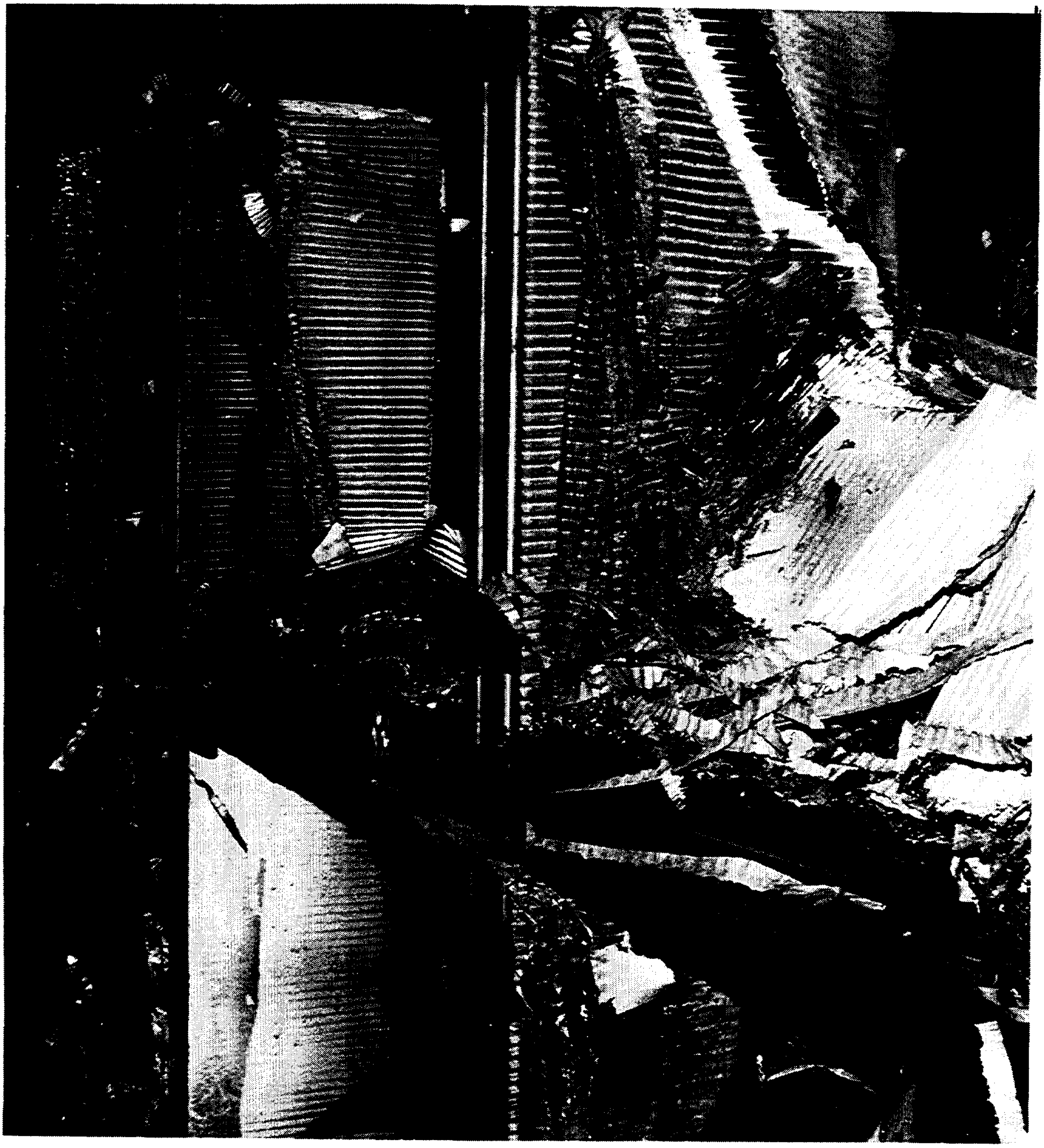

Figure 6. 1980 Filter Plenum Fire

1. Should ventilation be maintained during fires?
2. Should activation of the manual deluge system be allowed?
3. Should manual deluge testing be continued?
4. Should the automatic deluge system be activated manually?
5. Should the deluge systems be allowed to flow for unlimited time?
6. Is the plenum deluge system design adequate to support reliable operation?
7. Should there be remedial action taken for first stage HEPA filters affected by manual deluge system activation?
8. Is the fire fighting strategy for nuclear/radioactive fires adequate?
9. Is there a need for additional information or investigation to support or sharpen the team's recommendations?

Recommendations were developed for each issue:

Issue 1 - Maintenance of Ventilation During a Fire

- Throttle or discontinue ventilation on the affected plenum when dp across the final stage reaches 2-4" wg (4" wg is the current filter changeout criterion for normal operation).

Issue 2 - Activation of the Manual Deluge System

- Visually confirm, if possible, direct impingement of flame or burning embers on the first stage filters.
- Activate the manual deluge system only by the decision of the Fire Department sector officer based on a conclusion from the evidence available that flame is present on the first stage of filters.
- If flame is confirmed on any downstream stage, secure all fans connected to the affected plenum immediately.

Issue 3 - Continuation of Manual Deluge Testing

- Evaluate surveillance data to determine failure rates based on current surveillance operability criteria.
- Immediately extend the testing frequency for systems.
- For the longer term, consider application of the extension allowed by NFPA 25 to increase the test frequency to 18 months for all Site deluge systems.

Issue 4 - Manual Activation of the Automatic Deluge System

- Activate the automatic deluge system manually as soon as possible, rather than waiting for high temperature actuation.
- The decision to activate the system should be made by the Fire Department sector officer.
- Limited available data indicate that early activation is not beneficial in reducing the potential for smoke-induced plugging for those plena equipped with fog jet nozzles for automatic deluge. This recommendation should not be implemented for those plena.
- Perform tests to determine the effect of the automatic deluge system in conjunction with the demister screen on particulate removal to determine fire conditions, if any, that warrant deluge activation prior to 190 degrees F.

Issue 5 - Deluge System Flow Times

Extended flow times, particularly those resulting from early automatic system activation, will spread contaminated fire water should plena and plenum drain tanks overflow. As long as the water can be contained inside of the facility, the advantage gained in protecting the containment barrier clearly outweighs the risk. Even if the water has an unfiltered release path to the environment.

Issue 6 - Adequacy of Plenum Deluge System Design

During the evaluation of current test and surveillance practices, and existing system configurations, a previously recognized vulnerability for deluge system plugging was considered for significance.

- Conduct an engineering evaluation to determine the severity of the potential for deluge system plugging.

Issue 7 - Remedial Action for First Stage HEPA Filters

Based upon historical DOP testing results, there is no indication that manual deluge system testing degrades the filtration capability of HEPA filters under normal use conditions. The first stage filters are 17 years old and have been subject to approximately 16 manual deluge system tests. The manual deluge system test provides far less wetting than that which was studied in the service life investigation. Field data provides the best available indication of the actual impact. The new DOP test procedure has been completed two times on all other Site plena with similar results.

Despite this record of performance, however, both wetting and age are expected to degrade the filter design margin that may be challenged in severe fire events. Our recommendations which sacrifice initial filter stages, if necessary to permit fire fighting, and ensure integrity for the final stage. Nevertheless, recognizing that the recommendations presented both imply some credit for initial effectiveness of first stage filters and allow the first stage to be challenged to the point of failure, the following recommendations are made:

- When only a single stage of filters is credited in an accident analysis, the tested stage should not be the first stage.
- Evaluate DOP testing data and monitor failure trends in first stage filters; if a failure mechanism is identified for tested filters, extend appropriate surveillance to untested filters.
- Identify and implement practical means of providing infrequent, but periodic surveillance to ensure the integrity of untested filter stage.

Issue 8 - Adequacy of Fire Fighting Strategy

The team found the current Site fire fighting strategy to be sound and capable of achieving the accident management objectives established as the bases for the report s recommendations.

- Include explosion control as a priority objective in Fire Department operating procedures and pre-fire plans.
- Include instructions and restrictions for use of hose lines on the final filter stage.
- Modify existing plans and procedures to include the recommended actions and authorities contained in Issues 1, 2, 4, and 5.
- Train all affected personnel.

Issue 9 - Items for Further Investigation

- Conduct an engineering evaluation to determine the severity of the potential for deluge system plugging.
- Perform tests to determine the effect of the automatic deluge system in conjunction with the demister screen on particulate removal to determine fire conditions, if any, that warrant deluge activation prior to 190 degrees F.
- Evaluate surveillance data to determine failure rates of UL and non-UL listed valves.
- Conduct walkdowns to determine the number and location of fog head nozzles installed in plenum deluge systems.
- Evaluate the effects of early automatic deluge system activation.
- Determine if intentional failure of the first credited stage of HEPA filters is an unanalyzed condition in Buildings 371, 559, and 707 where two stages of filtration are credited. Modify these authorization basis documents as appropriate.

The main conclusion reached was that:

The Site should focus its efforts on fire prevention in the following areas:

- Ignition source control to reduce the possibility of fire initiation.

- Combustible material control limits to minimize available fuel and thereby limit fire size.
- Maintain effective automatic suppression systems.
- Maintain fire detection and manual fire suppression capabilities.

V. Engineering Operability Evaluation

This Engineering Operability Evaluation (EOE) determines the operability of filter plenum deluge systems installed for fire suppression in Rocky Flats Environmental Technology Site (Site) facilities. Typical Acceptance Criteria which demonstrate functionality include:

1. Automatic deluge activation upon receipt of a signal from the plenum heat detector.

2. Adequate spray pattern and coverage from the automatic and manual spray nozzles. The 1969 fire in Building 776 resulted in several site and complex wide fire suppression system modifications. Included in these upgrades were new designs to supply water to protect HEPA filter media against excessive heat and flame damage. The design modifications include components which, today, raise the question of operability. The components relative to this EOE include 1) flow control devices installed to meter flow; 2) non-Underwriter Laboratory (UL) listed automatic deluge valves. 3) air cooling water nozzles, 4) strainers and, 5) system materials of construction.

At the Site, most of the filter plena are provided with four protection devices. The first device encountered is a deflector plate. This plate prevents large particles from flowing directly into the plenum. The second device is an automatic deluge system. This system is actuated by heat detectors located in the duct entrances to the plenum. The spray of the automatic system is either in the form of a water curtain or a fine mist depending on the type of nozzle. The purpose of the automatic system is to cool the incoming air to below 325 degree F to prevent thermal damage to the HEPA filters. The next line of defense is a demister. The demister is designed to remove as much water from the air stream during automatic deluge as possible as well as large particulates such as burning embers. The final fire protection device is a manual deluge spray system. It is designed to protect the first stage from any exposing fire. It is only to be used in an emergency because water reduces filter media tensile strength and contributes to plugging which could cause filter failure. This manual system is only located on the first of multiple stages of HEPA filters.

The activation of the plenum deluge systems is accomplished in two ways. They can either be activated manually (both systems), or automatically (automatic deluge only). The automatic system is initiated by a signal from a 190 degree F heat detector located in the entrance duct to the plenum. The heat detector activates a fire alarm releasing panel which then releases the automatic deluge valve. Once a deluge valve is opened, water will flow to the respective open spray nozzles. A plenum deluge system would be considered Operable if it were able to meet its intended function on demand.

An Important Recommendation from the EOE was:

Modify existing surveillance procedures in accordance with the following:

A. Change automatic deluge flow testing on all systems to once a year and manual deluge flow testing to once every three years in accordance with FPE guidance and NFPA 25 requirements.

B. Extend automatic deluge system flow test duration's to 30 seconds to provide flushing and representative volumetric turnover. Where a 30 second test duration cannot be achieved because of applicable criticality safety limits, or limited capacity for retention of water, test duration's should be in accordance with FPE guidance.

C. Set Kates valves in accordance with 1980's test data unless an approved calculation exists.

D. Clean strainers following each deluge flow event.

E. Where possible, ensure that black steel pipe sections downstream of deluge valves are drained following flow tests.

F. Perform a visual inspection and PMO on Clayton deluge valves if the plenum supports nuclear operations and the period from the last documented PMO exceeds five years.

VI. SSOC Unreviewed Safety Question Process (USQD)

The USQD documents the evaluation of weather or not High Efficiency Particulate Air (HEPA) filter degradation in facility ventilation systems at the Rocky Flats Environmental Technology (RFET) Site represents an Unreviewed Safety Question (USQ). HEPA filters integrity could be degraded due to age, dust loading, and wetting of filters.

Based upon a review of a RFET site HEPA filter study, it was determined that the issues of significance relative to exhaust plena HEPA filters with respect to the facilities' authorization bases are as follow:

Issue 1 - Is HEPA filter efficiency affected due to the age or testing of the manual deluge systems?
Only one filter in the approximately 320 that comprise the first stage was replaced. This indicates that the HEPA filter age and testing of the manual deluge system has not impacted the efficiency of the HEPA filters. This testing addressed the efficiency of the HEPA filters during normal operating conditions.

Issue 2a - Is HEPA filter media strength affected due to age?
The data does not support the replacement of HEPA filters based solely on age or the development/establishment of age specific service life criteria.

Issue 2b - Is HEPA filter media strength affected due to the testing of the manual deluge systems?
The water will not only weaken the filter but also cause partial plugging. Under such conditions it is expected most of the filters will be degraded. Therefore, the efficiency of this stage cannot be credited during major fires. The filters are expected to continue to function to protect subsequent filter stage from water impingement and smoke buildup.

Issue 3 - What impacts are there on authorization basis safety analyses from weaker filter medium?

USQD Questions:

A USQD was is determined to exist for 3 buildings due to the structurally degraded first stage HEPA filters. The structurally degraded HEPA filters stem from testing of the manual deluge systems. Based on study information, the HEPA filter strength has been significantly reduced. It has been reduced to the extent that some HEPA filters will fail during a large fire, reducing the filter efficiency of the first stage to 90%. The majority of the HEPA filters will fail when the manual deluge system is activated during a major fire, reducing the efficiency of the first stage to zero. The resultant doses from increasing the Building Leak Path Factor (BLPF) for large and major fires are lower than the current criteria. The structurally degraded filters represents a USQ based on positive answers to question 6 and 7.

6. Could the Proposed Activity or Discovered Condition create the possibility of a malfunction of equipment important to safety of a different type than any previously evaluated in Safety Analyses?

7. Could the Proposed Activity or Discovered Condition reduce the margin of safety as defined in the bases for any TSR/OSR?

Question 6 and 7 are positive for (3) Buildings. Consequently, this Discovered Condition is an Unreviewed Safety Question for Buildings, when considering the current authorization bases discussed in this USQD that there is no increase in dose consequences resulting from fires over what was previously identified in the facilities' authorization bases. There is however a reduction in the margin of safety and an identified failure mode for first stage HEPA filters that was not considered in the current authorization bases. Changes to the facilities authorization bases will be proposed to address this condition for Buildings.

VII. Implementation Plan

The Implementation Plan was intended to incorporate the recommended changes from the SME team report published November 12, 1997, into Site practice and to outline a course of action to resolve the additional issues. The Implementation Plan is divided into three sections which encompass all of the recommendations contained in the report: utility, fire-fighting, and emergency operating procedure changes; plenum deluge system functionality; and authorization basis issues.

Procedure Changes

1. Fire-Fighting Procedures

- Control ventilation configurations, volumes, and flow rates in the field.
- Continuously monitor DP in the initial filter stages.
- For plena with four stages, monitor second and third stage DP at the first indication of loss of first stage filter integrity.
- Throttle or discontinue ventilation on the affected plenum when DP across the final stage reaches 2-4" wg (4" wg is the current filter change-out criterion for normal operation).
- In no case is ventilation to be continued when 4" wg DP is reached across the final stage of filters.
- At the first indication of an explosion, monitor first stage DP for a rapid or complete loss of DP as an indication of failure.

2. Activation of the Manual Deluge System

Manual deluge system activation will likely result in the loss of the first stage of filters either through plugging or media failure.

- Visually confirm, if possible, direct impingement of flame or burning embers on the first stage filters.

- Manual deluge activation is only warranted when it is clearly required.
- Activate the manual deluge system only by the decision of the Fire Department sector officer.
- Possible filter plugging and shutdown of ventilation should be anticipated once manual deluge is activated.
- If flame is confirmed on any downstream stage, secure all fans connected to the affected plenum immediately.

3. Manual Activation of the Automatic Deluge System

The report determined that early activation of the automatic deluge system could increase the potential for survivability of the first filter stage.

- Activate the automatic deluge system manually as soon as possible.
- The decision to activate the system should be made by the Fire Department sector officer.
- Limited available data indicate that early activation is not beneficial in reducing the potential for smoke-induced plugging for those plena equipped with fog jet nozzles for automatic deluge. This recommendation should not be implemented for those plena.

4. Remedial Action for First Stage HEPA Filters

Report recognized that the recommendations both imply some credit for initial effectiveness of the first stage filters and allow the first stage to be challenged to the point of failure.

- When only a single stage of filters is credited in an accident analysis, the tested stage should not be the first stage.
- Evaluate DOP testing data and monitor failure trends in first stage filters.
- Identify and implement practical means of providing periodic surveillance to ensure the integrity of untested filter stages.
- Provide a recommendation with technical justification and cost-benefit analysis for replacing the first stage of HEPA filters for Buildings 371, 559, and 707 that are credited in their authorization basis. This analysis may include other options, such as including these replacements in the B371 Interim Storage Upgrades (94-3)

5. Adequacy of Fire Fighting Strategy

- Include explosion control as a priority objective in Fire Department operating procedures and pre-fire plans

- Include instructions and restrictions for use of hose lines on the final filter stage.
- Conduct emergency response drills.

Plenum Deluge System Functionality Issues

1. Continuation of Manual Deluge Testing

- Immediately extend the testing frequency for systems with non-UL listed valves.
- For the longer term, consider application of the extension allowed by NFPA 25 to increase the test frequency.
- Perform a cost-benefit study of modifying the manual deluge systems to not deliver water (or other aqueous agents) to HEPAs during manual testing for Buildings 371, 559 and 707, or investigate alternative fluid testing means (e.g., air or nitrogen flow, indication, and spray patterns).

2. Adequacy of Plenum Deluge System Design

- Conduct an engineering evaluation to determine the severity of the potential for deluge system plugging.

3. Items for Further Investigation

- Perform tests to determine the effect of the automatic deluge system in conjunction with the demister screen on particulate removal to determine fire conditions, if any, that warrant deluge activation prior to 190° F.
- Consider modification of systems to allow for earlier automatic actuation based on the results of the above testing, expected facility life, and mission.
- Particulate, rather than temperature sensors, should be considered for automatic actuation.

Authorization Basis Issue

- Evaluate the effects of early automatic deluge system activation on current criticality safety controls.
- Determine if intentional failure of the first credited stage of HEPA filters is an unanalyzed condition in Buildings where two stages of filtration are credited. Modify these authorization basis documents as appropriate.

VIII. Conclusion Summary

Service Life Study:

- The test data does not support replacement of HEPA filters solely on age.
- HEPA filters show a wide variability of measured parameters between and within manufacturing.
- Wetting of HEPA filters produces a significant reduction of the physical properties of the filter.

Team Report:

- Under normal operations, the filter will function as required.
- Fire prevention in the exhaust system should be the focus of efforts.
- The fire suppresser systems in the plenums should be maintained.

Engineering Operability Evaluation (Exhaust Plenum)

- A more stringent maintenance program must be adopted - strainer cleaning, etc.
- Testing frequency should be lengthened on automatic system based on historical data (min-1year).
- Testing of the manual system should be extended to 3 years with the entent of discontinuing testing.

USQD

- Water on testable stage is a positive USQ in three buildings.
- The acceptance Building Leak Path Factor (BLPF) is not exceeded in any of the three buildings.

Implementation Plan:

- Revise plenum fire system tests procedures.
- Discontinue wetting of HEPA filters.
- Revise fire fighting procedures.
- Address USQD and Authorization Basis Requirements.
- Cost benefit study on replacement testing stage HEPA filters that had been wetted during manual fire spray testing.