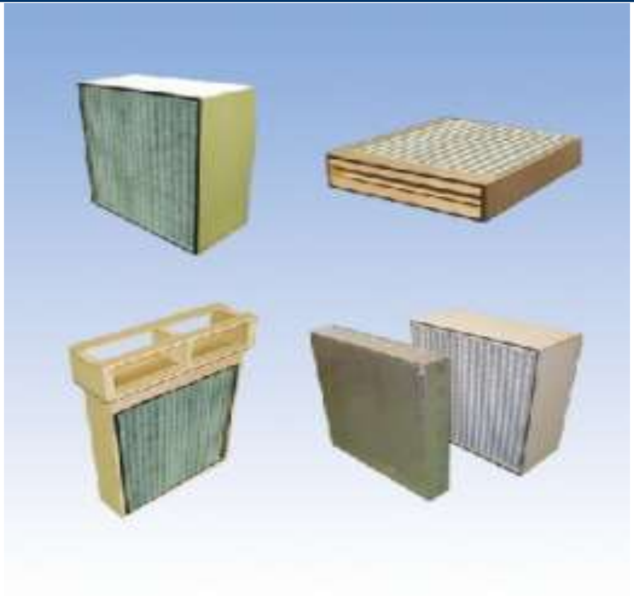
Worthy Activated Carbon fiber filter
(WAC Filter)

For the use at nuclear power plant



Wakaida Engineering, Inc.

Contents

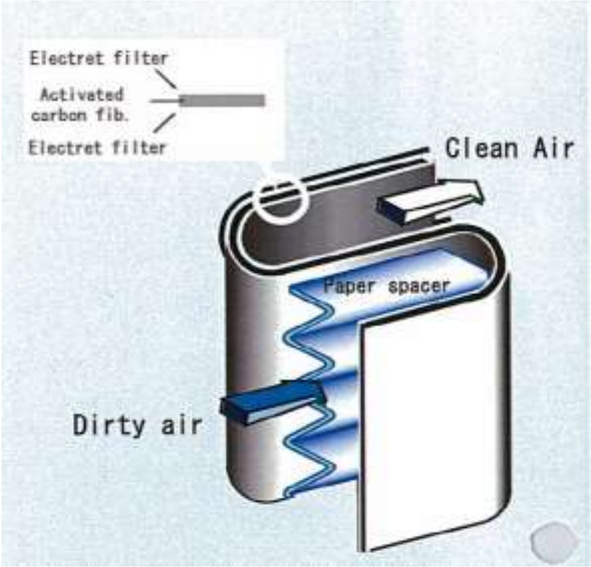
1．Outline of Worthy Activated Carbon fiber filter（WAC filter)

[Structure]

WAC Filter is a composite filter; Put activated carbon fiber filters between the electret unwoven cloth filters to prevent scattering coal dust and hold them. The composite filter material is supported with paper separators. This activated carbon fiber filter is newly developed for the capture of radioactive iodine and methyl iodine. This filter material is thin and accordion-folded. Thus the surface speed is smaller, collection efficiency became larger, and material stabilization will be better than conventional filters.

[Specialty]

The collection efficiency of WAC filter（Type-K , TEDA – impregnated, 3 layers）is more than 99.999% tested on United States examination standard（ASTM D-3803）. The efficiency change is almost nothing even under high humidity condition and the deterioration by the atmosphere weathering is very small . Thus, WAC filter can keep high collection efficiency so long time. All the materials used in WAC filter are non hazardous and can be incinerated without any problem. The volume reduction ratio of 1／1,100 after incineration gives significant reduction of radioactive waste disposal cost after use of the filter.
Moreover, WAC filter can be transported and handled safely and easily as the weight is less than 1／3 of conventional type, i.e. granular activated carbon filter.



＜Comparison table between WAC Filter and granular activated carbon filter 1＞

Table 1（standard type）

Items		WAC Filter （WAC-292）	Granular type activated carbon filter （W-25C）
Dimension	mm	610×610×292	610×610×290
Volume	ℓ	107.9	107.9
Total weight	kg	13	40
Throughput	m^3/min	28	28.3
Type of activated carbon		Type-K(3 layers)	AAF-2701
Raw material		Synthetic fiber	Coconut shell
Micro pore radius	nm	0.4～1.0	0.4～10,000
Impregnant		10% TEDA	3% TEDA 2% $KI+I_2$
Activated carbon weight	kg	6.73	21
Filtering area	m^2	6	1.35
Activated carbon layer thickness	mm	10.5	25.4
Filtration speed	m/sec	0.08	0.35
Passing time	sec.	0.13	0.07

Items		WAC Filter （WAC-292）	Granular type activated carbon filter （W-25C）
CH_3I collecting efficiency	%	More than 99.999%	97%
Pressure loss (Initial)	Pa	250	254
Weathering		More than 98% after 360days	Less than 98%after 120days
Recommended replacement cycle	year	3 years (8 hr／d)	1 year (8 hr／d)
Outer frame		Plywood	Plywood
Separator		PE coat paper	ABS resin porous plate
Ignition point	℃	421	487.8
Treatment after use		Can be incinerated	Can be incinerated
Volume after incineration		1／1,169	1／94
Quality control		ASTM D-3883 test for each lot	ASTM D-3883 test for each lot
Effect from humidity		99.999% of adsorption ratio at 95% humidity	82% of adsorption ratio at 95% humidity
Adsorbent desorption		Minimum	Big possibility
Easiness of handling		Easy	Difficult

＜Comparison table between WAC Filter and granular activated carbon filter 2＞

Table 2（Tray type）

Items		WAC Filter (WAC−292)	Granular type activated carbon filter (W−25C)
Dimension	mm	620×702×163	616×700×160
Volume	ℓ	70.9	69.0
Total weight	kg	11	35
Throughput	m^3/min	9.5	9.4
Type of activated carbon		Type−K（3 layers）	AAF−2701
Raw material		Synthetic fiber	Coconut shell
Micro pore radius	nm	0.4～1.0	0.4～10000
Impregnant		10% TEDA	3% TEDA 2% KI＋I_2
Activated carbon weight	kg	3.33	19
Filtering area	m^2	3.9	0.84
Activated carbon layer thickness	mm	10.5	50.8
Filtration speed	m/sec	0.08	0.20
Passing time	sec.	0.13	0.25

Items		WAC Filter (WAC−292)	Granular type activated carbon filter (W−25C)
CH_3I collecting efficiency	%	More than 99.999%	99.82%
Pressure loss (Initial)	Pa	250	250±73
Weathering		More than 98% after 360days	Less than 98% after 120days
Recommended replacement cycle	year	3 years (8hr／d)	1year (8hr／d)
Outer frame		Plywood or Aluminum	Steel or stainless plate
Separator		Wave type Aluminum plate	—
Ignition point	℃	421	487.8
Treatment after use		Can be incinerated（after Aluminum removal）	Storage（Cannot be incinerated ）
Volume after incineration		1／300	—
Quality control		ASTM D−3883 test for each lot	ASTM D−3883 test for each lot
Effect from humidity		99.999% of adsorption ratio at 95% humidity	82% of adsorption ratio at 95% humidity
Adsorbent desorption		Minimum	Big possibility
Easiness of handling		Easy	Difficult

Wakaida Engineering, Inc.

2. Practical application history

Cooperation between Wakaida Engineering and University of Tokyo

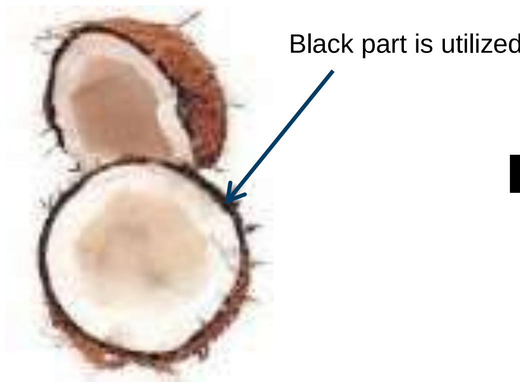
- ■2001 — Confirmation and evaluation of iodine adsorption capacity by University of Tokyo
- ■December 2003 — License application as the adsorption filter for radioactive inorganic iodine to Japanese government
- ■December 2004 — Awarded license after the additional submission of adsorption test data on radioactive methyl iodine（Type-G, KI impregnated）
- ■March 2005 — Awarded license as combustible filter after the test at Takizawa Institute of Japan Radioisotope Association
- ■October 2006 — According to the safety confirmation by Nuclear Safety Technology Center, maker recommended replacement cycle and its basis were submitted
- ■March 2007 — Announcement of long life type WAC filter（Type-K TEDA impregnated）
- ■April 2007 — According to the safety confirmation, data of long life type WAC filter were submitted additionally to Nuclear Safety Technology Center
- ■July 2010 — Patent granted

Wakaida Engineering, Inc.

（1）Shape and principle

■ Outer view（Raw material⇒Product）

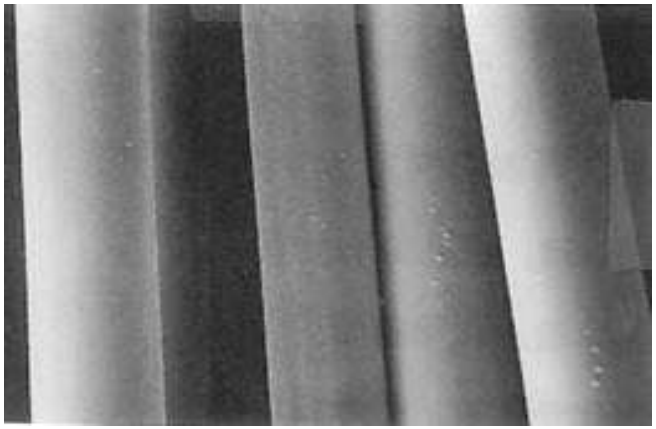
- **Conventional granular activated carbon (coconut shell)**



- **Activated carbon fiber (WAC）**

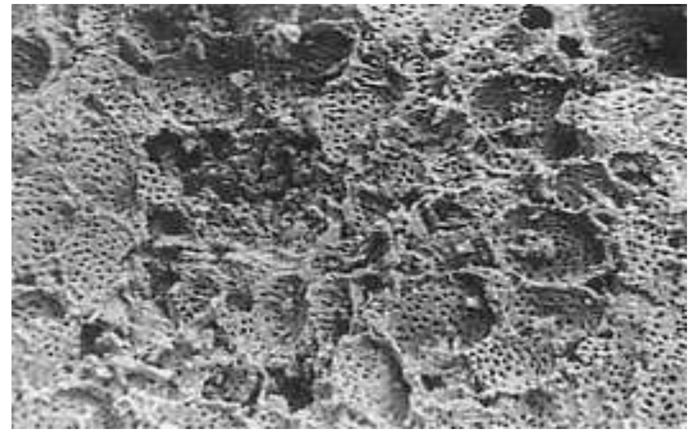
Photomicrograph

Activated carbon fiber



Fibrous smooth surface

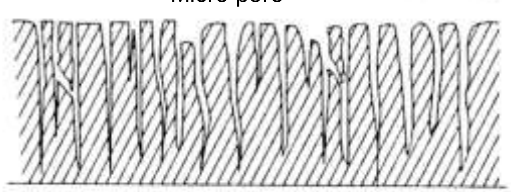
Granular activated carbon



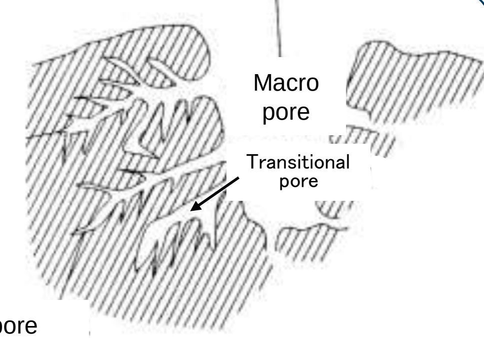
Highly unevenness with big and small holes

Micro pore model of activated carbon

Micro pore



Activated carbon fiber



Micro pore

Granular activated carbon

Wakaida Engineering, Inc.

<Principle of iodine adsorption by activated filter>

Surface of granular activated carbon is classified as outer surface and internal surface consists of inner wall of pores. Macro pore has the radius of more than 25nm and functions to collect adsorbate from outside to inside. Transitional pore has the radius of 1~25nm and mainly functions to bring adsorbate into micro pore but partially functions for adsorption. Micro pore has the radius of 0.4~1nm and most of micro pores contribute to adsorption, and thus control adsorption performance.

Generally, the mechanism of eliminating smells in air and impurities in water by activated carbon is that innumerable pores, large and small, take the molecules and impurities into pores and trap them tightly. The principle of the trap of radioactive iodine gas (Iodine sublimes under room temperature and changes to gas) is same. Namely, radioactive iodine gas penetrates into innumerable pores, large and small, on the surface of activated carbon and keeps such state for long time. This state is called as physisorption.

The degree of radioactive iodine gas physisorption is significantly different between inorganic one and organic one. Most of inorganic radioactive iodine gas can be trapped in activated carbon by physisorption, while almost no organic radioactive iodine gas can be trapped by such a way. In this case, organic radioactive iodine gas can be trapped by chemical reaction by micro pore as the catalyst which is formed by the impregnation of chemical substance containing non-active iodine on activated carbon. This method is called as chemical adsorption. Thus, radioactive iodine gas is trapped by both physisorption and chemical adsorption.

<Mechanism of trapping radioactive iodine gas>

① Inorganic radioactive iodine (physisorption)

Inorganic radioactive iodine ($^*I_2$) is trapped on activated carbon and kept stably, thus desorption hardly occurs.

② Organic radioactive iodine (chemical adsorption)

A. In case KI or I_2 is used as impregnant

Radioactive iodine in radioactive methyl iodide ($CH_3{}^*I$) makes isotope exchange reaction with nonradioactive iodine in impregnant and remains in activated carbon.

$$KI + CH_3{}^*I \rightarrow K{}^*I + CH_3I \qquad I_2 + CH_3{}^*I \rightarrow {}^*I_2 + CH_3I$$

B. In case triethylenediamine (TDEA) is used as impregnant

Radioactive iodine in radioactive methyl iodide ($CH_3{}^*I$) makes chemical reaction catalyzed by micro pore of activated carbon, and produces quaternaty ammonium compounds (solids) which is retained by activated carbon

$$N(CH_2CH_2)_3N + 2\,CH_3{}^*I \Rightarrow {}^*I^- + [\,CH_3N(CH_2CH_2)_3NCH_3\,]\cdot{}^*I^-$$

Activated carbon is gradually deteriorated due to the decrease of adsorption area caused by the adsorption of water vapor, SO_2, NO_2 and etc in air.

(2) Collection efficiency

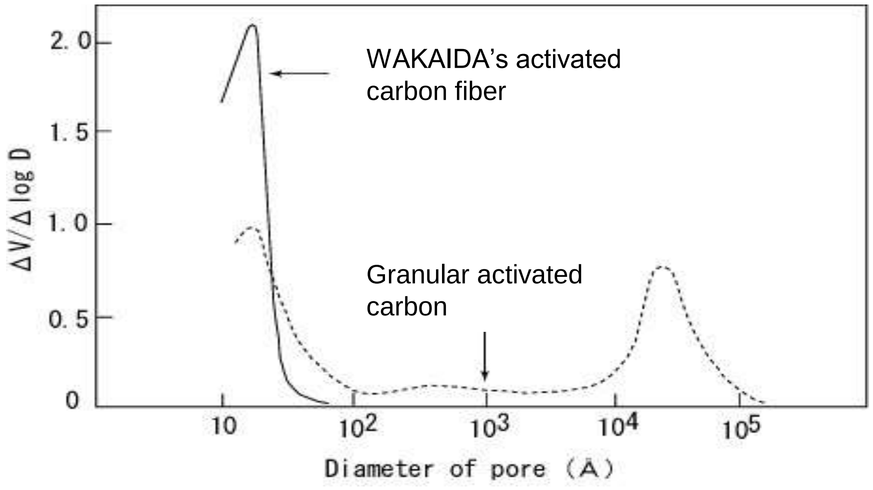
Activated carbon fiber filter (WAC-292 and etc) developed by WAKAIDA Engineering Inc. has specially high adsorption capacity compared with conventional granular activated carbon filter due to following reasons.

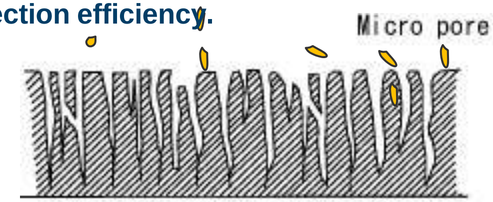
■ Conventional granular activated carbon has 3 kinds of pores consist of micro pore which has the radius of 0.4～1nm and contributes adsorption, macro pore which has the radius of more than 25nm, and transitional pore which connects both pores. Macro pore and transitional pore account for almost all pore surface area. It is said that macro pore mainly traps water droplets into the pore and the droplets block adsorbate invasion into micro pore. On the other hand, the surface of activated carbon fiber is covered by only micro pores which have even pore size and contribute adsorption.

■ It is said that the specific surface of all pores of granular activated carbon is 900～1,500 ㎡/g. Contrastingly, surface of activated carbon fiber is covered by only micro pore and the specific surface is 1,000～2,000 ㎡/g. This means that the number of micro pore is more than 1000 times larger than granular activated carbon.

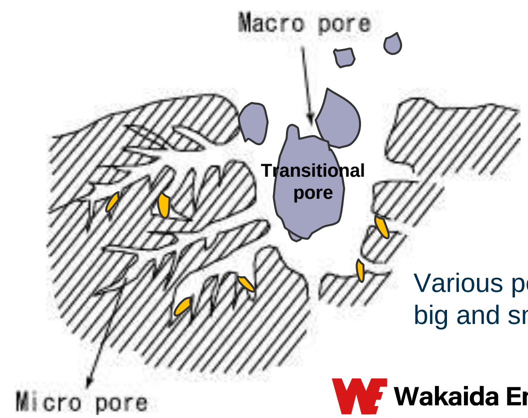
■ Thanks to the thin filter media of activated carbon fiber filter, the number of accordion fold can be increased. Therefore ,the filtration area is 4 times larger than granular activated carbon filter. This means that activated carbon fiber filter can lower filtration speed and longer reaction time, then gives high collection efficiency.

Distribution condition of pores of activated carbon





Can make uniform pore size artificially (10～20Å)



Various pore size, big and small

Wakaida Engineering, Inc.

＜Performance standard＞

■ In Japan, there is no performance standard for activated carbon used for the removal of radioactive material. Then, Standard Test Method for Nuclear-Grade Activated Carbon（ASTM D-3803） is used as the international standard for testing initial efficiency .

Deterioration test conditions under high humidity/20 hours

Adjustment of equilibrium preparation time（Pre-steaming）	960min （16hours）
Adjustment of equilibrium time (Steaming)	120min （2hours）
Methyl iodide injection time	60min （1hour）
Elution/separation time	60min （1hour）
Chemical form（radioactive iodine）	$CH_3{}^{131}I$
Temperature	30 **℃**
Humidity	95 **%**

Required collection efficiency for nuclear application（ASME AG-1）; More than **97%**

■ WAC Filter satisfies the standard as measured collection efficiency according to the above procedure is more than 99.999%.

ASTM：American Society for Testing and Materials
ASME：American Society of Mechanical Engineers

Wakaida Engineering, Inc.

■ Test results of nuclear grade activated carbon from coconut shell (TEDA impregnated)

NCS CORPORATION
1385 West Goodale Boulevard Columbus, Ohio 43212
Tel. 614-340-3700
FAX 614-340-3707

RADIOIODINE RETENTION / PENETRATION / EFFICIENCY TEST REPORT

CLIENT ______ PURCHASE ORDER NO. ______
TEST REPORT NO. ______
SAMPLE NO. ______

SAMPLE IDENTITY ______
Date Sampled N/A Date Tested ______

TEST CONDITIONS:		TEST METHOD: Run per ASTM D3803-1989	
Temperature	30 °C	Duration of Post Sweep	60 minutes
Pressure	101 kPa	Pre-Equilibration Time	16 hours
Relative Humidity	95%	I^{131} Content	0.2 uci
Face Velocity	12.2 m/min.	Chemical Form I^{131}	Methyl Iodide
Adsorbate Concentration	1.75 mg/m3	Equilibration Time	120 Minutes
Duration of Loading	60 minutes	S.D. Total Counting Error	0.006 %

RADIOIODINE TEST RESULTS AT:	% RETENTION	%PENETRATION	%EFFICIENCY
1"	___ %	___ %	___ %
2"	___ %	0.18 %	99.82 %
4"	___ %	___ %	___ %
	___ %	___ %	___ %

Standard Deviation
1st 2" Canister 73.487
2nd 2" Canister 3.035
3rd 2" Canister 0.866
4th 2" Canister N/A

NCS Distribution
(1) Lab File
(1) QA File

CERTIFICATE OF CONFORMANCE
The above test was performed in accordance with current revision of NCS-178 and with the above referenced purchase order.

APPROVED BY/TITLE DATE TEST PERFORMED

Face velocity cm/sec	**20**
Thickness of bed cm	**5.08** **(2 inch)**
ASTM D-3803 collection efficiency %	**99.82**
Penetration %	**0.18**

Wakaida Engineering, Inc.

■ Test results of activated carbon fiber（TEDA impregnated)

— Commercialized as WAC filter with 3 layers —

Test Results [3]

Actual & Standard Deviation

	Bed 1		Bed 4
Penetration	**0.570%** ± 0.026	Penetration	**<0.001%** ± 0.008
Efficiency	**99.430%** ± 0.026	Efficiency	**>99.999%** ± 0.008
	Bed 2		Bed 5
Penetration	**0.008%** ± 0.017	Penetration	**<0.001%** ± 0.008
Efficiency	**99.992%** ± 0.017	Efficiency	**>99.999%** ± 0.017
	Bed 3		Bed 6
Penetration	**<0.001%** ± 0.013	Penetration	**<0.001%** ± 0.008
Efficiency	**>99.999%** ± 0.013 ○	Efficiency	**>99.999%** ± 0.008

[3] The standard deviation indicated above is associated with the precision of the radio-iodine measurement process. The actual accuracy of the penetration result must be estimated from interlaboratory bias and precision data used to support the ASTM standard. For the ASTM standard, this data indicates that for laboratories which rigorously follow the test method, the relative standard deviation of a 1% penetration result is approximately ±25% and of a 10% penetration result is approximately ±6%. (Ref. ASTM D3808-1989)

Performed By ______________ Date 30 June 2008

Gregory J. Glasco ANSI N45.2.6 Level II since Oct 2002

Approved By ______________ Date 30 Ju 08

Joseph C.Enneking ANSI N45.2.6 Level III since June 1987

1

Face velocity cm/sec	**8**
Thickness of Bed 3 (3 layers) cm	**1**
ASTM D-3803 Collection efficiency %	**More than 99.999**
Penetration %	**<0.001**

Confirmed collection efficiency of more than99.999% at the face velocity of 15cm/sec and 20cm/sec

↓

Development of large air volume type

（Refer to next page）

Test results by NUCON along with the principle of ASTM D-3803

（No test procedure is available for activated carbon fiber）

Wakaida Engineering, Inc.

NUCON International, Inc.

I-Lab ID#	R838	NUCON	13FUTO3518/1
Client:	Wakaida Engineering Inc	P.O.	13027
Plant:		Rel. No.:	
Sample ID:	ACF TYPE-K FILTER	Test Date:	29-Apr-2009
System ID:			

Standard(s): **ASTM D3803-1989**

Parameter	Nominal Conditions[1]	Actual Conditions[2]
Pre-Equilibration Time (min)	960	960
Equilibration Time (min)	120	120
Challenge Time (min)	60	60
Elution Time (min)	60	60
Challenge Agent	CH3I	CH3I
Agent Concentration (mg/m³)	1.75	1.75
Test Bed Depth (mm)	3.5*	3.5
Test Bed Diameter (mm)	50	50
Number of Beds	6*	6
Pre-Equilibration Temp. (°C)	30	29.93 ± 0.04
Equilibration Temp. (°C)	30	[illegible]
Challenge Temp. (°C)	30	[illegible]
Elution Temp. (°C)	30	[illegible]
Velocity (m/min)	9*	9.00 ± 0.00
Relative Humidity (%)	95	94.79 ± 0.06
Pressure (kPa)	101.3	100.79 ± 0.19

9 m/min = 15 cm/s

[1] Tolerances are in accordance with the listed test method(s) and NUCON 13-248 Rev. 2.
[2] Actual Value or Time Weighted Average ± Standard Deviation as applicable
*Denotes a condition specified by the client that is an exception to the test method(s).

Test Results [3]

Actual & Standard Deviation

	Bed 1		Bed 4
Penetration	**0.164%** ± 0.004	Penetration	**<0.001%** ± 0.000
Efficiency	**99.836%** ± 0.004	Efficiency	**>99.999%** ± 0.000
	Bed 2		Bed 5
Penetration	**<0.001%** ± 0.000	Penetration	**<0.001%** ± 0.000
Efficiency	**>99.999%** ± 0.000	Efficiency	**>99.999%** ± 0.000
	Bed 3		Bed 6
Penetration	**<0.001%** ± 0.000	Penetration	**<0.001%** ± 0.000
Efficiency	**>99.999%** ± 0.000	Efficiency	**>99.999%** ± 0.000

[3] The standard deviation indicated above is associated with the precision of the radio-iodine measurement process. The actual accuracy of the penetration result must be estimated from interlaboratory bias and precision data used to support the ASTM standard. For the ASTM standard, this data indicates that for laboratories which rigorously follow the test method, the relative standard deviation of a 1% penetration result is approximately ±25% and of a 10% penetration result is approximately ±6%. (Ref. ASTM D3803-1989)

Performed By: ~~Gregory J. Glasen~~ LUCAS PRIMEL — ANSI N45.2.6 Level II since Oct 2002 — Date: 1/ May 2009

Approved By: Curtis E. Graves — ANSI N45.2.6 Level III Since Sept 1986 — Date: 01 May 2009

Available for use as large air volume type（50m³/min）

NUCON International, Inc.

I-Lab ID#	R839	NUCON	13FUTO3518/2
Client:	Wakaida Engineering Inc	P.O.	13027
Plant:		Rel. No.:	
Sample ID:	ACF TYPE-K FILTER	Test Date:	30-Apr-2009
System ID:			

Standard(s): **ASTM D3803-1989**

Parameter	Nominal Conditions[1]	Actual Conditions[2]
Pre-Equilibration Time (min)	960	960
Equilibration Time (min)	120	120
Challenge Time (min)	60	60
Elution Time (min)	60	60
Challenge Agent	CH3I	CH3I
Agent Concentration (mg/m³)	1.75	1.75
Test Bed Depth (mm)	3.5*	3.5
Test Bed Diameter (mm)	50	50
Number of Beds	6*	6
Pre-Equilibration Temp. (°C)	30	29.95 ± 0.04
Equilibration Temp. (°C)	30	[illegible]
Challenge Temp. (°C)	30	[illegible]
Elution Temp. (°C)	30	[illegible]
Velocity (m/min)	12*	12.00 ± 0.03
Relative Humidity (%)	95	94.78 ± 0.07
Pressure (kPa)	101.3	102.26 ± 0.09

12 m/min = 20 cm/s

[1] Tolerances are in accordance with the listed test method(s) and NUCON 13-248 Rev. 2.
[2] Actual Value or Time Weighted Average ± Standard Deviation as applicable
*Denotes a condition specified by the client that is an exception to the test method(s).

Test Results [3]

Actual & Standard Deviation

	Bed 1		Bed 4
Penetration	**0.403%** ± 0.005	Penetration	**<0.001%** ± 0.000
Efficiency	**99.597%** ± 0.005	Efficiency	**>99.999%** ± 0.000
	Bed 2		Bed 5
Penetration	**<0.001%** ± 0.000	Penetration	**<0.001%** ± 0.000
Efficiency	**>99.999%** ± 0.000	Efficiency	**>99.999%** ± 0.000
	Bed 3		Bed 6
Penetration	**<0.001%** ± 0.000	Penetration	**<0.001%** ± 0.000
Efficiency	**>99.999%** ± 0.000	Efficiency	**>99.999%** ± 0.000

[3] The standard deviation indicated above is associated with the precision of the radio-iodine measurement process. The actual accuracy of the penetration result must be estimated from interlaboratory bias and precision data used to support the ASTM standard. For the ASTM standard, this data indicates that for laboratories which rigorously follow the test method, the relative standard deviation of a 1% penetration result is approximately ±25% and of a 10% penetration result is approximately ±6%. (Ref. ASTM D3803-1989)

Performed By: ~~Gregory J. Glasen~~ LUCAS PRIMEL — ANSI N45.2.6 Level II since Oct 2002 — Date: 1 May 2009

Approved By: Curtis E. Graves — ANSI N45.2.6 Level III Since Sept 1986 — Date: 01 May 2009

Available for use as flat tray type（no accordion fold ）

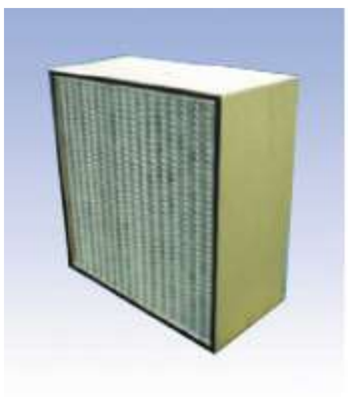
■ Collection efficiency of various filters

Collection efficiency test results (initial efficiency) under the temperature of 30℃ and the humidity of 95%（ASTM D-3803 ：1989）

● Tray shaped granular activated carbon filter 2 inch layer thickness（9.4m^3/min）	99.8%
◎ Tray shaped WAC filter（9.4m^3/min）	More than 99.999%
◎ Standard WAC filter（28m^3/min）	More than 99.999%
◎ Large air volume WAC filter (50m^3/min)	More than 99.999%
◎ Hybrid WAC filter（28m^3/min）	More than 99.999%

■One large air volume type WAC filter equals 9 granular activated filter (2inch W type）in adsorption and collection capacity

(Calculated assuming that the air volume is more than 50m^3/min ÷17m^3/min = 2.9 units, and the life time is more than 12 months÷4 months＝3)



＝

(3) Iodine amount adsorbed

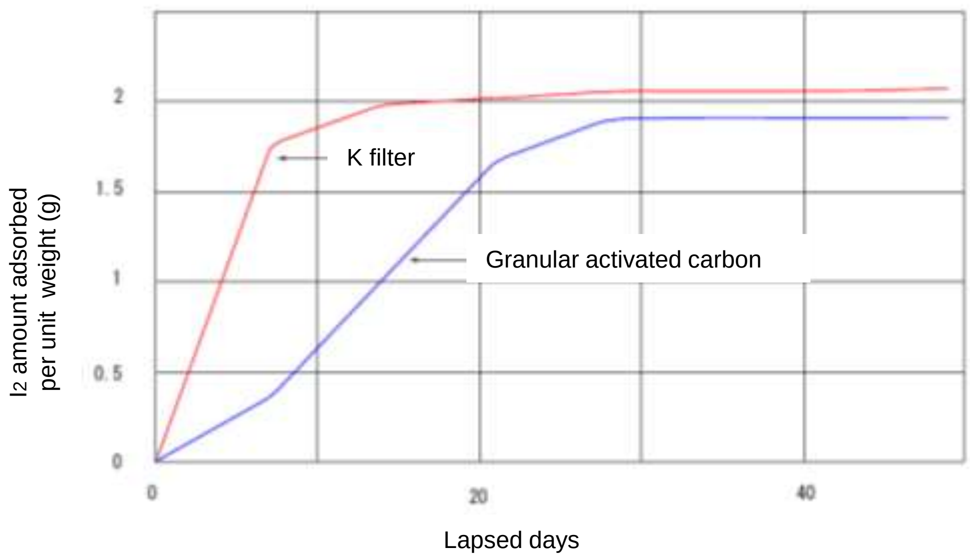
■ Static testing results

Following test results on iodine gas adsorption were obtained when activated carbon fiber and granular activated carbon were set in the desiccator filled with Methyl iodine. The results seems to be caused by the strong adsorption and containment due to the intermolecular forces (Van der Waals force).

- Saturated in 15 days for activated carbon fiber, while 30 days for granular activated carbon
- Adsorption speed of activated carbon fiber was very high, more than 3 times higher than granular activated carbon at initial stage
- Iodine amount adsorbed was equal to 83TBq／cm^2 for activated carbon fiber

(Note)
Although iodine has the characteristics of easy vaporization and diffusion, iodine is heavier than air. Therefore, good result can be expected to prevent pollution expansion if activated carbon fiber sheet is used for floor protection.

I_2 adsorption static test for activated carbon fiber and granular activated carbon



Methyl iodine static adsorption in desicator
（Type-K：Adsorption media test）

■ Kinetic testing results

Break through test results are shown as follows. The test was implemented using activated carbon fiber filter adding methyl iodine from upstream, and analyzing permeated methyl iodine at downstream.

・Removal efficiency (collection efficiency) of more than 99% was kept until the amount of methyl iodine loading reached to 0.55ml/cm^2.

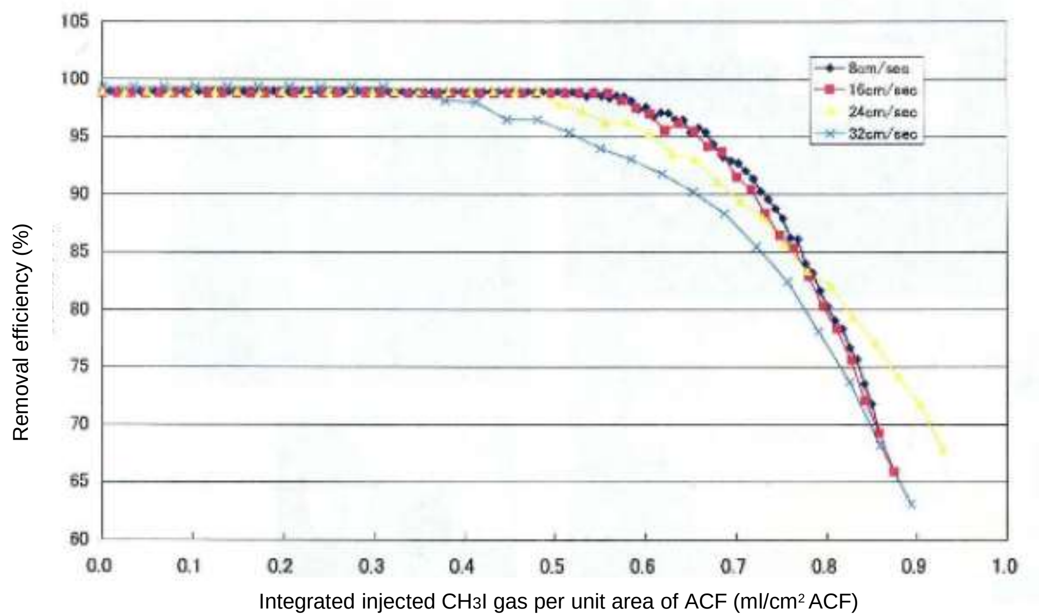
・The amount of collected iodine by activated carbon fiber filter **WAC-292**（610×610×292mm）was equal to 14.7TBq/cm^2. Therefore, the amount of collected iodine per 1 filter unit（adsorption area is 6m^2）can be 14.7TBq × 60,000 = 882PBq. This means approx 24 million Ci .（It is said that approx 50 million Ci of radioactive iodine was released to atmosphere during the accident at Chernobyl NPS. (refer to the calculation in next page)

・Desorption test was implemented to measure the amount of released radioactive CH_3I and elapsed time by adding 3% of CH_3I at the flow rate of 20ml/min for 40 sec to activated carbon fiber filter already loaded with radioactive iodine. As the result, desorption ratio was kept below 0.5% even after 30 min. This means that adsorbed CH_3I can be trapped in activated carbon fiber so long time.

・ As the result of adsorbate transfer test to measure the transfer speed of radioactive iodine adsorbed in activated carbon filter with elapsed time, transferred iodine was 30.8g/cm^2 in 68.1 days for activated carbon fiber filter, while 71.78g/cm^2 in 60 days for granular activated carbon filter. Although the thickness of adsorbent is different, transfer rate of radioactive iodine adsorbed by both activated carbon fiber filter and granular activated carbon filter are almost same. In addition, both transfer speed change is not affected significantly by adsorbent thickness since the slope of the curves in the graph is almost parallel each other.

・We have test results implemented by ORNL (Oak Ridge National Laboratory) regarding the effect of humidity on the removal efficiency of radioactive methyl iodine using granular impregnated activated carbon. According to the results, removal efficiency starts to decrease when the humidity exceeds approx 80%, and drops to 95% at 90% humidity. Then removal efficiency drops to 82% at 95% humidity, and rapidly drops to 5% at 100% humidity.
On the other hand, according to the results of methyl iodine adsorption test using activated carbon fiber filter (WAC) implemented by NUCON, marvellous adsorption efficiency was measured to be 99.999% at 95% humidity.

Break through test on activated carbon fiber filter (ACF)



＜Calculation of total amount of adsorbed iodine＞

From above graph, total adsorbed iodine up to the collection efficiency decreases to 99% was $0.55 ml/cm^2$.
Number of molecules is 6.0×10^{23} per 1mole and the volume of 1mole gaseous molecule is 22.4×10^3 ml in standard condition. Then, number of molecules of 0.55ml of gaseous methyl iodine adsorbed in1cm^2 is;

$$6.0 \times 10^{23} \times 0.55/(22.4 \times 10^3) = 1.47 \times 10^{19}$$

Therefore, the number of iodine atoms is also 1.47×10^{19}. Next, substitute the half life of ^{131}I (8.02days= 692928sec) into the equation of radioactive decay, $dN/dt = \lambda N = 0.693/T \times N$ while, λ: decay constant ,T : half life (sec) , N: number of atoms. As the result, adsorbed radioactivity of ^{131}I is;

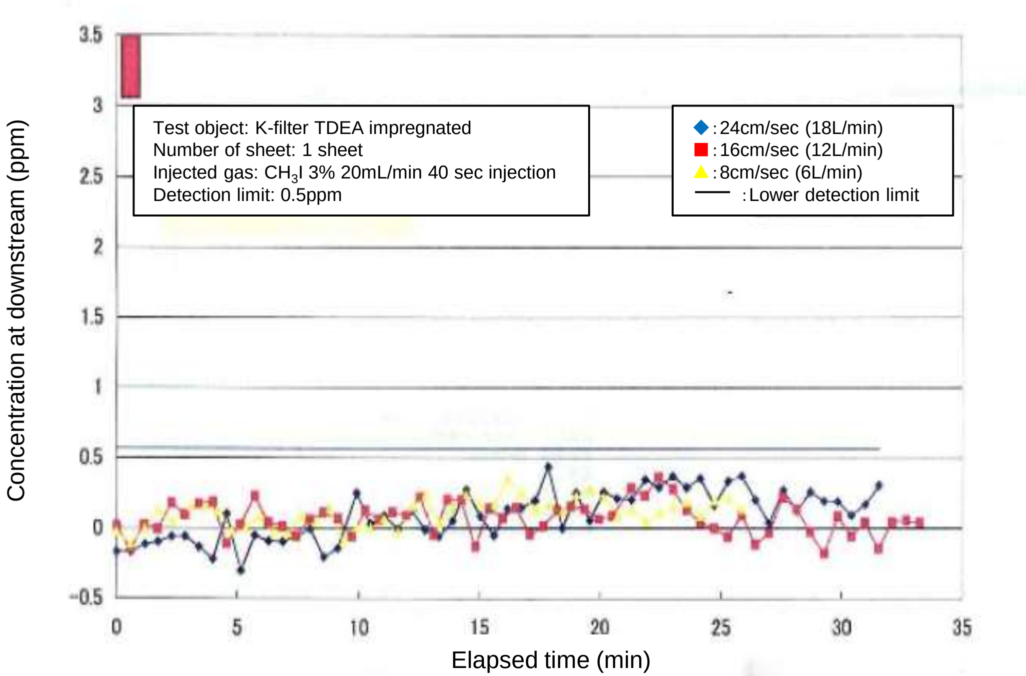
$$dN/dt = 0.693/692928 \times 1.47 \times 10^{19} = 1.47 \times 10^{13} Bq \ (= 14.7 TBq)$$

Since adsorption area of WAC－292 is $6m^2$ per unit, adsorbed radioactive iodine by 1 filter unit is as follows.

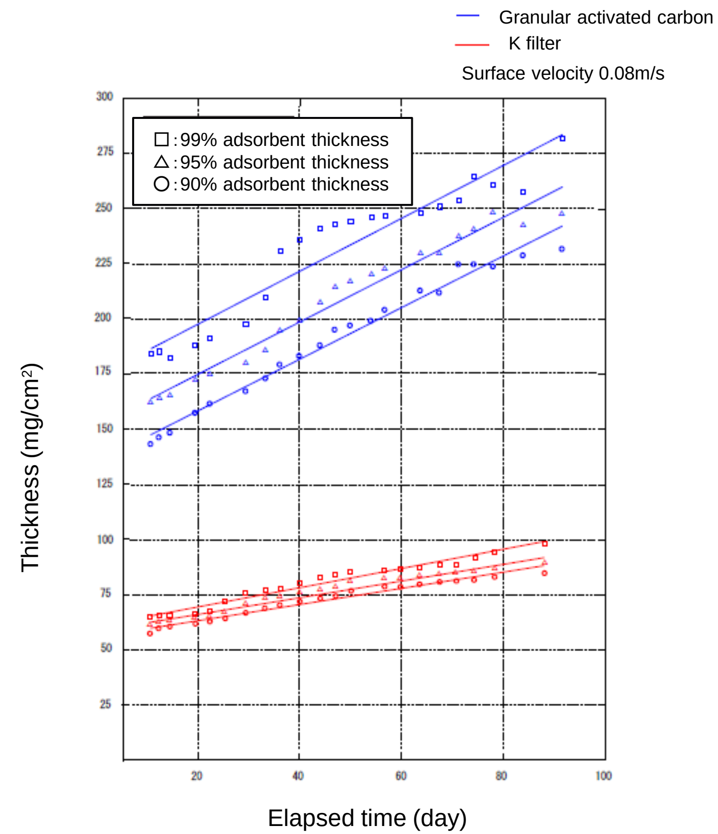
$$1.47 \times 10^{13} Bq/cm^2 \times 60,000 cm^2 = 8.82 \times 10^{17} Bq = 882 PBq \fallingdotseq 24 \text{ million } \mathbf{Ci}$$

Wakaida Engineering, Inc.

Desorption test of activated carbon fiber

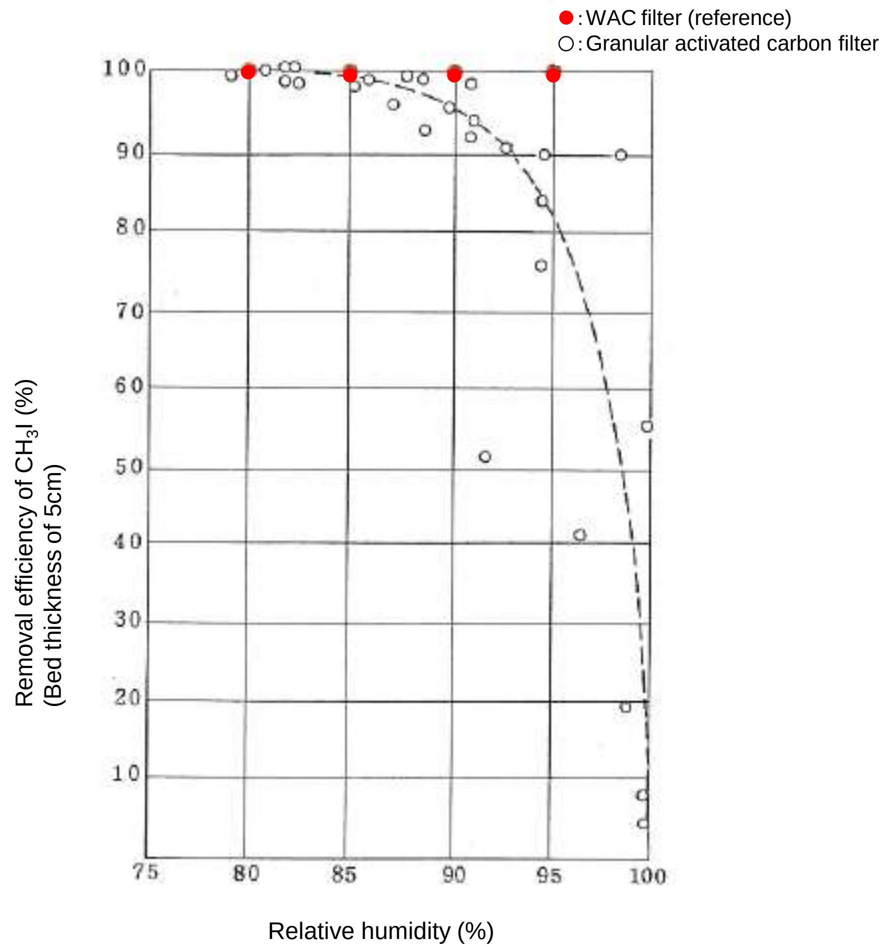


Comparison of ^{131}I transfer speed adsorbed in activated carbon



Wakaida Engineering, Inc.

Effect of humidity on organic iodine removal efficiency of granular impregnated activated carbon



Effect of humidity on organic iodine removal efficiency of impregnated activated carbon

Reference
ORNL-4180 "Removal of Radioactive Methyl Iodine from Steam-Air Systems"

Wakaida Engineering, Inc.

(4) Weathering

■ Activated carbon filter is deteriorated not only by iodine but also by interfering substance in atmosphere (mostly humidity, another SOx, NOx, and etc)

■ Weathering test (room temp, approx 60% humidity) showed 3 times longer life time of activated carbon fiber filter compared with granular activated carbon filter.

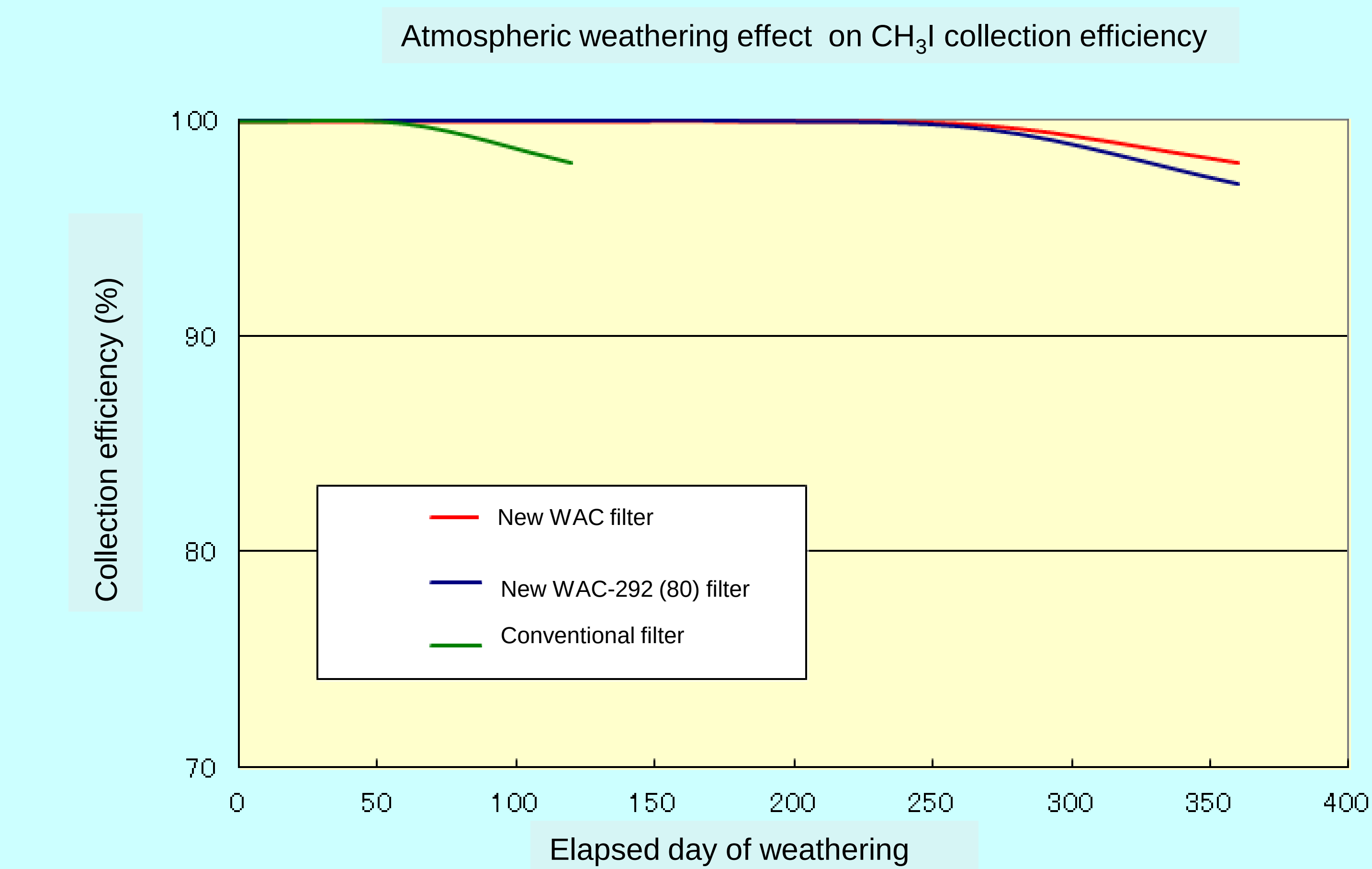
- 1967 Oak Ridge National Laboratory tested under room temp and approx 50% humidity
- 1972 Japan Atomic Energy Res. Inst. tested under 15～25℃ and 40～60% humidity

Granular activated carbon filter (50mm thickness layer) is deteriorated to 98% in 4 months

- TOYOBO research institute tested under 25℃ and 60% humidity
- University of Tokyo isotope center tested under room temp and more than 90% humidity

Activated carbon fiber (WAC) filter kept more than 98% of performance for 12 months.

■ Activated carbon fiber (WAC) filter can be operated 8 hours /day for **more than 3 years.**



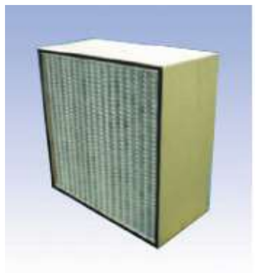
Activated carbon fiber: Felt type, Type-K Surface velocity: 8cm/sec, humidity: 60%, impregnant: TEDA (triethylenediamine)
WAC-292 (80) filter can be used for permeability of 0.2 as applied.

(5) Incineration disposal

■ **WAC is combustible and the volume can be reduced． Volume after incineration is below 1/1,000**

(Demonstrated by Japan Radioisotope Assoc. using incinerator made by NGK)

WAC filter is combustible but safe due to high ignition temperature (421℃) (ASTM D-4069)



＝

After incineration: 38 ℓ× 1/1,000 =0.04 ℓ
= ¥400

Incombustible:72 ℓ× 9units = 648ℓ
= ¥6,480,000

※ Comparison of activated carbon only without outer frame
(Frame is made of stainless steel)

■ Approx 3000 pieces (equivalent to 200L) of spent activated carbon filters generated from RI facilities for 5 years from 2002 to 2006 have been stored at Japan Radioisotope Assoc., but have not been incinerated. Only 315 pieces generated from medical facilities have been incinerated.

■ At nuclear power stations, spent activated carbon filters have not been incinerated and have been stored in each site.

Granular activated carbon grinder（to below 80μm）

Air pre-heater（incineration mixed with propane gas）

Wakaida Engineering, Inc.

■ Incineration processing of WAC filter

Filter crusher

Crushing of WAC filter

After crushing（Glove box）

After crushing（1/20）

Feeding to incinerator（ self-sustained combustion type）

※In case of granular activated carbon filter, blanking from outer frame is necessary instead of crushing （same as HEPA filter）

Following application can be considered.

- Primary Containment Vessel Air Cleaning System (BWR･PWR)
- Annulus Air Cleaning System Iodine Removal Unit（PWR）
- Stand-by Gas Treatment System [SGTS]（BWR･PWR）
- Main Control Room Emergency Recirculation System（BWR･PWR）
- Fuel Pool Exhaust Gas Filter（BWR･PWR）
- Exhaust Gas Treatment Unit for S/G maintenance（PWR）
- Off-gas（Kr, Xe）hold-up system（BWR･PWR）
- Working Space Local Air Cleaning Unit for periodical inspection and maintenance
- Air Intake System for Important anti-seismic building, off-site center, etc

For the application, following technical issues should be examined.

- Adaptation with ASME AG-1, ANSI N509, NRC Regulatory Guide 1.52, etc
- Adaptation with design basis accident
- Adaptation and consideration with severe accident
- Conformity with HVAC design

Presentation Material

Wakaida Engineering, Inc.

Items mentioned in this material regarding numerical values and data are based on the information available at the preparation stage of this material.