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AEC RESEARCH AND DEVELOPMENT REPORT

PERFORMANCE OF ACTIVATED CARBON BEDS IN SRP REACTOR CONFINEMENT FACILITIES

PROGRESS REPORT
SEPTEMBER 1962 - SEPTEMBER 1965

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Aiken, South Carolina

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PERFORMANCE OF ACTIVATED CARBON BEDS IN SRP REACTOR CONFINEMENT FACILITIES
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ABSTRACT

The efficiency of activated carbon beds for removal of elemental iodine remains greater than the design efficiency of 99.9% after ~2 years of continuous exposure to exhaust ventilation air from Savannah River Plant reactor buildings. Because of corrosion of both the cadmium-plated and the painted mild steel frames that contain the carbon, replacement units are being fabricated of Type 304L stainless steel.

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INTRODUCTION

Confinement systems for nuclear installations should be inspected and tested periodically to ensure that the systems perform as specified. Examinations of the entire confinement facilities of the production reactors at the Savannah River Plant (SRP) are performed at regularly scheduled intervals. The purpose of this report is to describe the performance of one part of the system, the activated carbon beds for removal of halogen vapor.

This report describes tests to determine if elemental iodine removal efficiency remains equal to or greater than the design value of 99.9% for activated carbon that has been in service for about 2 years. Also discussed are inspections for corrosion and mechanical damage and revisions to specifications for carbon and carbon bed frames.

Earlier reports[1,2] described the SRP confinement system, and a brief description is included in this report. Development of the activated carbon beds[3] and final acceptance tests for each bed[4] are also summarized.

SUMMARY

The efficiency of activated carbon used at SRP for removal of elemental iodine remains above the design efficiency of 99.9% after ~2 years of continuous exposure to exhaust ventilation air. About 2/3 of the available adsorption capacity remains to maintain the design efficiency. NO_2 is probably the primary contaminant that reduces the iodine adsorption efficiency. Drying the carbon with hot, flowing air desorbs volatile impurities and increases the efficiency of used carbon to about 99.98%.

Both cadmium-plated and painted mild steel frames, which hold the carbon, are corroding from attack by compounds of nitrogen. Corrosion to a lesser extent also results from sulfur compounds. The compounds are present in exhaust air in trace quantities, but are concentrated by adsorption on the carbon.

The design of the carbon bed frames has been improved to increase air flow area and to incorporate Type 304L stainless steel to retard corrosion. The new frames should have a long life expectancy.

DISCUSSION

BACKGROUND

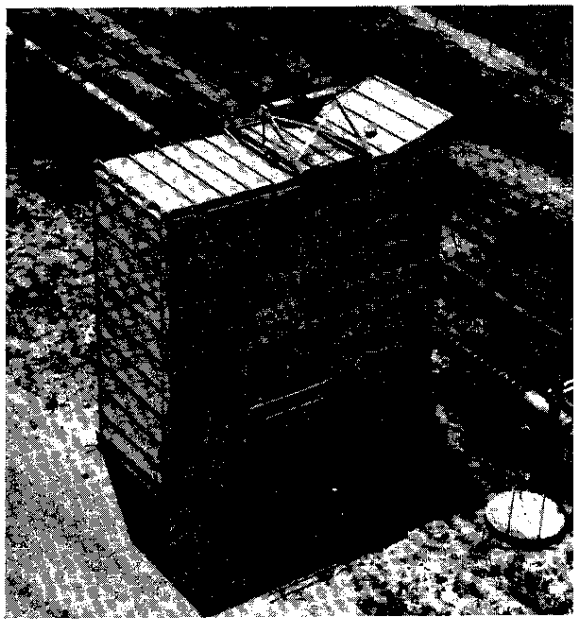
The exhaust ventilation system of the Savannah River Plant (SRP) reactors is equipped with filtration and adsorption units to confine radioactive contamination in the unlikely event of a major nuclear incident. The system consists of moisture separators to remove entrained water, particulate filters to remove 99% of the solid matter, and activated carbon beds to remove 99.9% of the halogen vapor activity. Filter compartments (Figure 1) are mounted on the roof of each reactor building. Each compartment contains moisture separators, water-repellent particulate filters, and activated carbon beds in the ratio of 5 to 8 to 8, respectively, as shown in Figure 2. Should a major release of fission products occur and deposit on the filters, the compartments can be delatched from the system after adequate decay has occurred, pulled along rails to the edge of the building, removed by a crane, and transported to a burial ground.

A program was undertaken by the Savannah River Laboratory (SRL) in 1961 to develop specifications for units of the system. In late 1962, the first facilities were erected in the reactor areas. Tests, design details, and specifications for moisture separators and particulate filters are described in Reference 5. Development of activated carbon beds is described in Reference 3, and a photograph of a typical bed is shown in Figure 3.

Originally, about 250 activated carbon beds were fabricated of cadmium-plated mild steel. Cadmium is a common industrial plating material that is normally quite serviceable for controlling corrosion from atmospheric moisture. For purely economic reasons, later units were fabricated of mild steel and painted with phenolic and epoxy coatings, as described in the Appendix, with a cost savings of about $30 per bed. Both types have corroded badly as described on page 12.

Prior to purchase of any units, samples of activated carbon were tested to ensure that specifications in Reference 3 were met. The results are shown in Tables A-II and III of the Appendix. Each bed was leak tested individually prior to plant installation by procedures described in Reference 4. "Freon-12"* was injected upstream of the bed and penetration was measured by an electron capture detector. More than 800 beds had leaks $\leqslant 0.01\%$ while only one bed was rejected because of leakage in excess of the specified maximum of 0.1%.

* "Freon" and combinations of "Freon-" or "F-" with numerals are Du Pont's registered trademarks for its fluorinated hydrocarbons.



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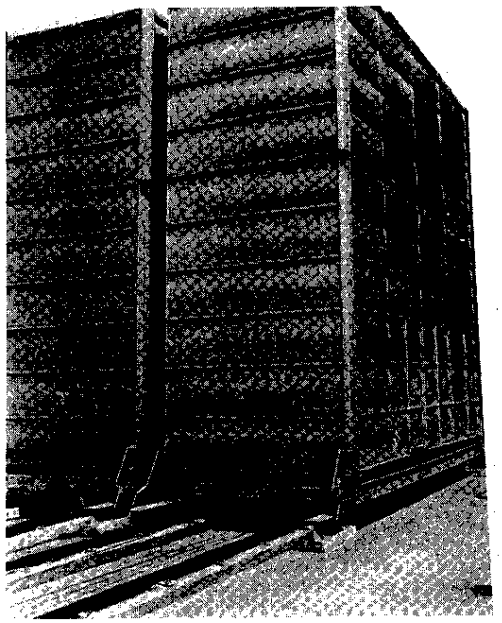
Filter Compartment Prior to Installation



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Filter Compartments in Operating Position on Reactor Building Roof

FIG. 1 SRP FILTER COMPARTMENTS

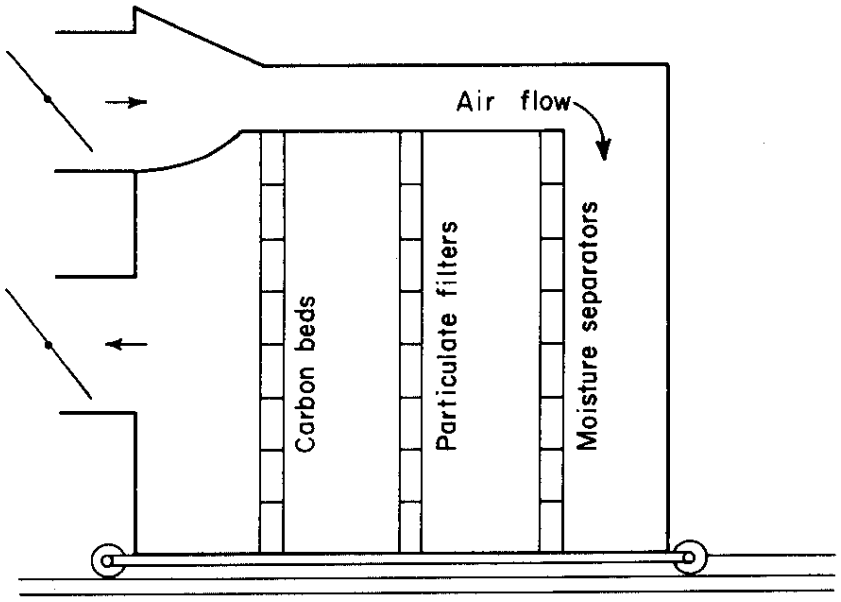


FIG. 2 SCHEMATIC OF SRP FILTER COMPARTMENT

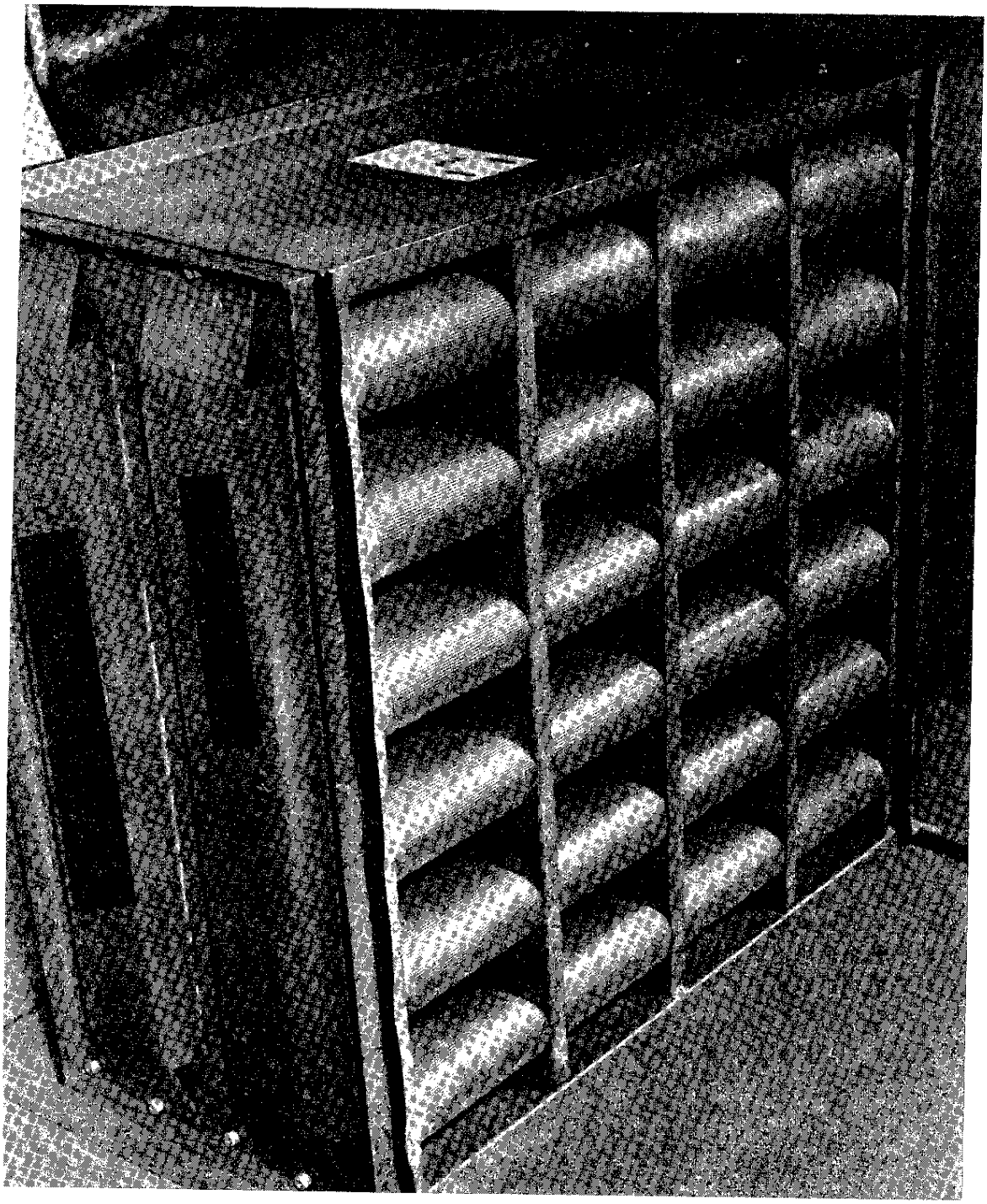


FIG. 3 SRP ACTIVATED CARBON BED

Normally, one filter compartment is off-line for inspection and maintenance while the remaining banks are continuously on-line. The exposure is shown in Table I.

TABLE I

On-Line Exposure of Activated Carbon Beds as of August 1965

Area	Cadmium-Plated Units, months	Painted Units, months
R(a)	15	-
P	28	18
L	28	18
K	28	16
C	-	20

(a) Not now in operation.

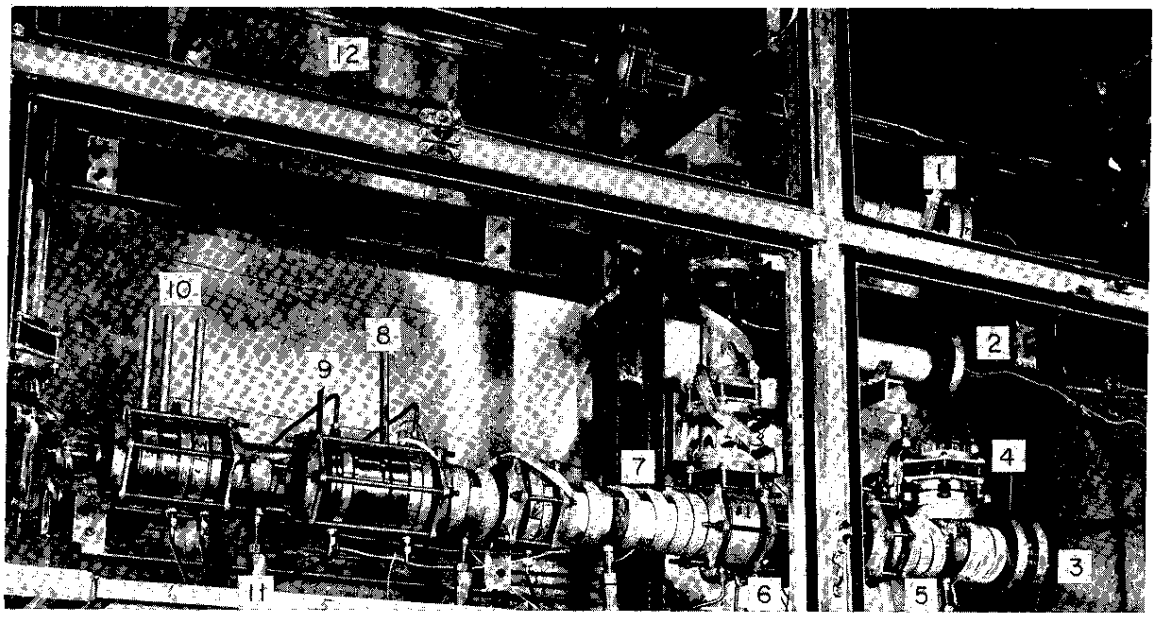
To determine the effects of in-service exposure on efficiency and life of activated carbon, an interim procedure was adapted for destructive testing of one bed annually from each reactor area. This type of test shows the efficiency and capacity of the used carbon for iodine. Leak paths in the beds that could reduce the iodine removal efficiency will be detected with an in-line "Freon-112" leak test of the entire bank of installed beds. The "Freon" test, which is non-destructive, was recently developed by SRL[6,7,8,9].

IODINE ADSORPTION EFFICIENCY

Equipment and Procedures for Small-Scale Tests

The facility shown in Figure 4 was used to determine iodine removal efficiencies for activated carbon in both air and steam-air environments. Normally the equipment shown in the figure is insulated with one-inch-thick "Fiberglas"* to retard condensation. The equipment and procedures were similar to those described in Reference 3, except in two respects. First, a 2-inch-thick moisture separator of "Teflon"**

* Owen-Corning Fiberglas Corp.
** Du Pont's trademark for its fluorocarbon plastic.



1. Steam supply
2. Main air supply
3. Bypass air supply
4. Iodine source
5. Typical heating tape
6. Moisture separator
7. Particulate filter
8. Test carbon bed
9. Particulate filter
10. Backup carbon beds
11. Typical of 6 condensate drains
12. To vacuum pump

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FIG. 4 IODINE-131 TEST FACILITY

fibers woven on stainless steel wire was installed between the upstream particulate filter and the steam supply. This reduced blinding of the particulate filter with condensate and produced a system that mocked up the reactor installation.

Second, the carbon granules were packed in small test beds in approximately the same relative location as in the full-size bed; that is, those granules which were at the upstream face of the production unit were packed at the upstream face of the test bed. All carbon from a fold of the full-size bed was removed for a depth of about 3 inches and discarded to prevent use of material which may have been protected from the main airstream by baffles or unperforated metal.

For special tests where migration of sorbed contaminants was studied, only granules from specific bed locations were used.

Results

Test results are summarized in Table A-I of the Appendix. The following conclusions were drawn:

- The efficiency of the carbon for removal of elemental iodine after ~2 years of exposure is better than the design objective of 99.9%.
- Drying partially expended carbon with hot flowing air desorbs volatile impurities and increases the iodine adsorption efficiency to about 99.98%.
- Contaminants in the carbon that reduce efficiency migrate through the bed even at room temperature. Initially, the material is sorbed in greatest concentrations on the front face of the bed. Although the efficiency at the front face may be low, the overall efficiency of the bed still remains high.
- Iodine loading on the carbon did not affect the efficiency within the range tested. Tests were run with loadings in excess of those probable for a major incident.
- The probable mechanism of reduction in efficiency is that NO_2 reduces to NO in the presence of carbon. Irrecoverable adsorption sites are lost by the oxidation of carbon, and recoverable sites are occupied by the NO that adsorbs after the NO_2 is reduced.

Analysis of Impurities

Several mass spectrometric tests were made to determine impurities that could contribute to reduction in adsorption efficiency and corrosion of frames. Analyses were made of carbon grains, rust from corroded frames, and gas desorbed from the carbon.

About a tenfold increase in iodine, chlorine, and sulfur on used carbon, compared to new carbon, was indicated from spark-source mass spectrometric tests on single granules. The tests showed only the elements present and not the compounds. These impurities may have some minor bearing on corrosion and iodine adsorption efficiency, but these quantitative effects have not been established. Probable sources within the reactor areas of the impurities are: iodine and sulfur from coal burned in power houses in the reactor areas, and chlorine compounds from degreasing operations with trichloroethylene in the assembly areas of the reactor buildings.

Qualitative analysis of rust from the front face of an R-Area bed showed $S^{=}$ and NO_3^-.

Mass spectrometric analyses were made on gas that was vacuum-extracted at ~100°C from carbon grains. The analyses of gas from R, P, L, and K-Area carbon showed as much as 7 mol % NO, the primary constituent that apparently affects both the corrosion and the degradation in efficiency. The sensitivity of the analysis, however, is about 100 ppm; hence, trace impurities are not detected by this method. Qualitative analysis with a gas chromatograph and electron capture detector[4] of air samples from used carbon confirmed that trichloroethylene ($Cl_2C{:}CHCl$) is sorbed on the carbon. Although other impurities were observed in much lesser amounts, identification was not attempted.

Effect of NO_2 on Iodine Adsorption Efficiency

Accelerated tests were made on the effects of NO_2 on iodine adsorption efficiency to obtain information for estimating the effective life of activated carbon. NO_2 diluted with bottled breathing air was pumped through carbon to obtain the desired exposures. The results are shown in Table II.

TABLE II

Results of Tests with Carbon Exposed to NO_2

Test No.	1	2	3
Exposure, hr	18	84	138
Air flow, cfm	0.6	0.6	0.6
Accumulative weight[a], g NO_2 per g carbon	0.10	0.55	0.80
Iodine adsorption efficiency in steam-air test, %	99.99+	99.99+	79

(a) Assumes 100% of NO_2 adsorbed on carbon.

The tests show that a saturation effect with a sharp drop in adsorption efficiency occurs, although the exact saturation value has not been determined. Test 2 indicated a lower efficiency than Test 1; however the precision of the tests did not justify showing the difference in the table. These results indicate the desirability of periodic retesting of systems where a high degree of reliability is necessary.

Because of the small quantity of NO_2 in the exhaust air from the reactor building and the insensitiveness of available analytical methods, the service life equivalent to the accelerated tests has not been determined. Use of more sensitive analytical methods and equipment is being studied.

INSPECTION OF IN-SERVICE UNITS

An inspection of the filter compartments in each reactor area was performed, beginning during the summer of 1964, and is summarized in Table A-IV in the Appendix. In R- and P-Areas, all cadmium-plated frames were corroded on the upstream face after 15 months of service. Most of the corrosion was concentrated on the sections of perforated screen through which air passes. These sections were completely coated with loose rust, both on the inner and outer surfaces.

The most severe corrosion occurred on L-Area cadmium-plated units. After 15 months of service, rust deposits were sufficiently thick on the beds to completely obscure holes in the perforated metal screens. Modest quantities of loose rust had blown through the beds and were deposited on the compartment floor downstream from the carbon beds and in folds of the downstream perforated screens after 20 months. Loose rust on the face of beds is of no consequence in the spread of contamination unless the rust penetration is coincident with the arrival of iodine at the carbon bed, which is extremely unlikely. After the second inspection, one bed was removed for closer examination. When the carbon was removed, a split about 6 inches in length was seen in the perforated screen. No loss of carbon, however, had occurred through this split.

In contrast to other reactor areas, cadmium-plated frames in K Area had almost no corrosion after 15 months of on-line service. Only three beds in one bank showed any rusting, which occurred in spots ($\sim$25 in^2) on the perforated screens inside the folds. After 20 months of service, all of the cadmium-plated beds were rusted over the entire perforated screen area through which air passes, but the spacing fingers and baffled areas of the screen were not corroded. In 28 months, most of the upstream surface area of the beds was rusted, but no loose rust was found on the downstream face.

During the first inspection of C Area (7 months service), traces of corrosion were found on only two carbon beds with painted frames (where paint had been marred). After 12 months, C-Area painted frames showed minor, but progressively increasing signs of corrosion. On the upstream faces, numerous rust spots existed on spacing fingers that position the screens, and in all locations where paint was marred. The third inspection (16 months service) revealed a general deteriora-

tion of the paint film on the front perforated screen on the inside and outside faces.

Perforated screens on P-Area painted units were more severely corroded after about 15 months of exposure than were those in C Area. Approximately 75% of the screen area was coated with rust. One P-Area painted bed screen was split similarly to the one in L Area. The split probably occurred during maintenance work in the compartment. Destructive testing of the damaged unit showed that the metal was embrittled and tended to tear rather than bend when subjected to sharp blows.

Corrosion of the downstream perforated screens in all reactor areas was much slower than on the upstream screens. After about 2 years, the color of the screens became yellow, and after about 28 months, minor rusting of cadmium-plated screens was observed.

Based on these inspections and examinations of individual units, the following is concluded to be the sequence of the progression of corrosion: The first deterioration occurs on the inside of the front perforated screen adjacent to the carbon. Corrosion then progresses to the outer surface of the front screen, but primarily at sections of the screen through which air passes. The baffled section of the front screen and the spacing fingers then begin to corrode. Then the casing rusts on the upstream side. Finally, plating corrodes on the screen on the downstream side.

PROBABLE CAUSES OF CORROSION

Gases desorbed from used carbon contain NO. Radiolytic decomposition of atmospheric nitrogen adjacent to the reactor and subsequent reaction with oxygen and/or water results in NO_2, nitrous, or nitric acid. Although the materials are in the exhaust air stream in trace quantities, sorption on carbon permits a buildup sufficient to result in significant corrosion on framing members. The effect of increased concentration is further evidenced by the absence of corrosion in cadmium-plated particulate filters.

Analysis of rust from corroded cadmium-plated beds showed the presence of CdS, which was also indicated by the presence of the characteristic yellow color of the initial corrosion products on the frames.

NO_2 probably contributes more to corrosion than do sulfur gases because of the remoteness of sulfur gas sources, and because of a close correlation between air leaks in the space between the reactor

and the biological shield and the extent of corrosion. L Area, which has had consistently large leaks from this space, has the greatest corrosion. K Area, until about September 1964, had only a small leak from the space, and the corrosion was negligible. During the fall of 1964, the K-Area system was modified and 90 cfm of dry air is blown through the space to retard corrosion of the biological shield. This air is discharged into process areas, then into the filter compartments. Although the dry air reduces corrosion on metal surfaces adjacent to the reactor, the potential for NO_2 formation and subsequent deposition on the carbon is increased. After the system modification, the rate of corrosion of K-Area frames increased.

About 5 pounds of water is sorbed in a carbon bed at normal operating conditions[8]; that is, at about 60% relative humidity. As much as 15 pounds is sorbed at 100% relative humidity. Under operating conditions, no liquid water is present on the frames, but condensation on the bed frames can occur if the filter compartment is off-line, thus accelerating corrosion from dilute acid formation.

EVALUATION OF MATERIALS

Because of corrosion of existing bed frames, a new material for fabrication was selected. Several factors were important in the selection. Among these were: material and fabrication cost, corrosion resistance, and structural properties. Service requirements of SRP facilities are stringent:

- The design must ensure that the 1-inch thickness of the carbon bed will not be changed from buckling or warping of the screens.
- The casing must be fabricated to relatively close tolerances to prevent air from bypassing the carbon.
- The casing must withstand mishandling and warping. The ability of the present beds to withstand mishandling was demonstrated when a bed was dropped about 5 feet onto a concrete pad. The corner of the frame was bent, but the integrity of the carbon layer and the frame was not compromised. The unit still passed the required "Freon" leak test.

The requirement of corrosion resistance to NO_2 and SO_2 was not recognized until plant experience was obtained. The quantity of corrosive gases in the airstream is insufficient to be detected accurately by normal analytical methods; however the concentrating effects of the carbon became an important consideration. In a system where a carbon bed is not continuously on-line, corrosion is generally

of little consequence. For example, in the HWCTR[10], cadmium-plated carbon beds were corrosion-free after 1-1/2 years of standby service. In contrast, severe embrittlement of the carbon steel has occurred from intergranular corrosion of cadmium-plated units in SRP production reactor areas.

Not only must the units be fabricated of a material not subject to rapid intergranular corrosion from corrosive gases, but protection must be provided from forming an electrolytic cell between the carbon and metal. Type 304L stainless steel was chosen as the material of construction for replacement units because of corrosion resistance, structural properties, fabrication ease, and cost. Stainless steel components of small-scale carbon beds that had been exposed to exhaust air in K Area for 2 years showed no signs of corrosion.

Type 304 stainless steel units were estimated to cost about $15-$25 less per unit than Type 304L; however, Type 304 is subject to intergranular corrosion. Type 316L was also considered but was rejected based on a 50% greater cost than for Type 304L with no advantage in corrosion resistance.

Aluminum offers an advantage in material cost but is subject to corrosion. Zinc plating, or galvanizing, also corrodes in the presence of nitrogen compounds. Inert organic coatings over carbon steel, such as fluorocarbons, are difficult to apply and are easily scratched.

REPLACEMENT OF UNITS

All cadmium-plated and painted units will be replaced by units fabricated of Type 304L stainless steel and conforming to the specifications in the Appendix.

One experimental stainless steel bed has been installed in each reactor area. Upon receipt of production stainless steel beds, the cadmium-plated beds will be replaced first, followed by the painted beds when the iodine adsorption efficiency falls below 99.9% or corrosion of the frames becomes severe.

REGENERATION OF CARBON

Electric dryers are being installed in each filter compartment. The purposes of the dryers are to remove:

- Moisture from dust deposits on particulate filters to reduce pressure drop

- Volatile contaminants from carbon beds to partially restore iodine removal efficiency
- Sorbed H_2O from carbon beds to permit in-line "Freon-112" leak testing of used carbon beds[8]

When the efficiency is permanently reduced below 99.9%, the carbon may be dumped, and the frames decontaminated and returned to the vendor for repacking with new carbon.

As an alternative to new carbon, a study is being made of a commercial process for regeneration of carbon containing low-level contamination.

Early efforts to refinish corroded frames were unsuccessful because of embrittlement of the metal; however, decontamination methods were developed and repacking costs were obtained. The frames can be decontaminated by steam cleaning and baking at 250-300°C to remove trace tritium. The cost of decontamination, fresh carbon, and new gaskets is estimated at about $80 per bed. The effective service life of carbon has not been established; however, about 4 years appears reasonable. The frames are expected to have an indefinite service life.

IGNITION TEMPERATURE OF SRP CARBON

Heat from decay of radioisotopes of halogens increases the temperature of the activated carbon on which adsorption has occurred. If sufficient material is deposited on the carbon and cooling is not provided, the temperature of the carbon could rise to the ignition point. Preliminary tests showed that the ignition temperature of both new and used SRP carbon is about 360°C. A program is in progress to obtain an adsorbent with an even higher ignition temperature[11]. To protect against ignition, a minimum ignition temperature of 330°C (625°F) has been specified for carbon to be used in the present replacement stainless steel frames.

SRP carbon beds are cooled by air flow, which is ensured by highly reliable fans operating in parallel with redundant electrical power supplies. Two of three exhaust fans are operated continuously during reactor operation. All exhaust fans including the spare fan may be powered through the normal electrical supplies or from a separate diesel driven emergency generator. The exhaust fan system has never experienced an unscheduled stoppage in over 10 years of operation. Flow from one fan is far in excess of that required to permit ignition of the activated carbon as calculated by the method of Wilke and Hougen[12].

APPENDIX

SAVANNAH RIVER PLANT
SPECIFICATIONS FOR ACTIVATED CARBON BEDS
FOR REACTOR CONTAINMENT SYSTEM
(Revision-December 1965)

I. GENERAL

1.1 Drawings

Fabrication of the activated carbon beds shall be in accordance with these specifications and drawing number ST5-10545. Savannah River Plant, E. I. du Pont de Nemours & Co., Inc.

1.2 Application

1.2.1 Carbon beds are installed in casings that are erected in process ventilation exhaust systems. They are mounted with pleats horizontal on a vertical holding frame which is arranged with supporting and clamping devices so that 100% of the horizontal air stream flows through the beds.

1.2.2 The carbon beds are used in containment facilities for radioactive iodine vapor that might be released in the event of a reactor incident. The units are to be constructed with air-tight joints so that all of the air contacts the one-inch-thick carbon beds. Slight bypassing of the beds, permissible in conventional applications for odor control, is unacceptable for the subject carbon units.

1.2.3 The assembled carbon unit, when fully charged with activated carbon, shall pass 1000 S.C.F.M. of air with a pressure drop of about 0.8 in W.G. The direction of flow shall be indelibly marked on one of the casing members that is permanently welded to the pleated section. This side will be designated TOP and so marked for shipping and installation purposes.

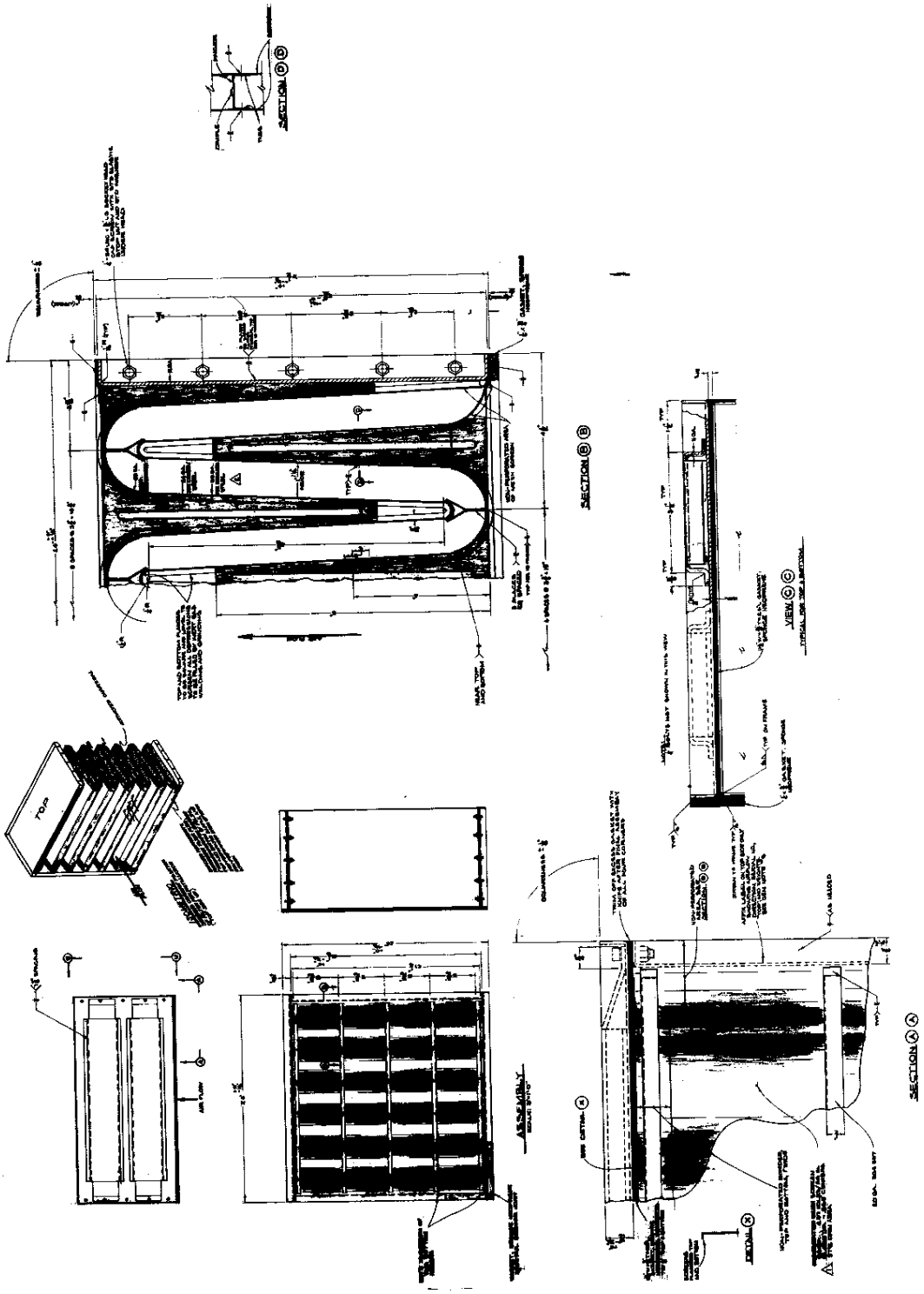
II. CONSTRUCTION

2.1 Casing

2.1.1 General

The units shall be built in accordance with the highest standards of workmanship and finish and be free from obscure and obvious flaws. Welds at flange and gasket surfaces shall be ground flush. Particular care shall be taken when installing gaskets that are required to prevent air from bypassing the carbon beds. Spacers shall not be installed within the carbon bed except as shown on drawing ST5-10545.

ST5-10545 - ASSEMBLY AND SECTIONS



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2.1.2 Air-Tight Seals

To prevent air from bypassing the carbon beds, air-tight seals shall be provided at all edges of the carbon bed in contact with the enclosing casing as follows:

Where the two end legs of the pleated carbon bed join their respective casing surfaces, the bed walls shall not be perforated. They shall be lapped into a flange and spot welded to the casing surface before assembling gaskets and neoprene sealing pads.

The two side casing surfaces shall be furnished with internal neoprene pads that are cemented to the casing flanges with the specified adhesive. These pads shall bear jointly on the flanged edges of the pleated carbon bed walls and on the mating casing flanges such that when assembled and bolted, compression of the pads will form the required air-tight seals.

2.1.3 Materials

2.1.3.1 Casing

The casing shall be fabricated of either Type 304L stainless steel or cold-rolled carbon steel, whichever is specified on the purchase order. Stainless steel should be specified for use in areas where NO_2 or SO_2 are present, even in trace quantities.

2.1.3.2 Gasketing Materials

Gasket materials shall maintain its integrity and resilient properties when subjected to air at 250°F. The flange gasket shall be ¼-inch thick by 3/4-inch wide, ozone-resistant neoprene sponge (15-20 durometer) of identical material specified below for the sealing pads. It shall be formed from die-cut gasket pieces for dove-tail mating. Mating surfaces of die-cut ends shall be coated with the specified adhesive and interlocked to form a flawless joint. Gaskets shall be firmly and continuously cemented to the upstream flange surface with the specified adhesive.

The sealing pads, cemented to the 24 in. by 11½-inch casing flanges, shall be fabricated of neoprene sponge 3/8-inch thick. They shall be completely cemented to the inner surfaces of their casing pieces with the specified adhesive.

2.1.3.3 Adhesive

The adhesive used for the gasketing and sealing pads shall be neoprene base and cured. It shall be resilient, water resistent, and resistent to

a minimum temperature of 250°F for 8 hours when cured. If capable of ignition, it shall be self-extinguishing and shall meet all operating conditions without change in physical properties and without loss of seal or strength. Adhesive shall not show cracks, checks, "alligatoring", or separation.

2.1.3.4 Finish

This section is applicable only to carbon steel units. Dip all sub-assemblies in phenolic coating (Tithcoat LC24 or Hanna XB8081 or equal), air dry, and then subsequently dry parts in oven. All parts are then sprayed with at least two coats of moisture resistant paint (Reliance 150-HB1-63 or Hanna XB-4357 Epon Black or equal) and baked in oven until dried. (Exception: mask areas which are to be spot welded or arc welded in subsequent operations.) After final assembly of parts, clean and neutralize welds, brush coat bare spots with phenolic coating, and then apply at least two additional coats of moisture resistant paint and bake in oven until dried.

2.2 Adsorbent Media

The adsorbent shall be new activated carbon made from coconut shells in accordance with the following:

2.2.1 Physical Properties

a. Particle size*: 10-14 range, Tyler mesh size, as per following distribution:

Mesh	Retention
8	0.1% Maximum
10	10.0% Maximum
14	88.9% Minimum
Through 14	1.0% Maximum

b. Packing Density: 34 lb/ft^3 nominal, bone dry carbon based on apparent density measurement method (laboratory measurement, 32-36 lb/ft^3 range-free fill).

c. Charge per unit: 53 lb (actual filled weight based on 2% sorbed water in carbon) minimum weight to be adjusted for water content measured at time of filling units - one test at the beginning of the use of each batch and repeating at the beginning of each day when a batch is used that was held over from the work the preceeding day.

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* As per methods described in Military Specification, MIL-C-13724A, dated May 4, 1960.

d. Fines: After packing, carbon fines and dust shall be blown from the unit with compressed air at a minimum nozzle velocity of 5000 fpm. Compressed air supply shall be free of oil, dust, and other contaminants. Nozzle orifice area shall be 0.8-in^2 minimum. Nozzle shall be fish-tail shaped and arranged so that the upstream screen surface of the entire pleated carbon bed, including the crevice at the apex of each pleat, can be blown with air. The direction of flow shall be the same as the installed air flow as marked on the top of the unit and specified in Section 1.2.3.

e. Hardness*: 97% minimum.

2.2.2 Chemical Properties**

a. Iodine number: Minimum of 1050 mg per gram of carbon.

b. Activity for carbon tetrachloride: 50% by weight, minimum.

c. Activity, Standard Accelerated Chloropicrin Test: 50 minutes minimum.

d. Retentivity for carbon tetrachloride: 30% by weight, minimum.

e. Ash content: 4% by weight, maximum.

2.2.3 Loading

The hopper used for loading the carbon unit shall provide a minimum of 3 ft of "free fall" for the carbon granules (excluding the height of the unit). There shall be at least three dispersal screens or baffles for scattering the falling granules in this 3-ft "free fall". The feed rate of the carbon through the hopper shall be as small as practically possible. During the initial filling operation, the unit shall not be vibrated. The unit shall be gravity filled half way with carbon and then vibrated for 30 seconds; after the initial vibration, the remaining volume of the unit shall be gravity filled with carbon and then vibrated again for 30 seconds; after the final vibration operation, carbon shall be added by gravity feed to fill all void spaces. As indicated in Section 4.1, this operation shall be witnessed by purchaser's representative.

III. TESTING

3.1 Physical and chemical tests specified in Sections 2.2.1 and 2.2.2 need not be witnessed by purchaser's representative. Tests confirming the specified properties shall be performed by the vendor on a representative sample from each 2000-lb carbon lot, and the certified results in 16 copies submitted to purchaser.

* As per methods described in Military Specification, MIL-C-13724A, dated May 4, 1960.

** For definition of tests, see Adsorption, C. L. Mantell, McGraw-Hill Book Co., New York, N. Y., 2nd Edition, 1951.

3.2 The carbon must have a high efficiency for the removal of iodine. The units are used in a containment facility for removing radioactive iodine that might be released during a reactor incident. Under incident conditions, the carbon could be exposed to air at 250°F, wet steam at 212°F, or mixtures of steam and air. In addition to the tests specified in Sections 2.2.1 and 2.2.2, the vendor shall submit a 5 lb representative sample of carbon to the purchaser for testing of iodine removal efficiency and ignition temperature. This carbon shall be certified as being representative of that carbon which the vendor will use in the carbon beds. The carbon shall remove 99.99+% of the iodine when exposed to a steam-air mixture at 160°F and flowing at a face velocity of 70 ft/min and with an iodine loading of 1 mg per gram of carbon.

The carbon must have an ignition temperature greater than 625°F under the following conditions:

Air velocity: 75 ft/min
Rate of heating: 2-4°F/min
Bed thickness: 1 inch
Bed diameter: 3½ inches with ¼-inch wide baffle on front and back sides
Apparatus: Stainless steel construction

3.3 All units shall be tested for leaks with "Freon"* or equal by purchaser prior to installation in the containment system. Testing shall be in accordance with that specified in AEC Research and Development Report, DP-870, "Nondestructive Test of Carbon Beds for Reactor Containment Application, Progress Report, June 1962 - Decenber 1963' Those units which are not acceptable (leaks greater than 0.1% of total bed flow) shall be returned to the vendor at the vendor's expense, for repair.

IV. SHIPPING

Each carbon unit shall be packed for shipment in substantial containers completely enclosing and protecting the units from physical damage during storage and shipping. They shall be palletized for convenience and economy in handling and shipping, and shall be stored and shipped with the TOP side up, as defined in Section 1.2.3. The carbon weight, carbon lot number, and bed serial number shall be indelibly marked on the casing.

4.1 Inspection

All units shall be inspected by purchaser's representative for quality construction and freedom from obvious and obscure flaws, before, during, and after charging. Particular attention will be directed to construction details affecting quality of air-tight seals and the loading operation.

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* Du Pont's registered trademark for its fluorinated hydrocarbons.

TABLE A-I

Iodine Tests Of Used Carbon Samples From SRP Reactor Areas

Test No.	Area	Bed Serial No.	Months of Service	Type Test	Efficiency, %	Bed Loading, mgI_2/g Carbon	Notes
113	R	24	14	Steam-air	99.95	1.3	(1,2)
114	R	24	14	Steam-air	99.92	0.9	(1,2)
115	R	24	14	Air	99.99	0.8	(1,2)
117	R	24	14	Steam-air	99.89	0.6	(1,2)
119	R	24	14	Steam-air	99.99+	0.5	(1,3)
122	R	23	14	Steam-air	99.98	0.5	(1,2)
123	R	23	14	Steam-air	99.98	0.4	(1,4)
124	R	23	14	Steam-air	99.98	0.4	(1,5)
111	P	114	15	Air	99.99+	1.6	(1,2)
112	P	114	15	Steam-air	99.99+	1.2	(1,2)
118	P	114	15	Steam-air	99.99+	1.2	(1,2)
133	L	132	20	Steam-air	99.97	0.4	(1,2)
134	L	132	20	Steam-air	99.99+	0.5	(1,6)
135	L	132	20	Steam-air	99.99+	0.5	(7,2)
136	L	132	20	Steam-air	99.99+	0.6	(8,2)
137	L	132	20	Steam-air	99.99	0.6	(9,2)
138	L	132	20	Steam-air	99.94	0.6	(10,2)
139	L	132	20	Steam-air	99.99	0.6	(11,2)
140	K	76	20	Steam-air	99.99+	0.6	(1,2)
141	K	76	20	Steam-air	99.89	0.7	(8,2)
143	K	76	20	Steam-air	99.60	0.4	(8,2,12)
144	K	76	20	Steam-air	99.93	0.6	(8,2,13,14)
145	K	76	20	Steam-air	99.96	0.6	(1,2)
146	K	76	20	Steam-air	99.92	0.6	(10,2)
120	C	668	7	Steam-air	99.99	0.6	(1,2)
121	C	668	7	Steam-air	99.99+	0.7	(1,2)

NOTES:

(1) Test bed was packed with 3 layers of carbon taken from the front, middle, and back of the 1" thick layer in the full-size bed.
(2) Carbon was not dried.
(3) Carbon was dried for 20 hr at 200°F and 70 fpm air flow.
(4) Carbon was dried for 24 hr at 200°F and 70 fpm air flow.
(5) Carbon was dried for 24 hr at 150°F and 70 fpm air flow.
(6) Carbon was dried for 16 hr at 150°F and 70 fpm air flow.
(7) Test bed was packed with carbon from the front 1/2" of full-size carbon bed.
(8) Test bed was packed with carbon from the front 1/8" of full-size carbon bed.
(9) Test bed was packed with carbon from the back 1/2" of full-size carbon bed.
(10) Test bed was packed with carbon from the center 1/3" of full-size carbon bed.
(11) Test bed was packed with carbon from the back 1/8" of full-size carbon bed.
(12) Carbon removed from full-size bed 1 wk after carbon removed for test No. 141.
(13) Carbon for tests No. 143 and 144 identical.
(14) Carbon was dried for 16 hr at 200°F and 70 fpm air flow.

Conditions for air test:
Duration of test: 2-1/2 - 3 hr
Face velocity: 70 ft/min
Temperature at test bed: ~35°C (~95°F)
Isotopic dilution: 1.5 mc ^{131}I per 100 mg ^{127}I

Conditions for steam-air test:
Duration of test: 2-1/2 - 3 hr
Face velocity: 70 ft/min
Steam flow: 1 ft^3/min
Temperature of test bed: ~68°C (~155°F)
Isotopic dilution: 1.5 mc ^{131}I per 100 mg ^{127}I

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TABLE A-II

Properties of Activated Carbon Used in SRP

Cadmium-Plated Beds

	Physical Properties						Chemical Properties***					
	Particle Size (Mesh Tyler)							Activity		%		
Batch No.	on 8	on 10	on 14	thru 14	Apparent Density	%** Hardness	Iodine No.	% CCl_4	Minutes P.S.	Retentivity CCl_4	% Ash	% Moisture
3	T*	9.7	89.8	0.3	0.590	99.4	1051.9	51.5	51.5	33.9	3.4	1.2
4	T	9.8	89.8	0.4	0.588	99.4	1068.3	51.4	51.0	33.9	1.8	1.3
5	T	9.6	89.9	0.3	0.583	99.0	1083.4	51.9	51.5	34.6	1.9	2.0
6	T	8.9	90.6	0.2	0.539	99.4	1196.4	60.5	57.2	37.6	2.2	1.7
7	T	9.7	90.0	0.3	0.560	99.6	1191.2	56.9	54.2	36.2	2.5	1.8
8	T	9.3	90.6	0.7	0.552	99.2	1166.6	53.5	51.8	39.6	1.9	2.0
9	T	5.3	94.3	0.8	0.556	99.6	1176.8	56.8	52.5	38.5	2.6	0.6
10	T	2.4	96.0	1.0	0.570	99.4	1188.4	57.8	53.4	37.8	2.1	1.9
11	T	3.4	94.2	0.9	0.554	99.2	1188.2	57.3	53.4	38.4	2.6	0.3
12	T	6.5	93.6	0.2	0.557	99.4	1175.7	55.8	52.0	38.4	2.9	0.4
13	T	8.6	91.1	0.4	0.550	99.3	1198.1	59.3	55.0	38.9	3.3	1.6
14	T	9.8	90.5	0.4	0.550	99.4	1199.2	58.0	54.9	38.6	2.8	1.2

*Trace

**As per methods described in Military Specification, MIL-C-13724A dated May 4, 1960.

***For definition of tests, see Adsorption, C. L. Mantell, McGraw-Hill Book Co., New York, N. Y., 2nd Edition, 1951.

TABLE A-III

Properties of Activated Carbon Used in SRP Painted Beds

	Physical Properties						Chemical Properties***					
	Particle Size (Mesh Tyler)							Activity				
Batch No.	on 8	on 10	on 14	thru 14	Apparent Density	%** Hardness	Iodine No.	% CCl_4	Minutes P.S.	% Retentivity CCl_4	% Ash	% Moisture
1	T*	9.7	89.7	0.6	0.550	98.6	1069.4	57.4	51.5	36.9	3.2	1.9
2	T	9.9	89.5	0.6	0.561	97.2	1093.1	52.7	52.4	35.1	3.1	2.0
3	T	7.1	93.3	0.5	0.550	98.6	1119.3	53.3	50.3	34.9	2.6	1.6
4	T	6.5	93.6	0.6	0.550	99.4	1110.4	51.5	50.3	33.3	2.2	1.4
5	T	7.1	92.7	0.5	0.545	98.8	1116.7	53.1	50.4	34.9	2.5	1.6
6	T	10.0	90.0	0.2	0.546	99.7	1131.3	57.4	51.8	38.7	2.2	1.3
7	T	5.9	94.4	0.5	0.542	98.6	1165.8	56.3	54.5	36.3	1.4	1.4
8	T	9.1	91.5	0.1	0.545	99.1	1157.6	57.0	52.5	36.5	2.1	1.6
9	T	9.8	90.1	0.2	0.562	97.5	1194.2	52.6	50.7	36.2	2.6	1.9
10	T	9.0	90.6	0.3	0.562	97.4	1192.2	50.4	54.7	34.3	2.8	2.0
11	T	6.0	94.3	0.3	0.535	99.5	1159.0	57.0	52.9	36.8	2.1	1.5
12	T	9.9	89.7	0.4	0.552	98.2	1157.6	54.7	52.6	34.9	3.3	1.9
13	T	6.8	93.8	0.5	0.550	97.4	1166.2	53.6	54.1	34.1	3.7	1.8
14	T	9.7	90.0	0.5	0.534	97.0	1198.4	58.1	56.1	35.1	3.5	2.0
15	T	9.2	90.2	0.5	0.547	97.6	1120.7	52.7	50.1	36.2	3.9	2.0
16	T	9.8	90.0	0.2	0.538	97.3	1170.8	55.0	58.8	35.7	3.5	1.7
17	T	10.0	89.7	0.2	0.547	98.6	1157.9	54.4	54.9	35.1	3.2	1.8
18	T	3.0	96.4	0.5	0.550	97.6	1164.3	53.6	57.8	34.9	3.1	1.5
19	T	9.2	90.3	0.4	0.542	98.4	1165.2	53.5	51.5	35.3	2.2	2.0
20	T	8.4	91.2	0.4	0.553	98.3	1120.6	50.8	50.4	34.0	3.3	1.4
21	T	10.0	89.7	0.4	0.545	98.6	1157.6	58.1	54.4	35.2	2.6	1.2

*Trace

**As per methods described in Military Specification, MIL-C-13724A dated May 4, 1960.

***For definition of tests, see Adsorption, C. L. Mantell, McGraw-Hill Book Co., New York, N. Y., 2nd Edition, 1951.

TABLE A-IV

Inspection of In-Service Carbon Beds

Area	Type	Exposure, months	Severity of Corrosion*
R	Cadmium-plated	15	Moderate to severe
R	Painted	7	Trace
P	Cadmium-plated	15	Moderate to severe
		28	Moderate to severe
P	Painted	5	None
		15	Moderate to severe**
L	Cadmium-plated	15	Severe
		20	Severe**
		28	Severe
L	Painted	14	Moderate
K	Cadmium-plated	15	Minor
		20	Moderate
		28	Moderate
K	Painted	13	Moderate
C	Painted	7	Trace
		12	Minor
		16	Moderate

* Degree of severity

(a) Trace: less than 6 rust spots or streaks no more than 1/32" diameter or width

(b) Minor: rusted areas about 25 in^2

(c) Moderate: entire perforated screen area through which air passes rusted, but perforations not plugged with loose rust

(d) Severe: entire front face of bed coated with loose rust, perforations plugged

** Split in perforated screen of one unit

BIBLIOGRAPHY

1. J. W. Walker and A. H. Peters. "Filters for Reactor Containment." Mech. Eng. 85, 46-54 (1963).

2. J. A. List. "The SRP Production Reactor Containment Program," Eighth AEC Air Cleaning Conference. Oak Ridge National Laboratory, October 22-25, 1963, TID-7677.

3. G. H. Prigge. Application of Activated Carbon Reactor Containment. USAEC Report DP-778, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1962).

4. A. H. Peters and D. R. Muhlbaier. Nondestructive Test of Carbon Beds for Reactor Containment Applications - Progress Report: June 1962 - December 1963. USAEC Report DP-870, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1964).

5. A. H. Peters. Application of Moisture Separators and Particulate Filters in Reactor Containment. USAEC Report DP-812, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1962).

6. D. R. Muhlbaier. Nondestructive Test of Carbon Beds for Reactor Containment Applications - Progress Report: January-March 1964. USAEC Report DP-910, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1964).

7. Ibid., April-June 1964. DP-920 (1964).

8. Ibid., July-September 1964. DP-950 (1965).

9. Ibid., September 1964 - September 1965. DP- (to be issued).

10. L. M. Arnett, et al. Final Hazards Evaluation of the Heavy Water Components Test Reactor (HWCTR). USAEC Report DP-600, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1962).

11. R. C. Milham. High Temperature Carbon for Iodine Adsorption. DP- , E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (to be issued).

12. C. R. Wilke and O. A. Hougen. "Mass Transfer in the Flow of Gases Through Granular Solids Extended to Low Modified Reynolds Numbers." Trans. Am. Inst. Chem. Engrs. 41, 445-51 (1945).