FIG. 1. OZONE FILTER TEST PROGRAM

- FLIGHT TESTS ON RA001
- SMALL SCALE LAB TESTS
  - FILTER MATERIALS SURVEY
  - ACCELERATED LIFE TESTS
- FULL SCALE LAB TESTS
  - DESIGN VERIFICATION TESTS
  - FLAME
  - VIBRATION
  - ACCELERATED CONTAMINATION
  - LIFE CYCLE
  - CABIN AIR QUALITY

FIG. 2. OZONE INSTRUMENTATION

Lab Test Ozone Monitors

- Ultra-Violet Adsorption Type
  - Dasibi Corp. Model 1003
- Chemiluminescent Type
  - Columbia Scientific Ind. (CSI Model 2000)
  - Analytical Instrument Development, Inc. (AID Model 560)
FIG. 3. OZONE ANALYZER SCHEMATIC - ULTRA-VIOLET LIGHT ADSORPTION TYPE

**REFERENCE CIRCUIT**

**X WINDOW**

**ULTRA-VIOLET LIGHT SOURCE**

**ABSORPTION CHAMBER**

**SAMPLE DETECTOR**

**SIGNAL PROCESSING**

**Y WINDOW**

**ZERO GAS**

**EXHAUST PUMP**

**EXHAUST**

**GAS VALVE**

**CATALYTIC CONVERTER**

**GAS SAMPLE INLET**

FIG. 4. OZONE ANALYZER SCHEMATIC - CHEMILUMINESCENT TYPE

**SAMPLE**

**REACTION CHAMBER**

**VENT**

**ZERO AIR**

**HIGH PRESSURE REGULATOR**

**REGULATOR**

**VALVE**

**GAUGE**

**ELECT**

**PM TUBE**

**PUMP**

**CHARCOAL TRAP**

**REMOTE READOUT**

**O_3 INDICATOR**

**ETHYLENE EXTERNAL RECHARGE**

**ETHYLENE STORAGE CYLINDER**
FIG. 5. SMALL SCALE OZONE FILTER TEST SETUP

FIG. 6. FULL SCALE PRODUCTION FILTER FUNCTIONAL LAB TEST - TEST SETUP SCHEMATIC

[Diagram showing small-scale ozone filter test setup]

[Diagram showing full-scale production filter functional lab test setup]
FIG. 7. PNEUMATIC DUCT - LAB TEST PHOTOS
FIG. 8. FULL SCALE LAB TEST PHOTOS
**FIG. 9. FULL SCALE LAB TESTS**

**FIG. 10. CABIN ADSORPTION FILTER MATERIALS**

**TESTED**

- CHARCOAL

  **BARNEY CHENEY TYPE AC**

  **BARNEY CHENEY TYPE 848**

  - WHITCO 955
  - NORTH AMERICAN G 210
  - NORTH AMERICAN G 212
  - UNION CARBIDE JXC
  - WESTAVACO Nuchar

- HOPCALITE & HOPCALITE/ CLOTH

- AMBERSORB

- ZEOLITES 4A, 5A, 718 13X

- SILVASAN (PURALOTOR)

- ULTRA-VIOLET

- MSA HOPCALITE FILTER PANEL

- ENGELHARD CATALYST PIN A-18673

* Presently In Use
FIG. 11. SMALL SCALE LAB TEST RESULTS - CHARCOAL

FIG. 12. FULL SCALE LAB TEST RESULTS - CHARCOAL FILTERS (ZONES 2 AND 3)
FIG. 13. FULL SCALE LAB TEST RESULTS - CHARCOAL FILTERS (ZONES 1 AND 4)

FIG. 14. DESIGN VERIFICATION TESTS

Objective: To Show Compliance With Certification Requirements
To Give Confidence For Safety
To Indicate Effectivity Vs. Time Effect

- Flame Tests (Certification Requirement)
  - Both 12 Sec & 60 Sec Flame Test Passed

- Vibration Tests
  - 0.24% Wt Loss In Simulated One Year Of Service
  - Result - Much Better Than Anticipated

- Accelerated Contamination Tests
  - 72 Hr. Ozone Test
  - Simulated Service Cycle Test
FIG. 15. OZONE FILTER EFFICIENCY VS TIME - LAB TEST OF RA001 FILTER

- 1100 CFM AIR WITH NO OZONE
- HIGH OZONE CONCENTRATION USED FOR LAB TEST TO ACCELERATE LIFE CYCLE TIME

FIG. 16. FULL SCALE LAB TEST RESULTS - RA001 FILTER CONTAMINATION CYCLE TEST - 1 INCH CHARCOAL BED

TEST CYCLE
(1) INJECT 10, CC OF JP-4
(2) OZONE INJECTED @ 1.0 PPM @ 2,200 CFM
(3) HOT AIR CLEAN AT 200°F
(4) NO HOT AIR CLEAN - 3 HR REST ONLY

HIGH OZONE CONCENTRATION USED FOR LAB TEST TO ACCELERATE LIFE CYCLE TIME
FIG. 17. ZONE 2 FILTER LIFE CYCLE TEST USING BARNEBY CHENEY TYPE A/C CHARCOAL

**DAILY CYCLE**
- 2 HRS., CLEAN AIR @ 2,200 CFM
- 12 HRS., O ZONE @ 1.5 PPM
- 2 HRS., CLEAN AIR

**SYMBOLS**
- • AT START OF DAILY CYCLE
- ○ AT END OF DAILY CYCLE
- --- AVG.

---

**FIG. 18. CONDITIONED AIR FILTER INSTALLATION**
FIG. 19. CONDITIONED AIR FILTER INSTALLATION

FILTER BOX WITH DOOR REMOVED

ZONE 3 DISTRIBUTION DUCT

FILTER TRAY (TYPICAL)

FWD

ZONE 3 FILTER (ZONE 2 FILTER SIMILAR)

FINAL FILTER

FASTENER (TYPICAL)

PIN HOLES FOR SPRING RETENTION

SEAL

COVER

FILTER TRAY, ZONE 2 OR ZONE 3

FASTENERS

FLANGE FASTENERS

FILTER CANNISTER

FLANGE FASTENERS

UPPER DECK DISTRIBUTION DUCT

UPPER DECK FILTER

FIG. 20. OZONE FILTER

CHARCOAL FILTERS

PARTICULATE FILTER

AIRFLOW
FIG. 21. CHARCOAL FILTER CANISTER TYPE - ZONES 1 AND 4

Charcoal Filter
Particulate Filter

FIG. 22. OZONE FILTER INSTALLATION ON AIRCRAFT
FIG. 23. ADDITIONAL CABIN FILTER LAB TESTS

- CHARCOAL SURVEY TESTS - SMALL SCALE
- PAA SERVICE FILTER LAB TESTS
- MSA PLEATED HOPCALITE MATERIAL
- ENGLEHARD CATALYST P/N A - 18673
FIG. 24. FILTER EFFICIENCY VS FILTER FACE VELOCITY - 1/2" CHARCOAL FILTERS

TEST CONDITION
- ONE PPM OZONE CONCENTRATION
- AMBIENT TEMPERATURE

-△ BARNEY CHENEY TYPE B48
-○ BARNEY CHENEY TYPE AC
-◇ NORTH AMERICAN G-212
-◇ WITCO GRADE 955
-◇ NORTH AMERICAN G-210
-◇ WESTVACO NICHAR
-◇ UNION CARBIDE JXC 6/8 H411-480
-◇ UNION CARBIDE JXC 6/8 H76-623
-◇ UNION CARBIDE 6B S8 V/H612-332
-◇ UNION CARBIDE "S"4/6 H612-256

FIG. 25. PAA CHARCOAL FILTER EFFICIENCIES AS DETERMINED FROM LAB TEST DATA

TEST CONDITIONS
- 2200 Cfm AIRFLOW
- 1.5 PPMv OZONE CONCENTRATION
  UPSTREAM OF FILTER
FIG. 26. MSA PLEATED HOPCALITE FILTER PANEL - LIFE CYCLE TESTING

SYMBOLS
- AT START OF DAILY CYCLE
- AT END OF DAILY CYCLE

DAILY CYCLE
- 2 HOURS CLEAN AIR @ 2200 Cfm
- 12 HOURS OZONE @ 1.5 PPM
- 2 HOURS CLEAN AIR @ 2200 Cfm

FIG. 27. MSA PLEATED HOPCALITE FILTER PANEL - FILTER EFFICIENCY VS. OZONE LEVEL

TEST CONDITIONS
- 2200 Cfm AIRFLOW
- AMBIENT AIR TEMPERATURE
- OZONE LEVEL VARIED AFTER END OF 13H DAILY CYCLE (156 HRS, OZONE 1.5 PPM)

DAILY CYCLE
- 2 HRS, CLEAN AIR @ 2200 Cfm
- 12 HRS, OZONE @ 1.5 PPM
- 2 HRS, CLEAN AIR @ 2200 Cfm
FIG. 28. FILTER EFFICIENCY VS FILTER FACE VELOCITY 1/2" THICK FILTERS

TEST CONDITIONS
- ONE PPM OZONE CONCENTRATION
- AMBIENT AIR TEMPERATURE

ENGLEHARD CATALYST P/N A-18673 50 LBS/FT³
BARNEY CHENEY CHARCOAL TYPE 848 32.6 LBS/FT³

FIG. 29. PNEUMATIC DUCT (CATALYTIC MATERIALS)

TESTED
- MSA Hopcalite
- Nickel Screens
- Nickel Wool
- Brass Wool
- Zeolites 4A, 5A, & 13X
- Purolator Silvasan Cert 361
- United Oil Products Catalysts
  - No. 3443-120-25
  - No. P3-3008
  - Honeycomb Filter
- Alumina & Alumina/Silver Oxide
- Alumina/Cu 0
- Alumina/Mn O₂

Engelhard Catalyst
- Spheres
- Cylinders
- Pellets P/N A-18673
- Raremetal On Tubes And Ceramic Honeycomb

DEOXO

3M Company Honeycomb Filter
Palladium (Rare Metal) Spheres
Emery Ceramic Honeycomb Filter
Dart Ind. Sintered Metal Filter
FIG. 30. PNEUMATIC MANIFOLD CATALYTIC FILTER LOCATIONS

FIG. 31. FULL SCALE PNEUMATIC DUCT FILTER LAB TEST - TEST SETUP SCHEMATIC

\[ P_T \] (TOTAL PRESSURE PICK-UP)
\[ P_S \] (STATIC PRESSURE PICK-UP)
\[ T/C \] (THERMOCOUPLE - AIR TEMPERATURE)
\[ O_3 \] (OZONE SENSE LINE)
FIG. 32. FULL SCALE PNEUMATIC DUCT FILTER OZONE MEASUREMENTS SCHEMATIC

FIG. 33. PNEUMATIC DUCT FILTER - LAB TEST SETUP
FIG. 34. OZONE MEASUREMENTS SETUP

FIG. 35. LAB TEST RESULTS

- ENGLEHARD CATALYST
- HOPCALITE
- HONEYCOMB CATALYST
- DART SINTERED METAL
FIG. 36. ENGLEHARD CATALYST PIN A-1867 FILTER PERFORMANCE - SMALL SCALE TEST RESULTS

FIG. 37. HOPCALITE OZONE FILTER PERFORMANCE - SMALL SCALE TEST RESULTS
FIG. 38. HONEYCOMB CATALYTIC OZONE FILTER PERFORMANCE - FULL SCALE TEST RESULTS

TEST CONDITIONS
- 1.5 PPMv UPSTREAM OZONE CONCENTRATION
- AIR TEMPERATURE
  - 450°F
  - 300°F
- 6 INCH FILTER LENGTH
- 20 PSIG AIR PRESSURE

FIG. 39. DART SINTERED METAL OZONE FILTER PERFORMANCE - FULL SCALE TEST RESULTS

TEST CONDITIONS
- 1.5 PPMv UPSTREAM OZONE CONDITION
- AIR TEMPERATURE
  - 400°F
  - 300°F
- 2 3/4 INCH FILTER LENGTH
- 20 PSIG AIR PRESSURE
FIG. 40. HONEYCOMB CATALYTIC FILTER EFFICIENCY VS BED CONTACT TIME

$\theta = 5000 \sqrt{v}$
$\theta =$ BED CONTACT TIME (M SEC.)
$L =$ FILTER ELEMENT LENGTH (INCHES)
$V =$ FILTER ELEMENT FACE VELOCITY (FT./MIN.)

FIG. 41. EFFECT OF FUEL CONTAMINATION ON OZONE FILTER EFFICIENCY - RARE METAL HONEYCOMB FILTER UNIT

**TEST CONDITIONS.**
(1) 2.9 LBS./SEC. AIRFLOW RATE
(2) 350°F AIR TEMPERATURE
(3) 1.5 PPM OZONE CONCENTRATION
(4) 20 PSIG, DUCT AIR PRESSURE

10 CC of JET A FUEL INJECTED INTO AIRSTREAM
FIG. 42. RARE METAL HONEYCOMB OZONE FILTER LIFE CYCLE TEST

TEST CONDITIONS
(1) 2.9 LBS/SEC AIRFLOW
(2) 1.5 PPMV UPSTREAM OZONE LEVEL
(3) 300°F AIR TEMPERATURE

DAILY CYCLE
1 HR. CLEAN AIR @ 2.9 LBS/SEC
14 HRS. OZONE @ 1.5 PPMV & 2.9 LBS/SEC. AIRFLOW
8 HRS. NO AIRFLOW

FIG. 43. METAL OXIDE HONEYCOMB OZONE FILTER LIFE CYCLE TEST

TEST CONDITIONS
(1) 3.71 LBS/SEC AIRFLOW
(2) 1.5 PPMV UPSTREAM OZONE LEVEL
(3) 300°F AIR TEMPERATURE

DAILY CYCLE
1 HR. CLEAN AIR @ 3.71 LBS/SEC
14 HRS. OZONE @ 1-5 PPMV & 3.71 LBS/SEC AIRFLOW
8 HRS. NO AIRFLOW
FIG. 44. EFFECT OF TIME & OZONE LEVEL ON METAL OXIDE TYPE FILTER CATALYST ELEMENT PERFORMANCE

\[ \theta = 5000 \frac{L}{V} \text{ IN MSEC,} \]

\[ L = \text{FILTER LENGTH IN INCHES} \]

\[ V = \text{FACE VELOCITY IN fpm} \]

\[ \theta = \text{BED CONTACT TIME IN MSEC.} \]

FIG. 45. FUTURE OZONE FILTER DEVELOPMENT PROGRAM

- MATERIAL TESTS
  - EVALUATE NEW MATERIALS
  - IMPROVE EFFICIENCY
  - REDUCE WEIGHT
  - ESTABLISH FILTER LIFE

- PRODUCTION FILTER
  - REQUEST PROPOSALS
  - PROCURE PROTOTYPE UNIT FOR LAB & SERVICE TESTS
  - FINAL PRODUCTION DESIGN & PROCUREMENT