

5045 Klystron & Thyatron Reliability

Presented by

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Dave Ficklin*

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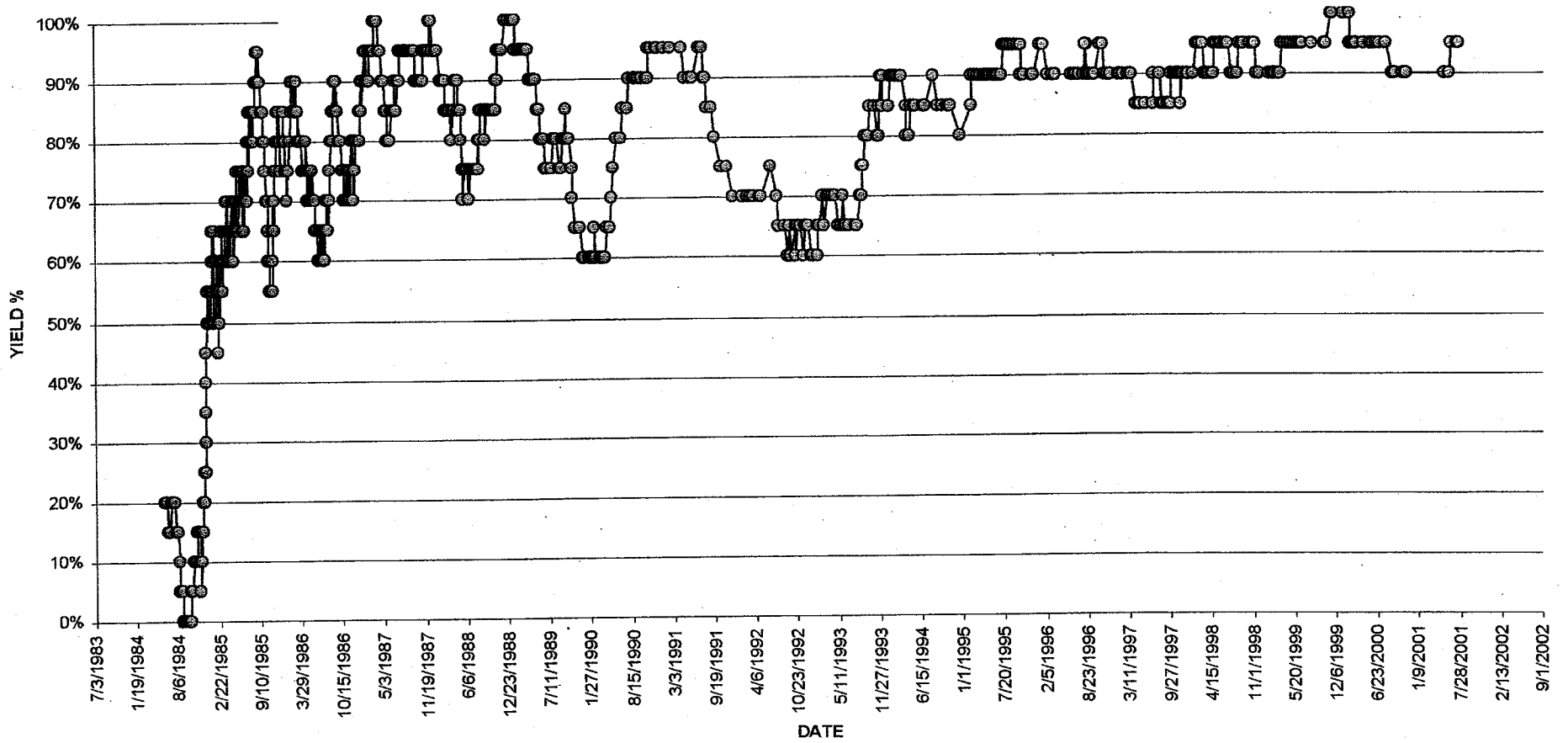
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5045 History

- *Manufacturing started in early 1980's*
- *Higher Power klystron but better Quality Control*
- *Gallery records from 1985*
- *1050 Total Klystrons manufactured*
 - *674 New Klystrons*
 - *376 Rebuilt Klystrons*
- *Klystron Production Yield Increases from Less than 20% to over 90%*

5045 PRODUCTION YIELD

20-TUBE RUNNING AVERAGE



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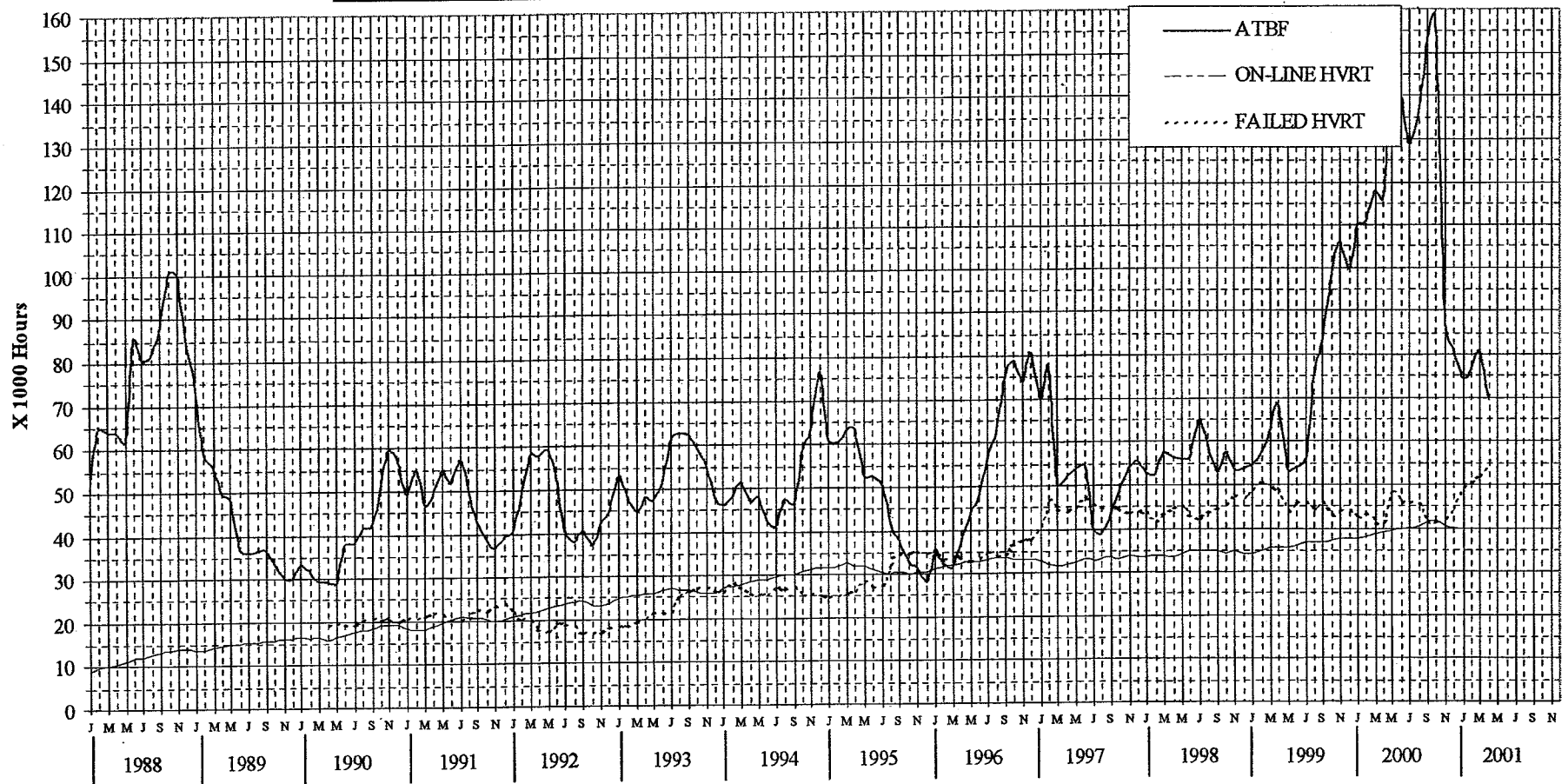
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5045 GALLERY KLYSTRONS

ATBF = Average Time Between Failures for the Previous 12 Months

ON-LINE HVRT = Average High Voltage Age of ON-LINE 5045 Klystrons

FAILED HVRT = Average High Voltage Age of 5045 Klystrons Failed in the Previous 12 Months

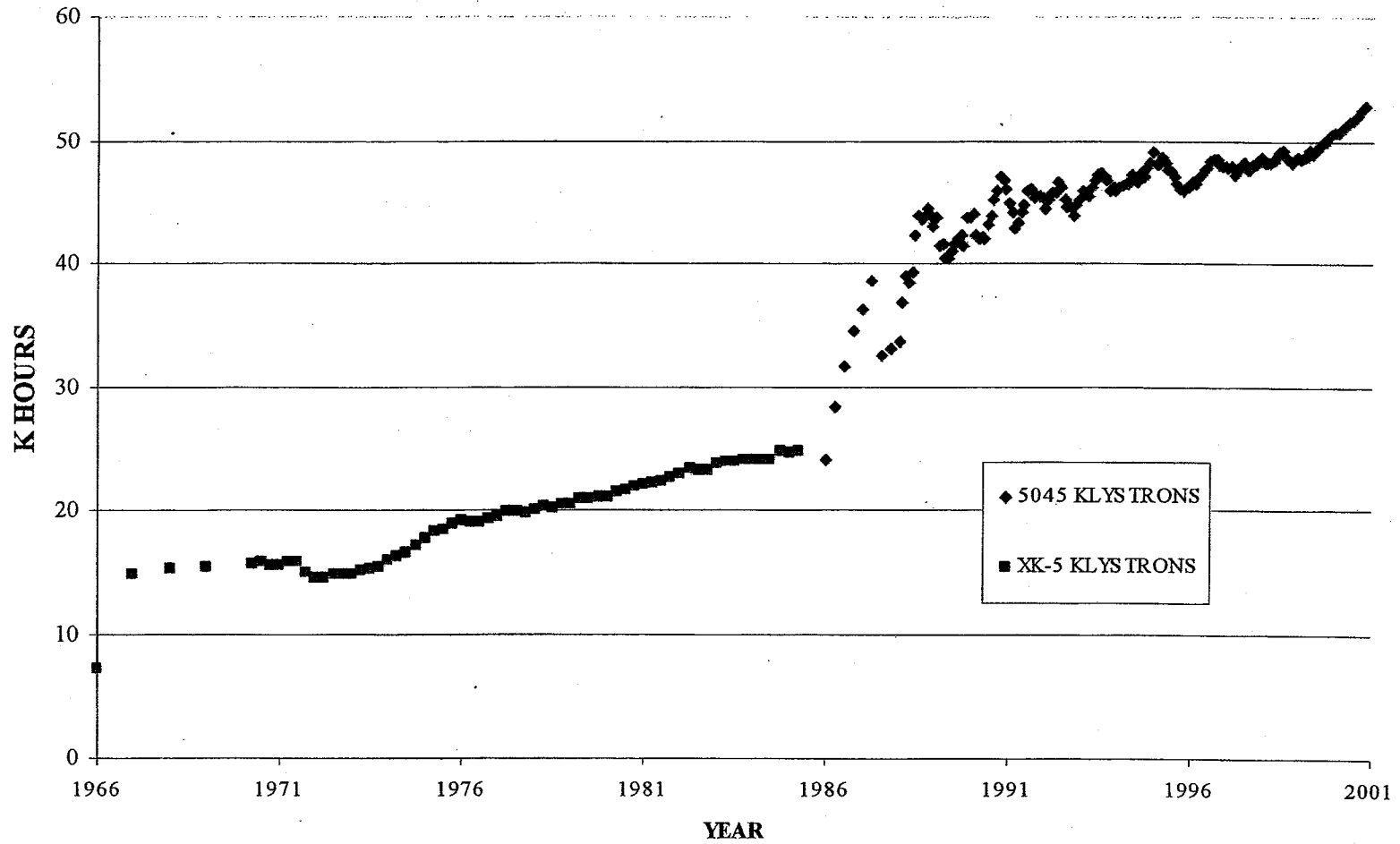


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**CUMULATIVE MEAN TIME BETWEEN FAILURES
SLAC LINAC KLYSTRONS**

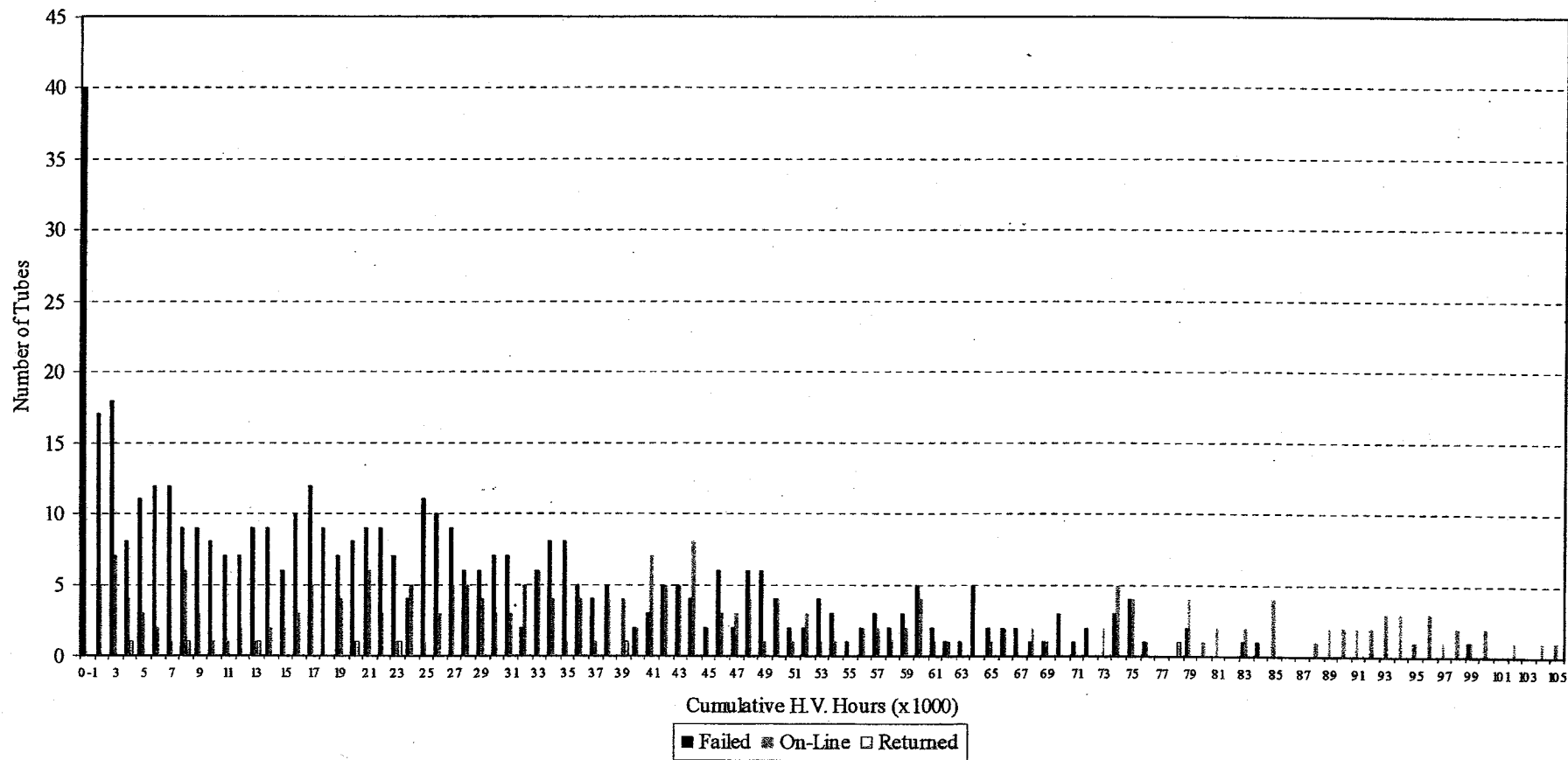


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Graph Showing Cumulative H.V. Hours
of On-Line, Failed, & Returned 5045 Klystrons
as of December 31, 2001



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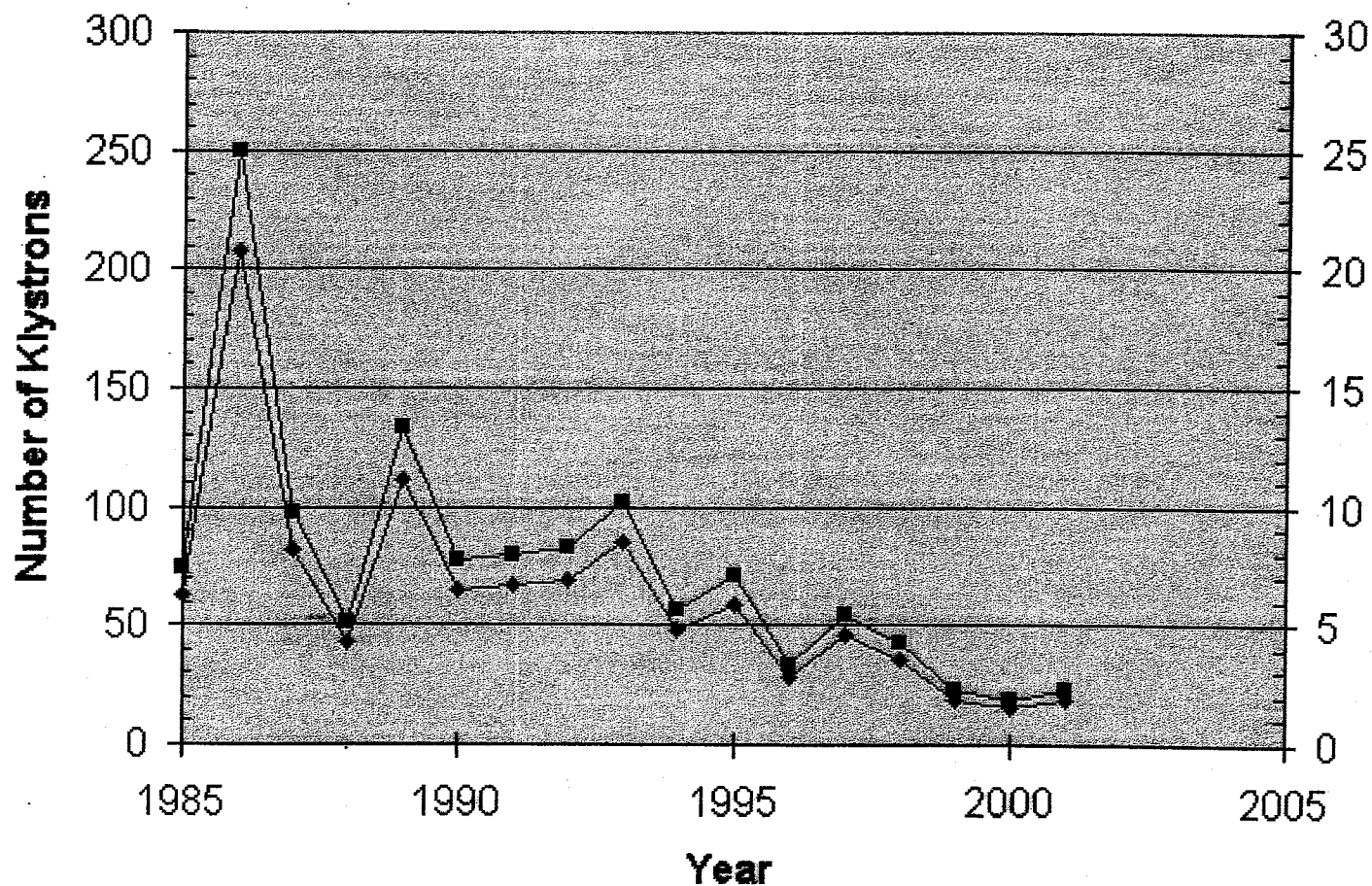
5045 Operational Data

- *Higher Powered 5045 has twice the cumulative MTBF of the XK5*
- *Initial klystron manufacturing and operating shakedown took ~5years*
- *Cumulative MTBF has a steady slope increase since ~1991*

Klystron Failures

- **Most klystrons fail for cathode end of life**
 - **Material depletion**
 - *Requires high heater power*
 - **Cathode Arcing**
 - *Barium deposited on surfaces flaking off*
 - **Cathode life related to temperature**
 - *Every increase of 25°C cuts life in half*
 - *Present good cathodes operate at 27A heater current as compared to 30-32A*

5045 Klystron Gallery Removals



—■— Yearly Removals —◆— Avg. Monthly Removals

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Reasons for 5045 Gallery Returns

- *Water Leak*
 - *Magnet or Klystron*
- *Oil Leak*
 - *Tank*
- *Magnet Temperature Interlock*
- *Klystron Window*
 - *When system vented*
 - *Klystron usually works normally with failed window*
- *Klystron Arcing and/ or Heater circuit failure*
 - *Sign of possible end of life*

Reliability Philosophy

- *Klystrons are not really different from other devices*
- *Reliability is increased by derating operating parameters*
 - *5045 acceptance tested at 180Hz and operated at 120Hz.*
 - *5045 has been tested to 400kV, runs at 350kV*
 - *Automobile engines do not have long life at their redline RPM.*

SLAC
Linac Thyratrons

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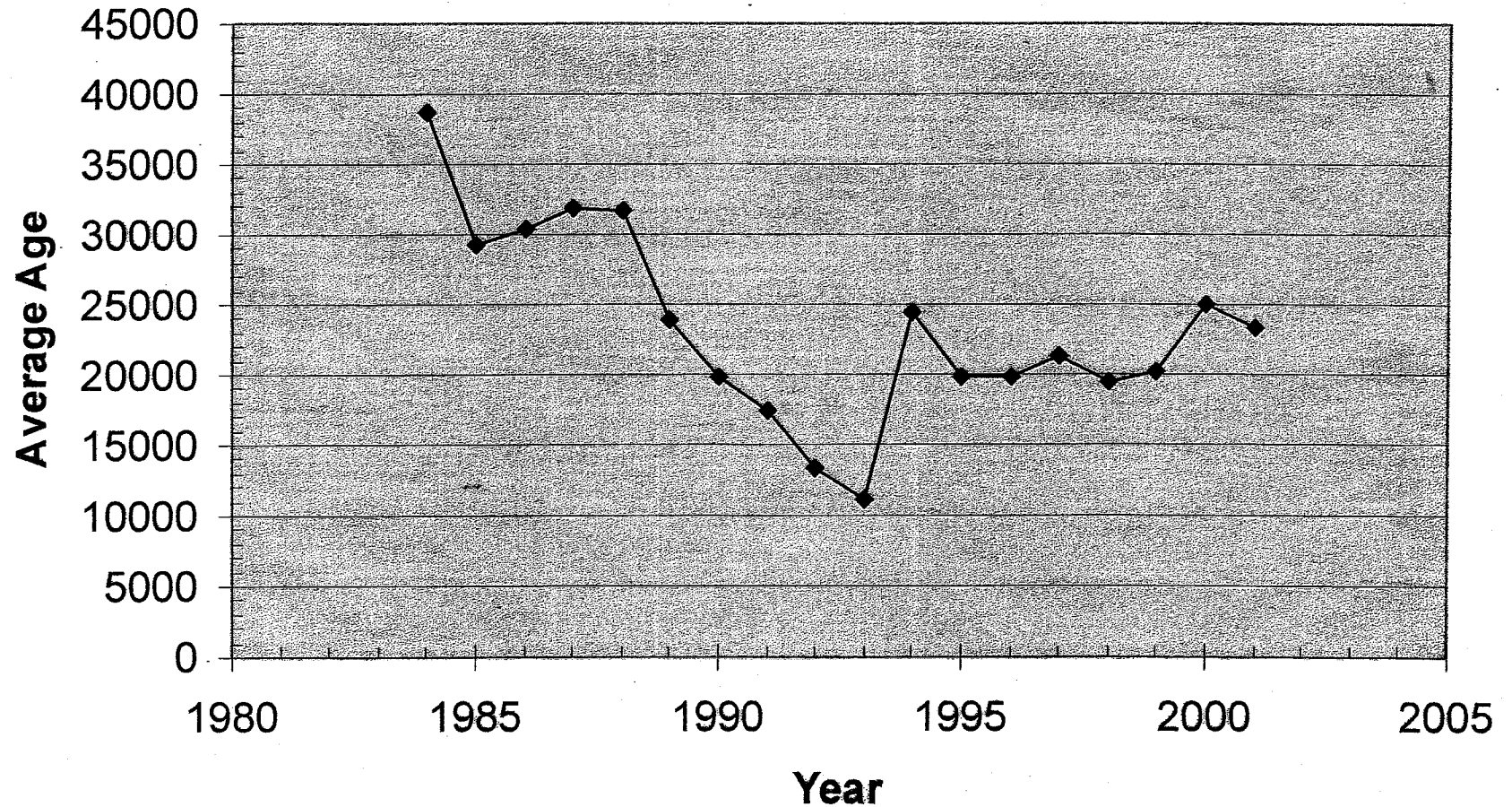
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Thyratron History

- *Thyratrons from previous XK5 modulator operation continued in use with switch to 5045 klystrons*
- *5045 operation began with mature thyratrons*
- *Thyratron manufacturers changed over time*
 - *Quality problems*
 - *Companies went out of business*
 - *Each new vendor startup has learning curve*

Calculated Average Thyatron Hours at Removal

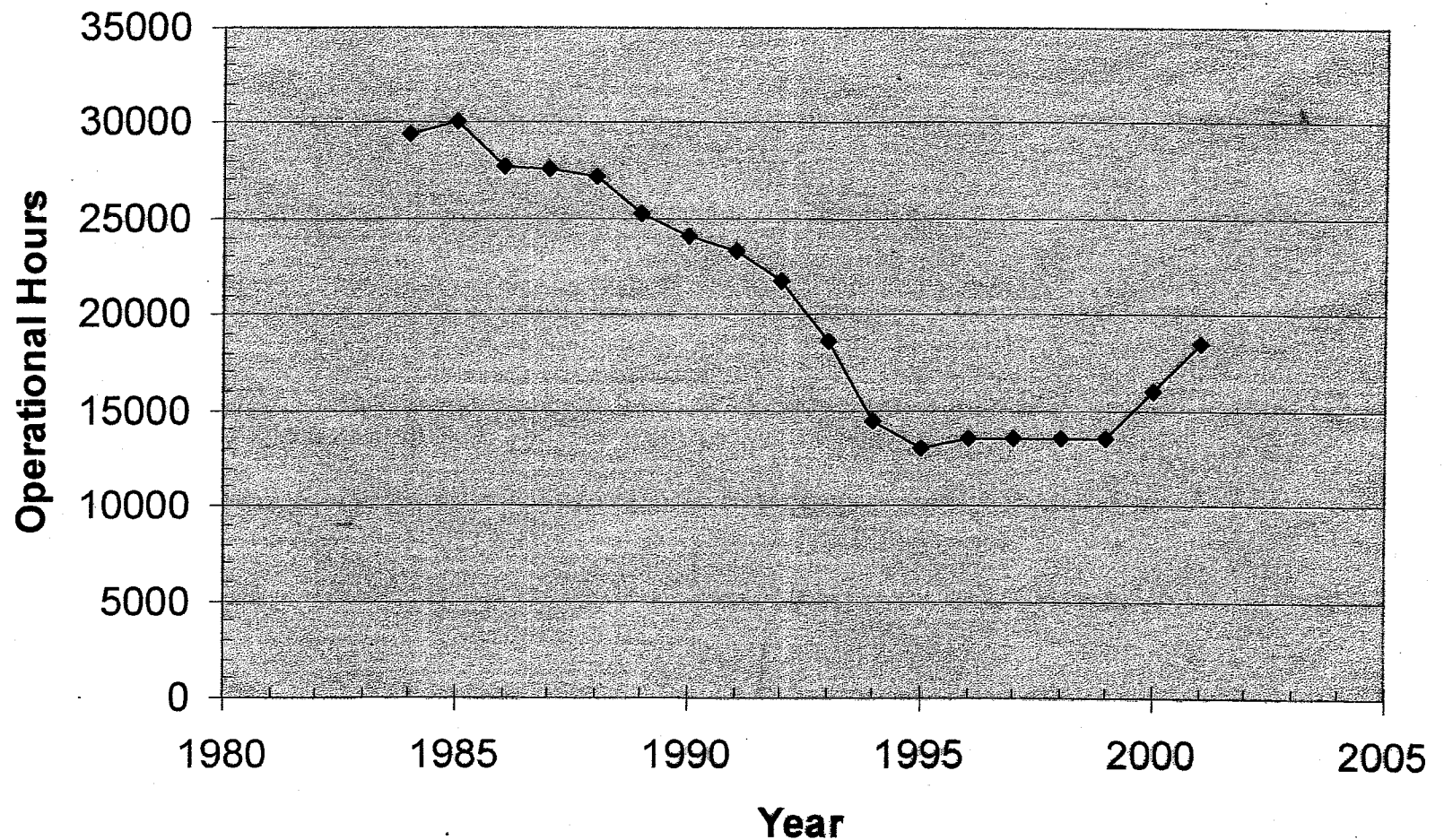


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Calculated Average Operational Hours of Active Gallery Thyratrons



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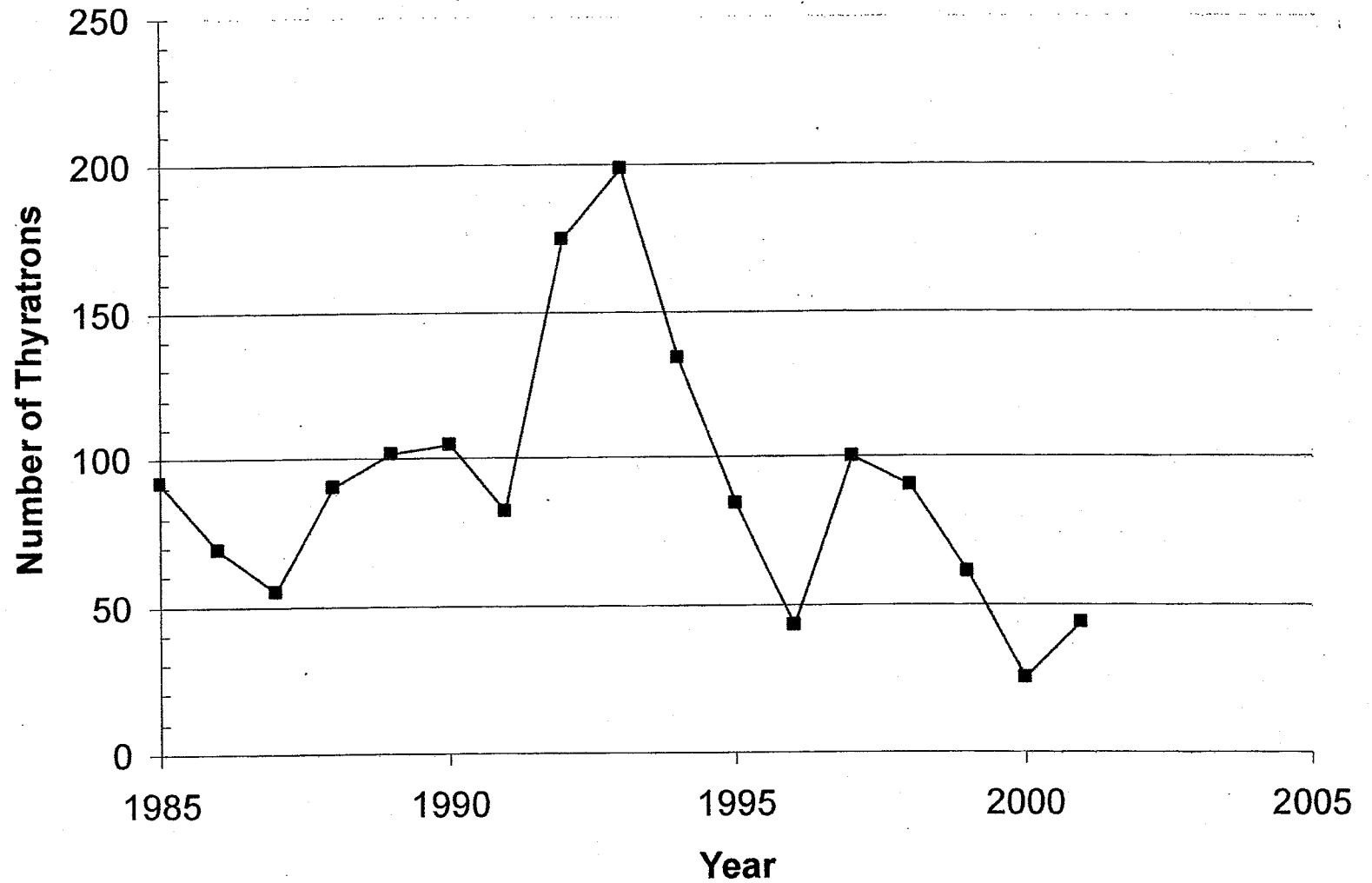
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Thyratron Operating Hours

- *Data from approx. 4000 thyratrons*
- *240+ thyratrons on the linac*
- *1985 average hours/ thyatron on the linac = 30k*
- *1995-1999 average hours/ thyatron on the linac = 13k (low)*
- *1985 average hours on a thyatron removed from the gallery =29k*
- *1993 average hours on a thyatron removed from the gallery =12k*
- *Since 1995, average hours on a thyatron removed from the gallery =20k+*

Thyratron Gallery Removals



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