ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE
Associazione ENEA-EURATOM sulla Fusione

FUSION UNIT
TECHNOLOGIES DIVISION

COLLECTION OF DATA RELATED TO JET and TLK OPERATIONAL EXPERIENCE on COMPONENT FAILURE

IEA Task 5
Princeton 10th October 2003

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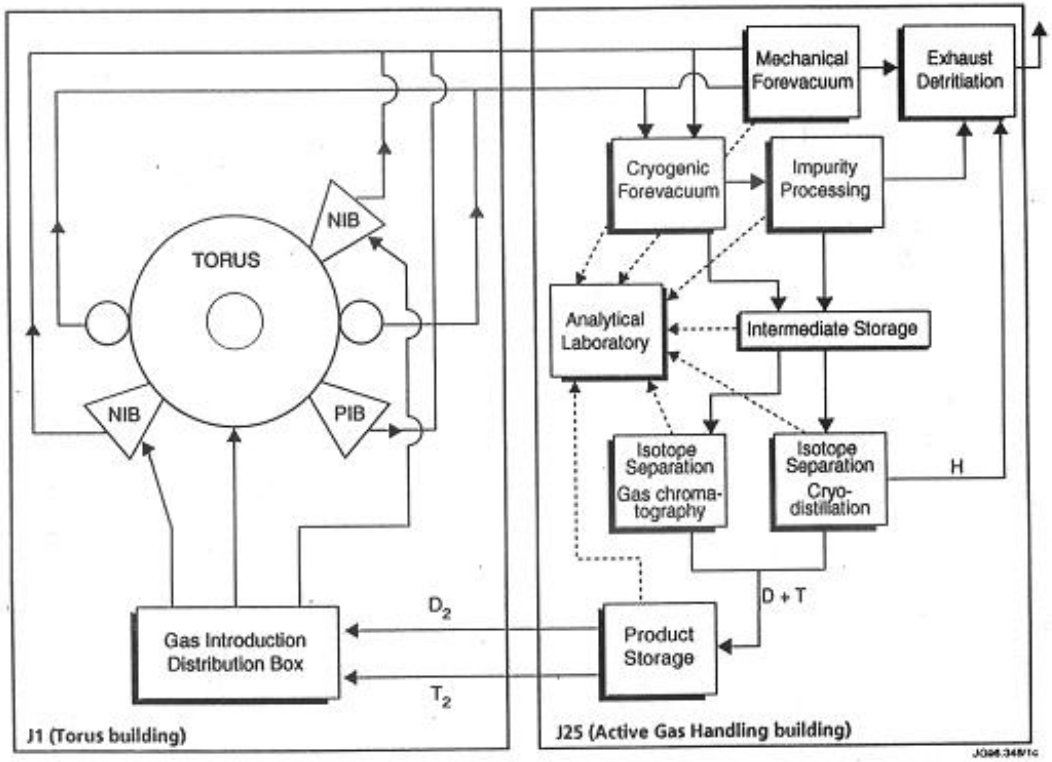
OBJECTIVE OF THE TASK

- Collect all the information available about **single component malfunctions and failures** of the **Vacuum** and **Tritium Systems** at JET and, of the single facilities installed at the **TLK**, pointing out causes, consequences, maintenance actions.
- Collect **information useful to evaluate probabilistic values** related to component malfunctions and failures.
- Estimate the main **reliability parameters**, (such as the failure rate and the corresponding standard errors and confidence intervals), associated to the components.
- Point out **practical information on the operating experience** acquired.

JET AGHS



Component Class	N° of components
Air Ejector	2
Alarm annuntiator	48
Amplifier	102
Blower	4
Catherometer	8
Circuit Breaker	5
Condenser	1
Contactor	55
Control Unit	60
Controller	67
Convertor	188
Electrical actuator	4
Electrical Power Board	10
Electronic unit	83
Emergency Shutdown	1
Evaporator	2
Fan	2
Fan of electrical board	40
Filter	8
Filter Regulator	21
Heater	155
Heat exchanger	1
Indicator	653
Ionization Chamber	36
Motorized Valve	1
Oil circulation pump	6
Omegatron	1
Orifice	3
Peristaltic Pump	2
Pressure Gauge	49
Probe	1
Residual Gas Analyser	5
Rupture Disc	50
Selector	24
Site Power Supply (from national grid)	1
Software Unit	242
Solid State Relay	15
Switch	1302
Thermocouple	228
Thermometer	2
Thermoresistance	43
Thyristor unit	1
Transducer	210
Transformer (High Voltage)	6
Transformer (Low Voltage)	7
Transmitter	305
Uninteruptable Power Supply	1
Vacuum Pump	42
Valve	2124
Vessel	32
Total	**6259**

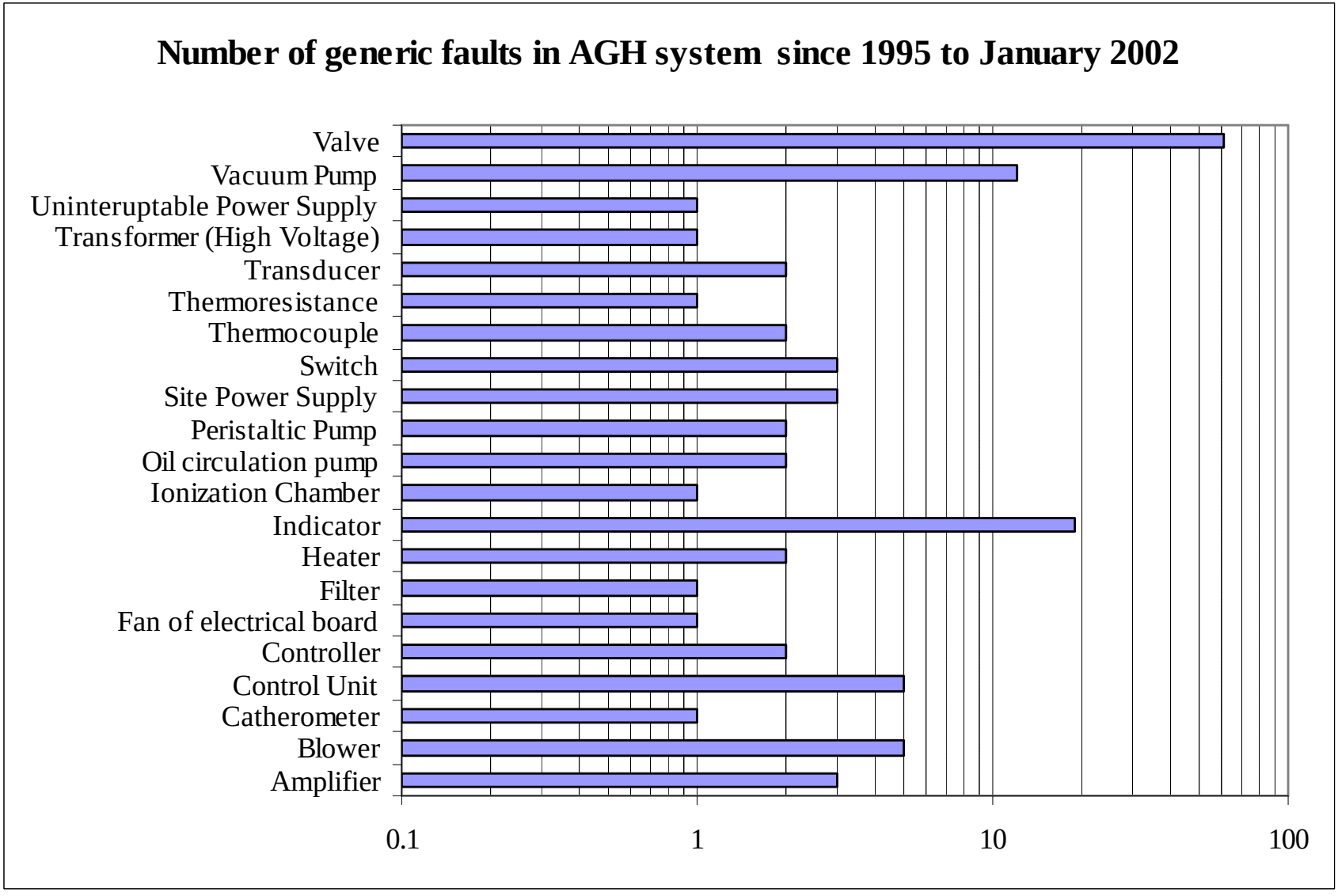
JET AGHS

Sub-system		Commissioning (h)		Operations (h)			Operations (h)			TOTAL
		1995	1996	1997	1998	1999	2000	2001	Jan-02	
MF	Mechanical Forevacuum	1000	1920	8760	3624	5328	6048	3024	744	30448
EMS	Exhaust Monitoring System	1000	1920	8760	3624	5328	6048	3024	744	30448
CF	Cryogenic Forevacuum	1000	1920	8760	3624	5328	6048	3024	744	30448
IP	Impurity Processing	1000	1920	8760	3624	5328	6048	3024	0	29704
IS	Intermediate Storage	1000	1920	8760	3624	5328	6048	3024	744	30448
GC	Gas Chromatography	1000	1920	8760	2160	0	0	0	0	13840
PS	Product Storage	1000	1920	8760	2400	240	240	240	0	14800
AN	Analytical Laboratory	1000	1920	2920	1208	1776	2016	1008	248	12096
GI	Gas Introduction	1000	1920	8760	2160	0	0	0	0	13840
GD	Gas Distribution	1000	1920	8760	2160	0	0	0	0	13840
OU	Over/Under Pressure Protection System	4872	8784	8760	8760	8760	8784	8760	31	57511
EDS	Exhaust Detritiation System	4872	8784	8760	8760	8760	8784	8760	31	57511
CD	Cryogenic Distillation	600	960	5880	2880	2880	4032	1680	0	18912

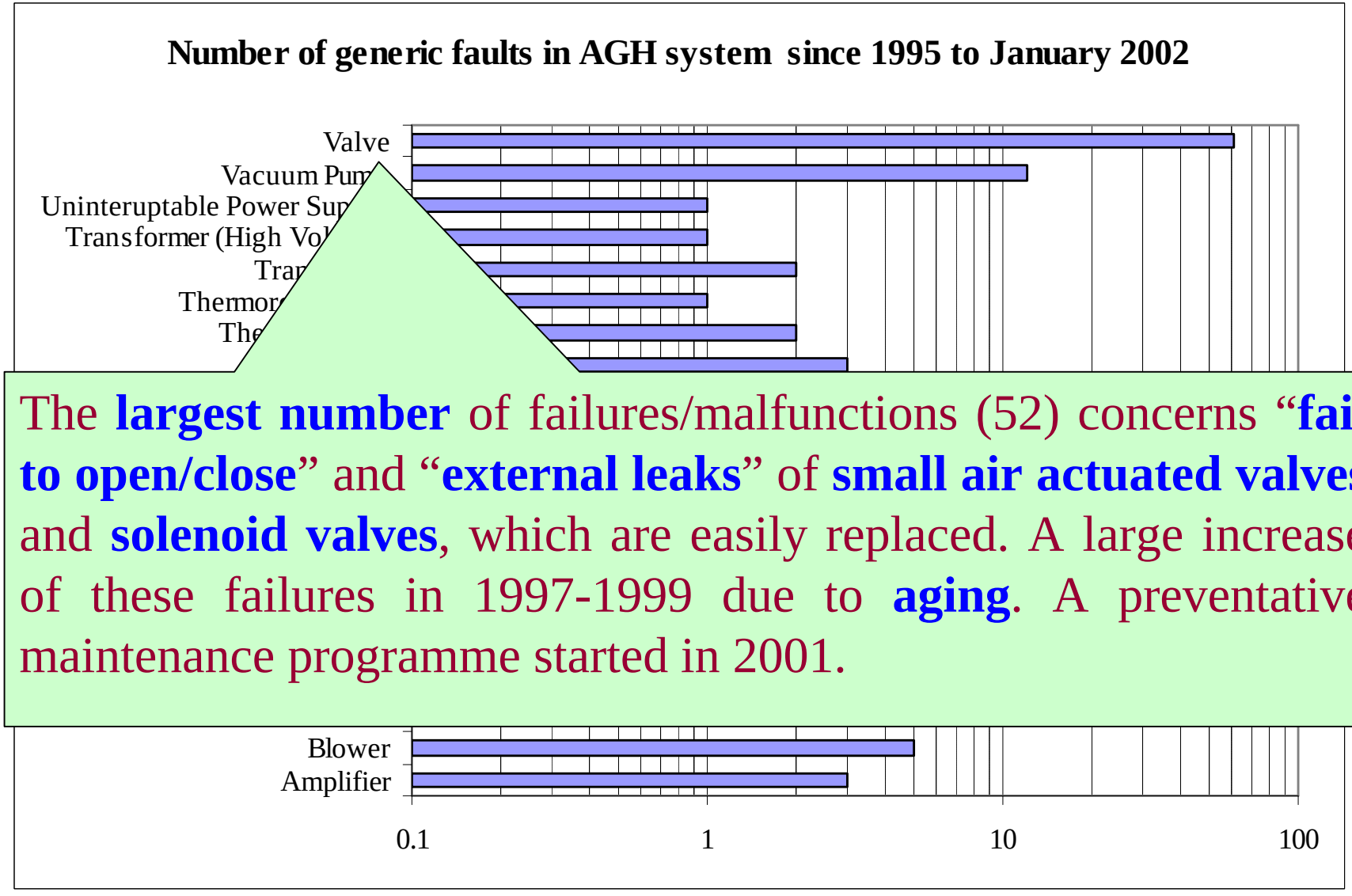
JET AGHS

About **130 failures/malfunctions** on a set of **6259 components**, operating for about **156 767 000 hours**, have been pointed out since **1995** up to **January 2002** for the AGHS.

JET AGHS

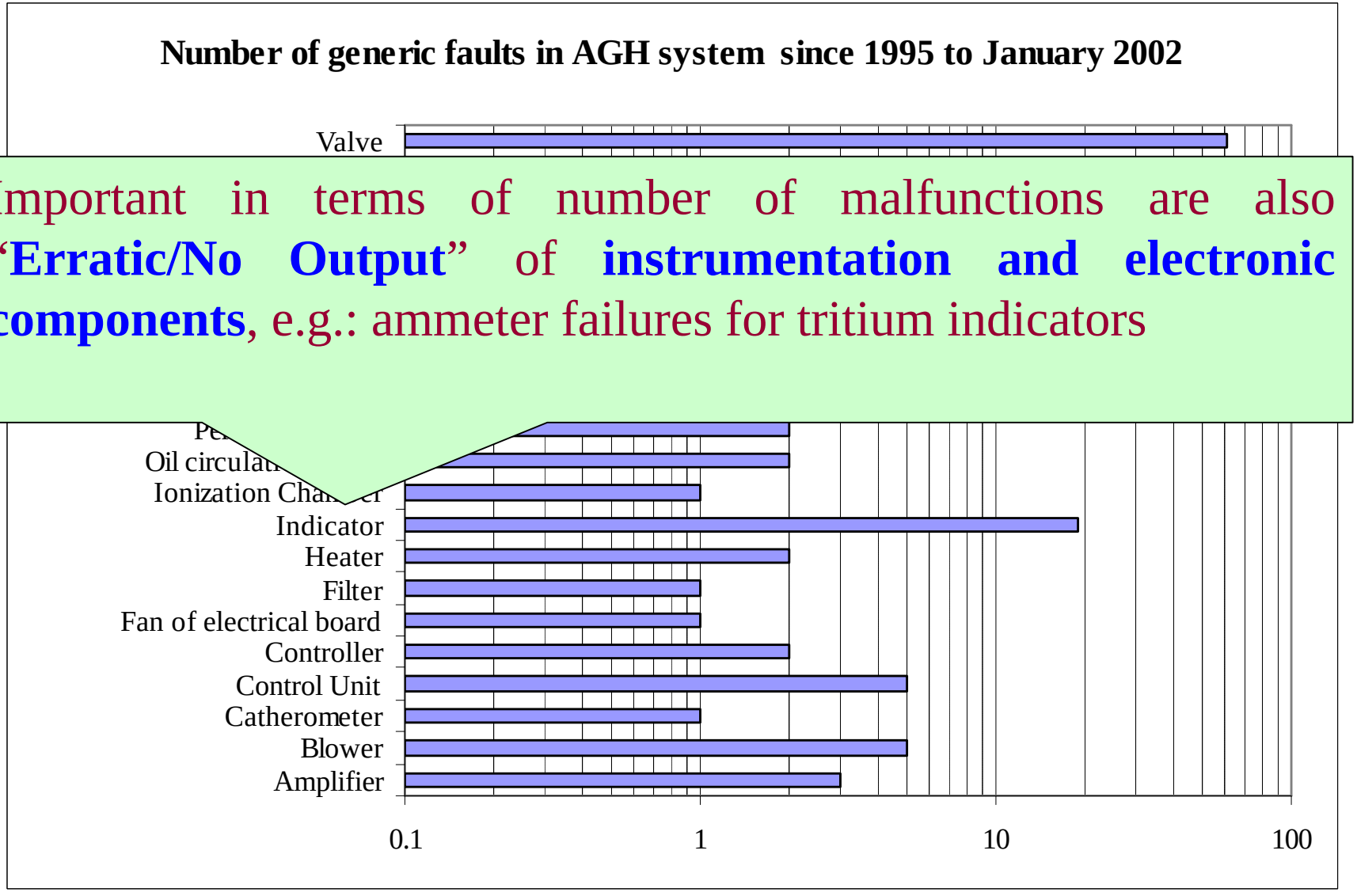

Number of generic faults in AGH system since 1995 to January 2002
Valve
Vacuum Pump
Uninteruptable Power Supply
Transformer (High Voltage)
Transducer
Thermoresistance
Thermocouple
Switch
Site Power Supply
Peristaltic Pump
Oil circulation pump
Ionization Chamber
Indicator
Heater
Filter
Fan of electrical board
Controller
Control Unit
Catherometer
Blower
Amplifier
0.1
1
10
100

JET AGHS



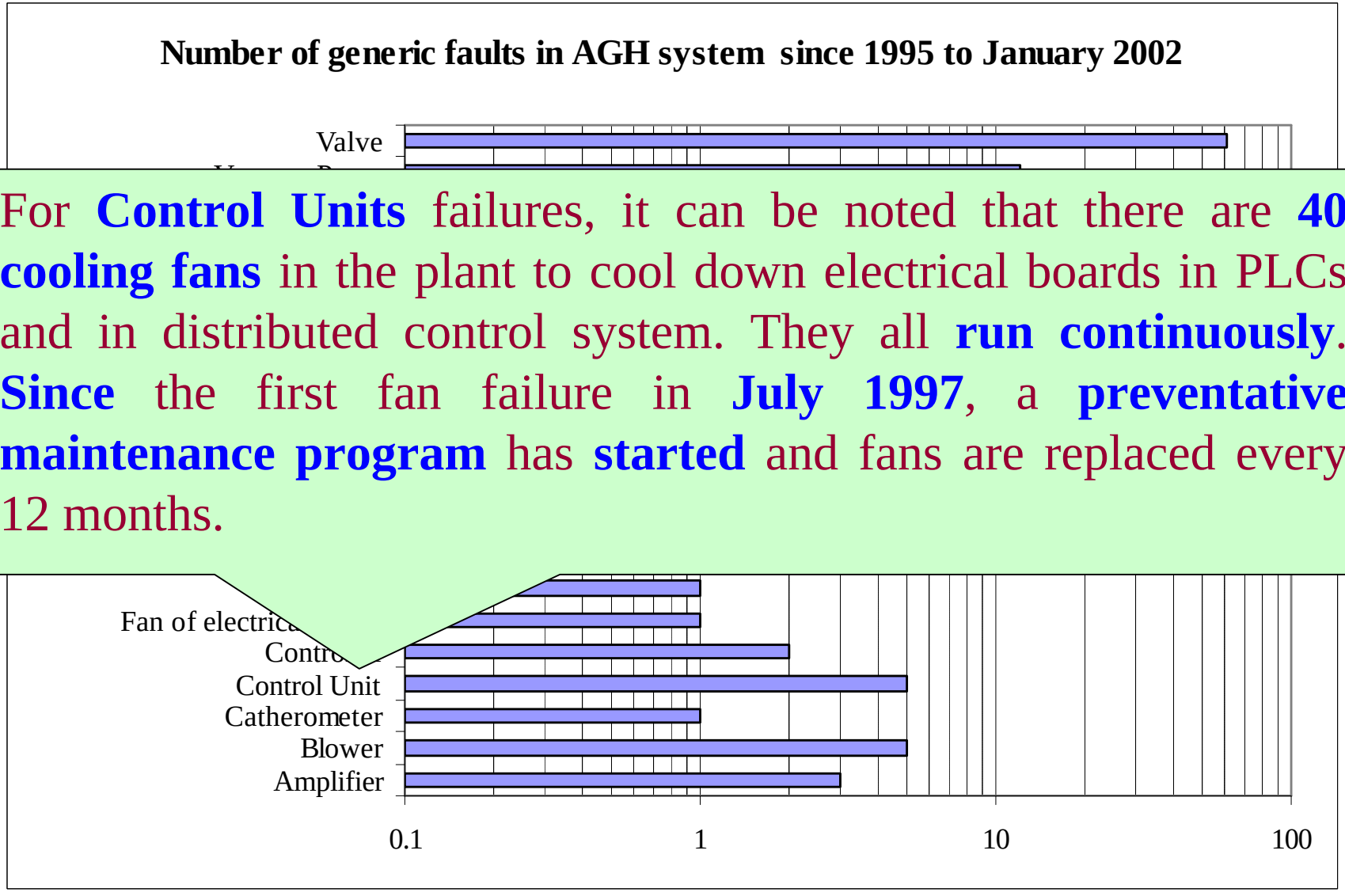
The **largest number** of failures/malfunctions (52) concerns "**fail to open/close**" and "**external leaks**" of **small air actuated valves** and **solenoid valves**, which are easily replaced. A large increase of these failures in 1997-1999 due to **aging**. A preventative maintenance programme started in 2001.

JET AGHS



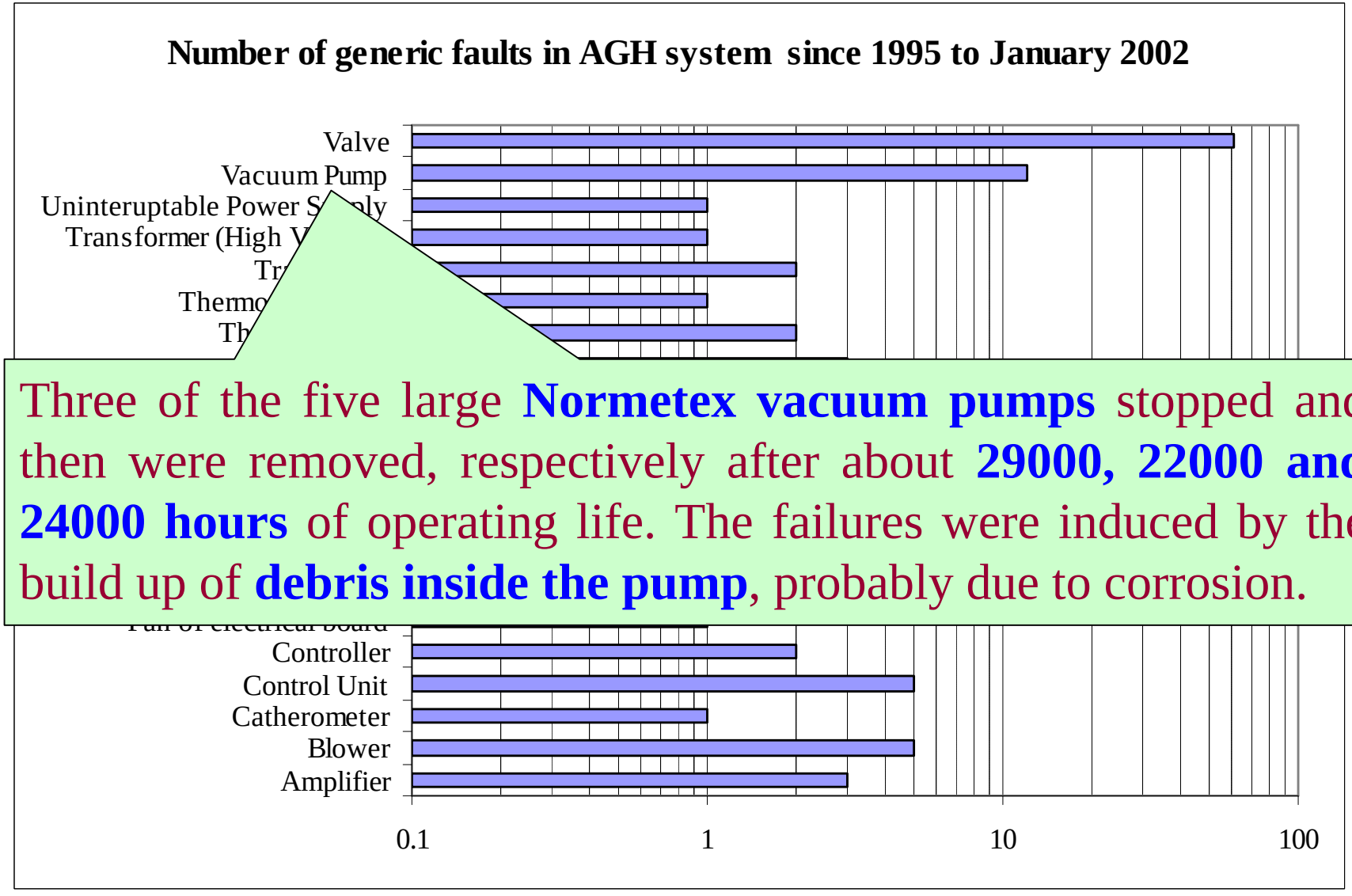
Important in terms of number of malfunctions are also "**Erratic/No Output**" of **instrumentation and electronic components**, e.g.: ammeter failures for tritium indicators

JET AGHS



For **Control Units** failures, it can be noted that there are **40 cooling fans** in the plant to cool down electrical boards in PLCs and in distributed control system. They all **run continuously**. **Since** the first fan failure in **July 1997**, a **preventative maintenance program** has **started** and fans are replaced every 12 months.

JET AGHS

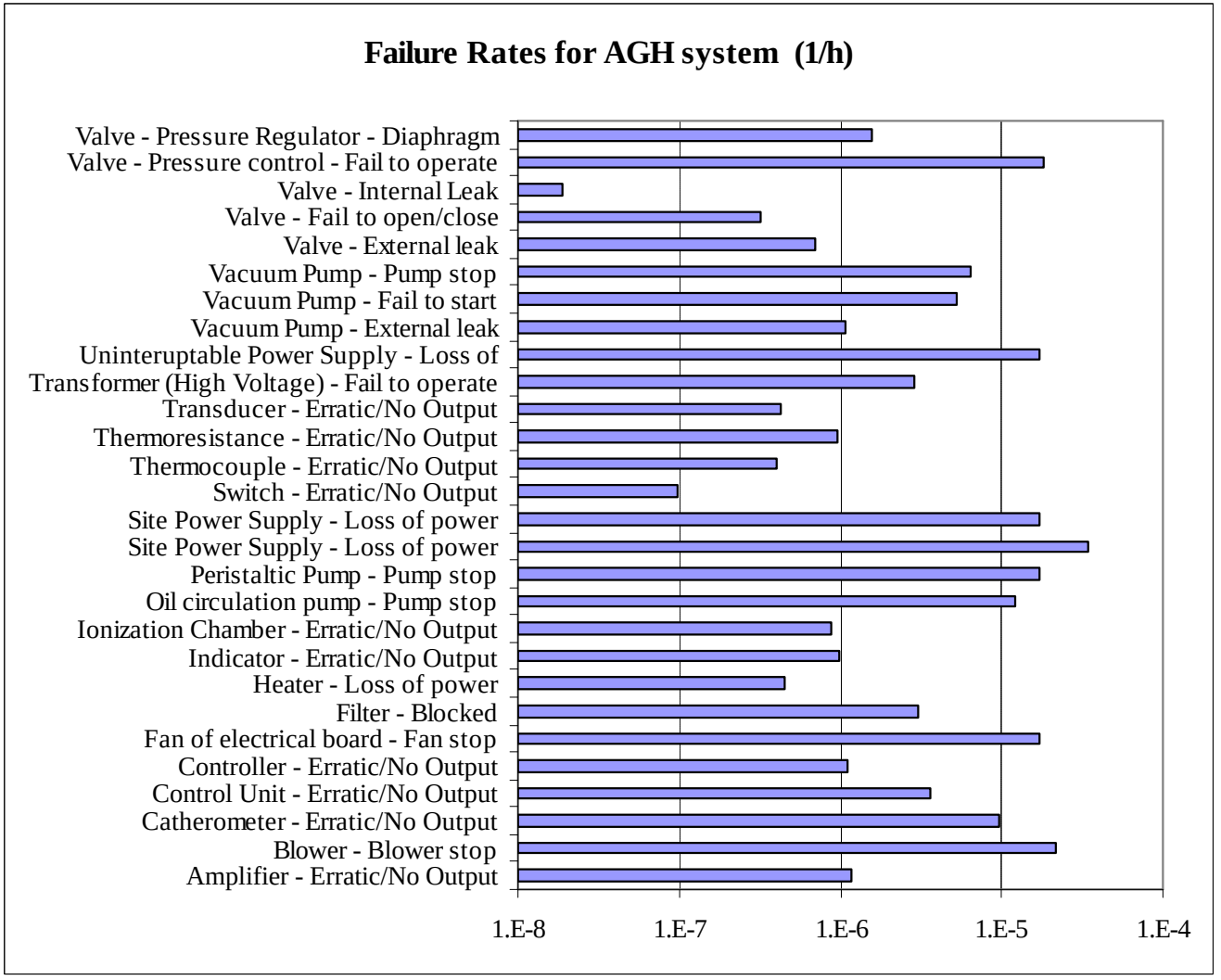


Three of the five large **Normetex vacuum pumps** stopped and then were removed, respectively after about **29000, 22000 and 24000 hours** of operating life. The failures were induced by the build up of **debris inside the pump**, probably due to corrosion.

JET AGHS

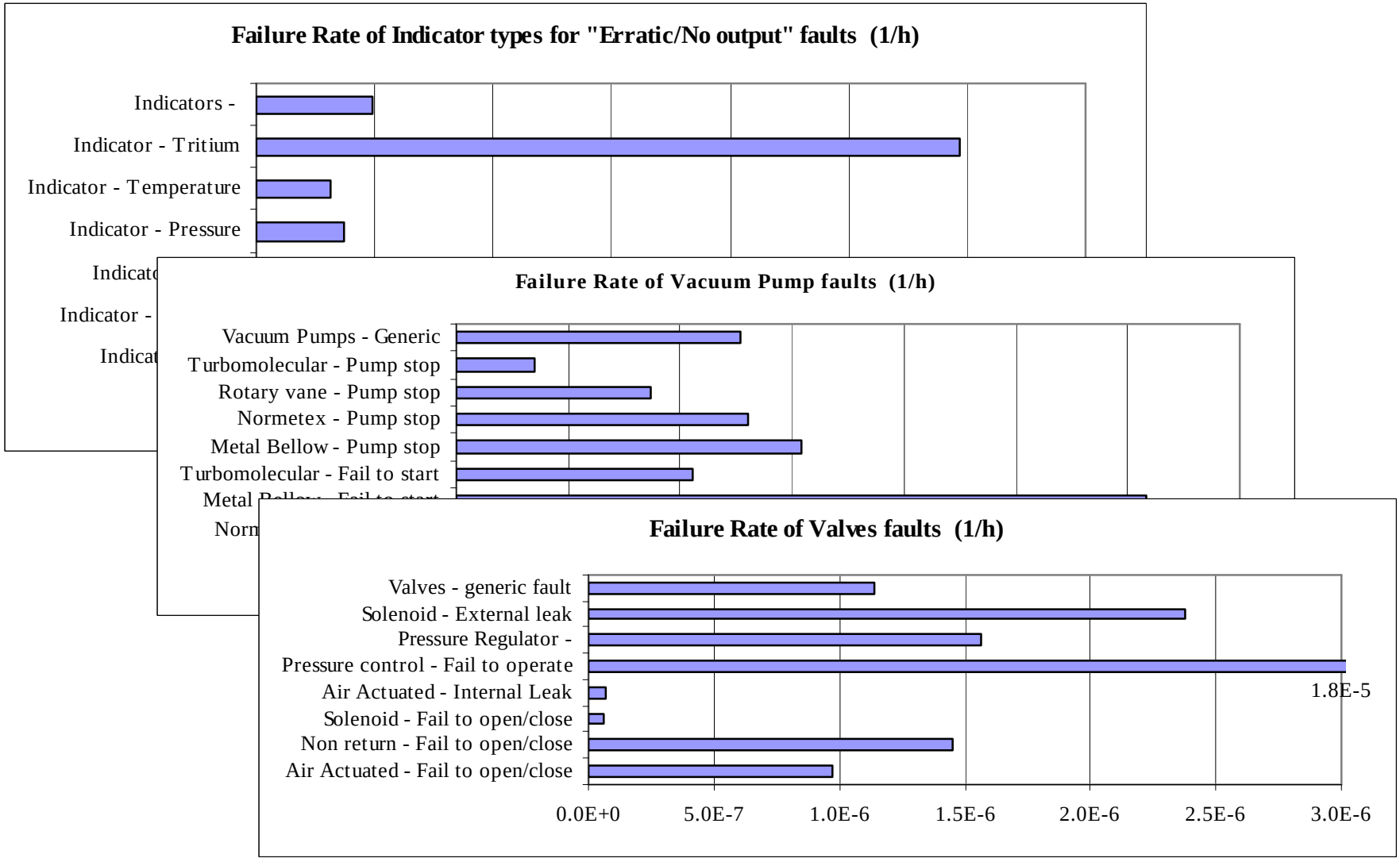
Component	N° of faults	N° of components	Total Hours	Tot N° of demands
Amplifier	3	102	2572408	
Blower	5	4	230044	
Catherometer	1	8	103744	
Control Unit	5	60	1378133	
Controller	2	67	1799919	
Fan of electrical board	1	40	57511	
Filter	1	8	324773	
Heater	2	155	4465061	797945
Indicator	19	653	19375448	
Ionization Chamber	1	36	1133523	
Oil circulation pump	2	6	164592	47417
Peristaltic Pump	2	2	115022	
Site Power Supply (from national grid)	3	1	57511	
Switch	3	1302	30864063	
Thermocouple	2	226	4965296	
Thermoresistance	1	43	1056560	
Transducer	2	210	4691600	
Transformer (High Voltage)	1	6	345066	
Uninteruptable Power Supply	1	1	57511	
Vacuum Pump	12	42	943740	289747
Valve	61	2124	53683827	52789038

JET AGHS

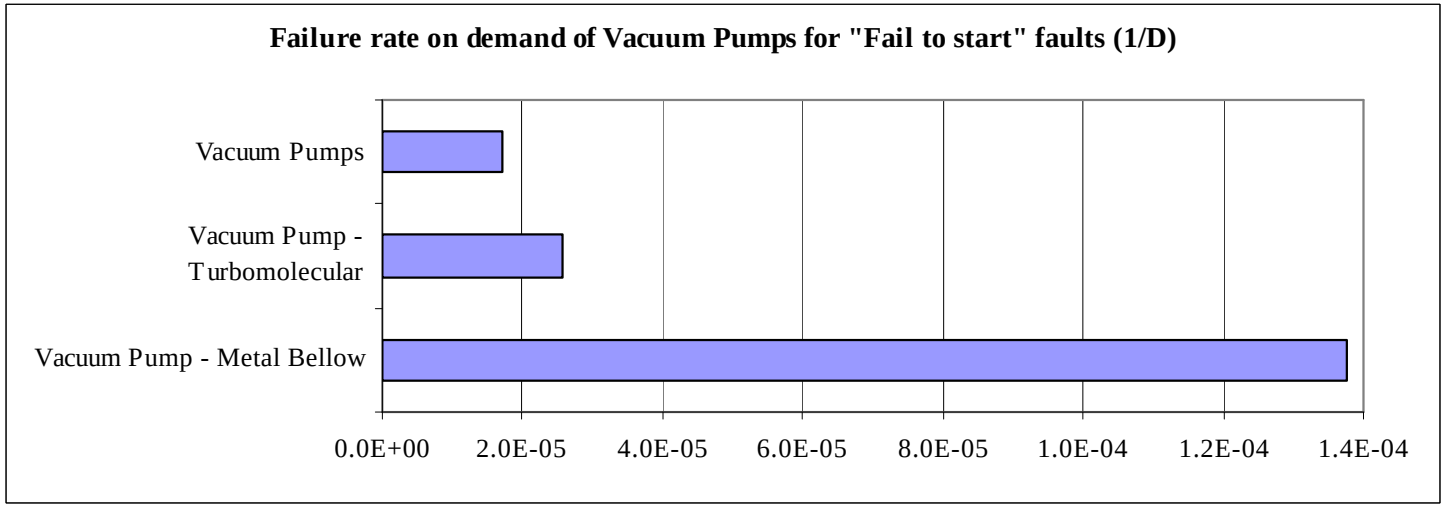


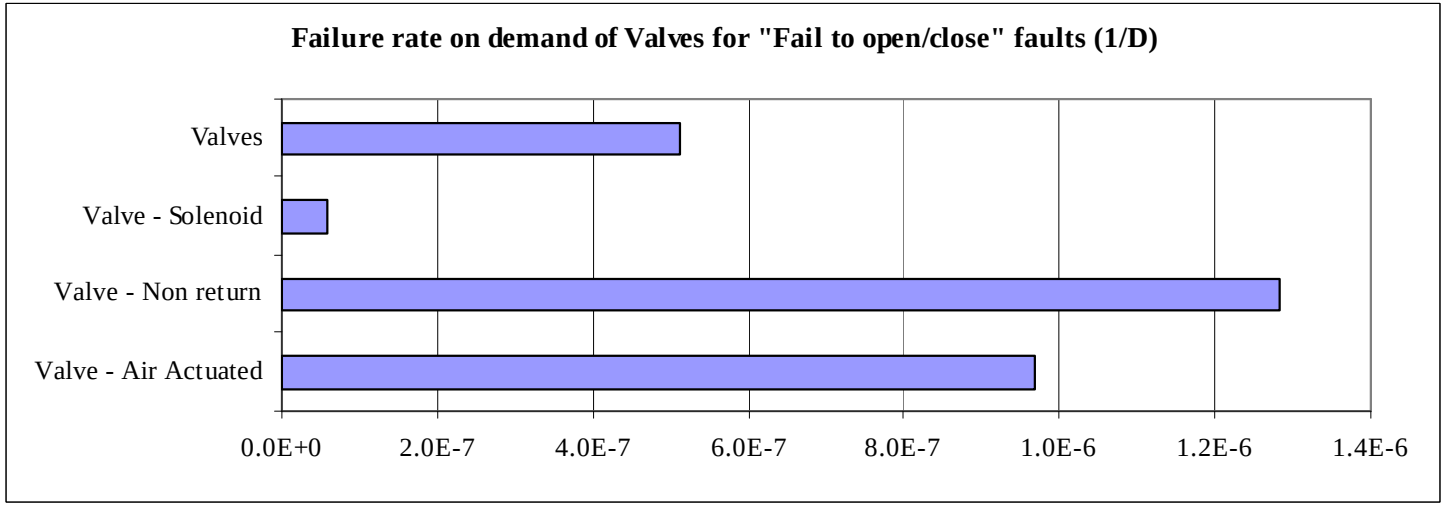
Component	Failure mode	Failure rate l	Standard error $s.e.(l)$	l_L (90%)	l_U (90%)
		(1/h)			
Amplifier	Erratic/No Output	1.2E-06	6.7E-07	3.2E-07	3.0E-06
Blower	Blower stop	2.2E-05	9.7E-06	8.6E-06	4.6E-05

JET AGHS


Failure Rate of Indicator types for "Erratic/No output" faults (1/h)
Indicators -
Indicator - Tritium
Indicator - Temperature
Indicator - Pressure
Failure Rate of Vacuum Pump faults (1/h)
Vacuum Pumps - Generic
Turbomolecular - Pump stop
Rotary vane - Pump stop
Normetex - Pump stop
Metal Bellow - Pump stop
Turbomolecular - Fail to start
Failure Rate of Valves faults (1/h)
Valves - generic fault
Solenoid - External leak
Pressure Regulator -
Pressure control - Fail to operate
Air Actuated - Internal Leak
Solenoid - Fail to open/close
Non return - Fail to open/close
Air Actuated - Fail to open/close
1.8E-5
0.0E+0
5.0E-7
1.0E-6
1.5E-6
2.0E-6
2.5E-6
3.0E-6

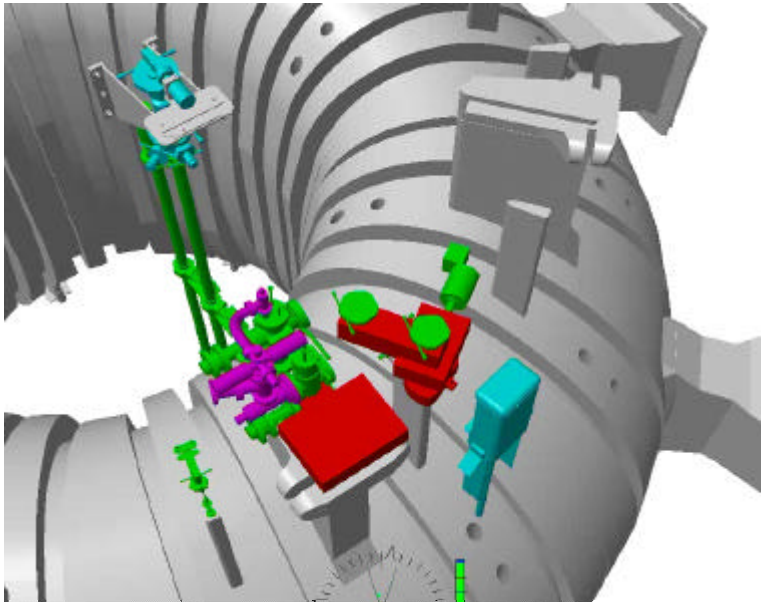
JET AGHS

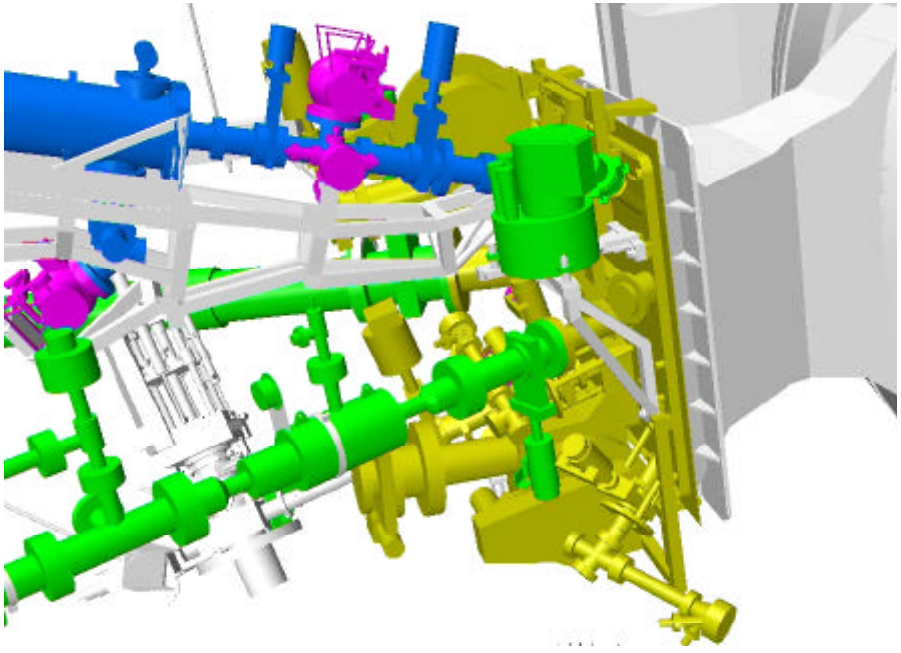

Failure rate on demand of Vacuum Pumps for "Fail to start" faults (1/D)
Vacuum Pumps
Vacuum Pump - Turbomolecular
Vacuum Pump - Metal Bellow
0.0E+00
2.0E-05
4.0E-05
6.0E-05
8.0E-05
1.0E-04
1.2E-04
1.4E-04


Failure rate on demand of Valves for "Fail to open/close" faults (1/D)
Valves
Valve - Solenoid
Valve - Non return
Valve - Air Actuated
0.0E+0
2.0E-7
4.0E-7
6.0E-7
8.0E-7
1.0E-6
1.2E-6
1.4E-6

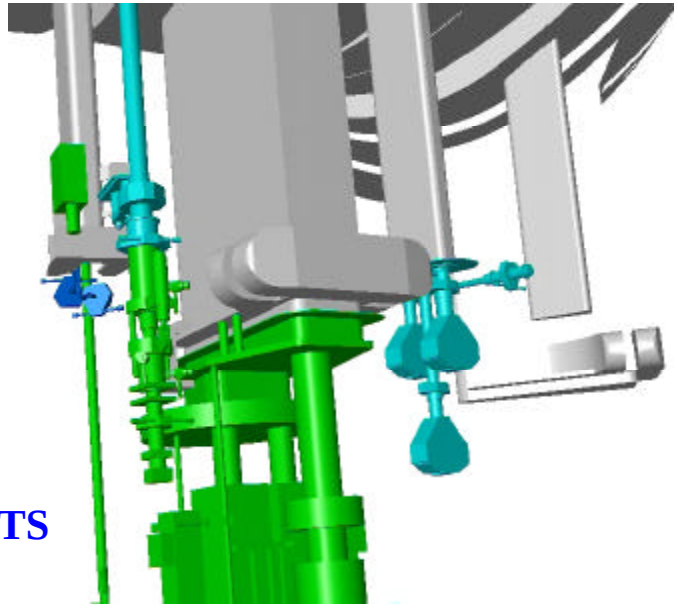
JET VACUUM SYSTEM

UPPER VERTICAL PORTS





EQUATORIAL PORTS



LOWER VERTICAL PORTS

JET VACUUM SYSTEM

Oct	Sect	Port	Sub system	Name	Purpose	Make	InDate	OutDate
1	BL	3	KT6D	Poloidal view visible spectroscopy of divertor plasma using a periscope	Periscope	JET	23-Jul-91	31-Jan-02
1	BL	4	LIM Cool	Limiter Cooling (In)			01-Jan-83	25-Jan-91
1	BL	4	DIV Cool	Divertor Target Plate Cooling (In)			25-Jan-91	31-Jan-02
1	BL	IVP	KC1	Magnetic Diagnostics	Plasma current, loop volts, plasma position, shape of flux surfaces, diamagnetic loop, fast MHD	JET	01-Jan-83	31-Jan-02
1	BL	IVP	KS4	Active Beam Diagnostics		JET	01-Jun-87	25-Jan-91
1	BL	IVP	SepLIMCool	Sep- Limiter Cooling			31-Oct-89	25-Jan-91
1	BL	IVP	DIV Baffle	Divertor Baffle Feed			25-Jan-91	31-Jan-02
1	BM	Lim	BeEvap.	Be evaporator			01-Jan-83	31-Jan-02
1	BM	Lim	KJ2	Toroidal Soft X-ray Arrays	NO compatible with Tritium	JET	01-Jan-88	18-Mar-91
1	BM	Lim	KS4	Active Beam Diagnostics		JET	18-Mar-91	19-May-92
1	BM	Lim	KS5	Active Balmer a spectroscopy	Active Beam Spect		19-May-92	31-Jan-02
1	BU	3	Instr.F/T	Instrumentation F/T			19-May-92	31-Jan-02
1	BU	4	LIM Cool	Limiter Cooling (Out)			01-Jan-83	25-Jan-91
1	BU	4	DIV Cool	Divertor Target Plate Cooling (Out)			25-Jan-91	31-Jan-02
1	BU	IVP	KS3	H-alpha and Visible Light Monitors	H-alpha	JET	01-Jan-83	31-Jan-02

JET VACUUM SYSTEM

Class	Type	Dimension	Shape
Bellow		Not identified	
Bellow		10÷100	Ø
Bellow		100÷500	Ø
Bellow		500÷1000	Ø
Bellow		1000÷1500	Ø
Bellow		>1500	Ø
Valve		Not identified	
Valve		10÷100	Ø
Valve		100÷250	Ø
Valve		250÷500	Ø
Valve		500÷1000	Ø
Valve		>1000	Ø
Weld	Fillet	500x500	?
Weld	Fillet	750x750	?
Weld	Fillet	1000x1000	?
Weld	Fillet	1500x1500	?
Weld	Lip	10÷100	Ø
Weld	Lip	100÷500	Ø
Weld	Lip	500÷1000	Ø
Weld	Lip	1000÷1500	Ø
Weld	Lip	>1500	Ø

JET VACUUM SYSTEM

Commissioning&Operations		Operating days	Operating hours	Shutdown (d)	Year	Operating days	Operating hours
Starts	End						
20/03/1983	31/07/1983	134	3216				
20/09/1983	20/12/1983	92	2208	50	**1983**	226	5424
20/02/1984	10/05/1984	81	1944	61			
07/06/1984	30/09/1984	116	2784	27			
05/12/1984	31/12/1984	27	648	65	**1984**	224	5376
01/01/1985	14/06/1985	165	3960	0			
10/10/1985	31/12/1985	83	1992	117	**1985**	248	5952
01/01/1986	30/11/1986	334	8016	0	**1986**	334	8016
10/05/1987	31/12/1987	236	5664	160	**1987**	236	5664
01/01/1988	21/05/1988	142	3408	0			
02/07/1988	25/10/1988	116	2784	41	**1988**	258	6192
15/03/1989	07/04/1989	24	576	140			
01/05/1989	15/07/1989	76	1824	23			
07/09/1989	07/10/1989	31	744	53	**1989**	131	3144
15/03/1990	02/04/1990	19	456	158			
08/04/1990	07/05/1990	30	720	5			
15/05/1990	30/07/1990	77	1848	7			
27/08/1990	08/11/1990	74	1776	27	**1990**	200	4800
10/03/1991	10/05/1991	62	1488	121			
02/06/1991	28/08/1991	88	2112	22			
20/09/1991	31/12/1991	103	2472	22	**1991**	253	6072
01/01/1992	15/03/1992	75	1800	0	**1992**	75	1800
12/02/1994	15/04/1994	63	1512	698			
15/05/1994	04/07/1994	51	1224	29			
22/07/1994	15/09/1994	56	1344	17			
07/10/1994	31/12/1994	86	2064	21	**1994**	256	6144

JET VACUUM SYSTEM

Oct.	Sect.	Port	Position	Location	Component	Dimension	Shape	Qty	Interface	InDate	OutDate	Item1	Item2	Oper.Hours
1	BL	3			Bellow	10÷100	Ø	2	KT6D	23-Jul-91	31-Jan-02			46656
1	BL	3	Outer End		DN63			2	KT6D	23-Jul-91	31-Jan-02	KT6D Tube	KT6D Window	46656
1	BL	3	Torus End		Lip	10÷100	Ø	2	KT6D	23-Jul-91	31-Jan-02	100mm Port	KT6D Tube	46656
1	BL	3			Window	10÷100	Ø	1	KT6D	23-Jul-91	31-Jan-02			46656
1	BL	4			F/T Lq	10÷100	Ø	1	DIV Cool	25-Jan-91	31-Jan-02	100mm Port	Div.Water Line	50256
1	BL	4	Torus End		Lip	10÷100	Ø	2	DIV Cool	25-Jan-91	31-Jan-02	100mm Port	Div.Water Line	50256
1	BL	4			F/T Lq	10÷100	Ø	1	LIM Cool	01-Jan-83	25-Jan-91	100mm Port	Limiter Water Line	44568
1	BL	4	Torus End		Lip	10÷100	Ø	2	LIM Cool	01-Jan-83	25-Jan-91	100mm Port	Limiter Water Line	44568
1	BL	IVP	Inner	Center	DN16			1	DIV Baffle	25-Jan-91	31-Jan-02	IVP Flange	Drain Plug	50256
1	BL	IVP	Inner	Back	Fillet	10÷100	Ø	1	DIV Baffle	25-Jan-91	31-Jan-02	IVP Flange	Div.Baffle Feed	50256
1	BL	IVP	Inner	Front	Fillet	10÷100	Ø	1	DIV Baffle	25-Jan-91	31-Jan-02	IVP Flange	Div.Baffle Feed	50256
1	BL	IVP	Center		F/T El	10÷100	Ø	1	KC1	01-Jan-83	31-Jan-02	IVP Flange		94824
1	BL	IVP	Outer		F/T El	10÷100	Ø	1	KC1	01-Jan-83	31-Jan-02	IVP Flange		94824
1	BL	IVP	Center		Fillet	10÷100	Ø	1	KC1	01-Jan-83	31-Jan-02	IVP Flange	KC1 Discr.Coil	94824
1	BL	IVP	Outer		Fillet	10÷100	Ø	1	KC1	01-Jan-83	31-Jan-02	IVP Flange	KC1 Discr.Coil	94824
1	BL	IVP	Center		Lip	10÷100	Ø	1	KC1	01-Jan-83	31-Jan-02	IVP Flange	KC1 Discr.Coil	94824
1	BL	IVP	Outer		Lip	10÷100	Ø	1	KC1	01-Jan-83	31-Jan-02	IVP Flange	KC1 Discr.Coil	94824
1	BL	IVP	Inner		Butt	10÷100	Ø	2	KS4	01-Jun-87	25-Jan-91			10728
1	BL	IVP	Inner		DN63			1	KS4	01-Jun-87	25-Jan-91			10728
1	BL	IVP	Inner		Fillet	10÷100	Ø	1	KS4	01-Jun-87	25-Jan-91			10728
1	BL	IVP	Inner		Lip	10÷100	Ø	2	KS4	01-Jun-87	25-Jan-91			10728
1	BL	IVP	Inner		Window	10÷100	Ø	1	KS4	01-Jun-87	25-Jan-91			10728
1	BL	IVP	Inner		DN16			1	SepLIMCool	31-Oct-89	25-Jan-91			4800
1	BL	IVP	Inner		Fillet	10÷100	Ø	1	SepLIMCool	31-Oct-89	25-Jan-91			4800
1	BL	IVP	Inner		Fillet	10÷100	Ø	1	SepLIMCool	31-Oct-89	25-Jan-91			4800
1	BM	Lim	Lower		Butt	100÷500	Ø	2	BeEvap.	01-Jan-83	31-Jan-02			94824
1	BM	Lim	Lower		ComFit			4	BeEvap.	01-Jan-83	31-Jan-02			94824
1	BM	Lim	Lower		RH225			1	BeEvap.	01-Jan-83	31-Jan-02	Lim.Flange	Spool Piece	94824
1	BM	Lim	Lower		RH225			1	BeEvap.	01-Jan-83	31-Jan-02	Spool Piece	Be Evaporator	94824

Reference data set: 2375 records

JET VACUUM SYSTEM

Component	Qty	Oper. Hours
Bellows	243	18107520
Burst Disks	2	189648
Com.Fit.	236	15604080
Flange DNnnn	462	26247048
Flange RHnnn	254	16758816
F/T Cryo	4	379296
F/T El	143	9169920
F/T Gas	19	1107168
F/T Lq	72	3482688
Insulator	1	50256
Vacuum Pumps	42	2858304
Vacuum Gauges	95	6276552
Valve	153	9295128
Butt Welds	686	41974752
Fillet Welds	806	52422576
Lip Welds	542	30331656
Window	252	15193992
	4012	249449400

Reference data set: 2375 records

Class type	Dimension	Shape	Qty
Butt Welds	Not identified		104
	>1500	Ø	2
	100÷500	Ø	284
	10÷100	Ø	290
	750x750	□	3
	500x500	□	3
Fillet Welds	Not identified		104
	>1500	Ø	8
	100÷500	Ø	161
	10÷100	Ø	507
	750x750	□	6
	500x500	□	10
	250x250	□	10
Lip Welds	>1500	Ø	3
	100÷500	Ø	36
	10÷100	Ø	450
	1500x1500	□	13
	750x750	□	23
	500x500	□	7
	250x250	□	10
Valves	Not identified		8
	250÷500	Ø	11
	100÷250	Ø	68
	10÷100	Ø	66
Windows	100÷250	Ø	24
	10÷100	Ø	228

JET VACUUM SYSTEM

ID	Date	Oct	Sector	Port	Type	Comp. Leak	Description	Size	Comments	Component Class			Failure Mode
1	23-Mar-83	6	BU	IVP	Inst.	DN32	KB1 Flange to IVP Flange	1.00E+00	Clamp Missing.Resealed.OK	DN32			Leak
2	23-Mar-83	7	BU	IVP	Inst.	DN32	KB1 Flange to IVP Flange	1.00E+00	Clamp Misaligned.Resealed.OK	DN32			Leak
3	23-Mar-83	5	BU	IVP	Inst.	DN32	KB1 Flange to IVP Flange	1.00E+00	Clamp Loose.Tightened.OK	DN32			Leak
4	23-Mar-83	8	BU	IVP	Inst.	DN32	KB1 Flange to IVP Flange	1.00E+00	Clamp Loose.Tightened.OK	DN32			Leak
5	10-May-83	7	Di	g.Cr.	Inst.	40KF	Diag.Crown Blank Missing	1.00E+01	Blank Installed.OK	ComFit			Leak
6	01-Jun-83	8	BU	IVP	Inst.	Butt	IVP Flange Tube to IVP Tube	1.00E-02	Internal Weld.Repaired.OK	Butt	10÷100	Ø	Leak
7	03-Jun-83	5	CL	MVP	Inst.	Lip	Blank Lip to MVP Lip	2.00E-05	Lip Weld.Rewelded.OK	Lip	10÷100	Ø	Leak
8	07-Jun-83	1	CM	P.Ch	Inst.	O Ring	Door Flange to P.Ch Door	1.00E-06	O Ring Replaced by Cefilac	RH1200			Leak O'Ring
9	07-Jun-83	5	CM	P.Ch	Inst.	O Ring	Door Flange to P.Ch Door	1.00E-05	O Ring Replaced by Cefilac	RH1200			Leak O'Ring
10	20-Jun-83	3	CL	MVP	Crit.	Water	GDC Elec.Int.to Torus	1.00E-02	GDC Electrode Mod/Replaced	F/T Lq	10÷100	Ø	Water Leak
11	21-Jun-83	6	CU	MVP	Crit.	Water	GDC Elec.Int.to Torus	1.00E-04	GDC Electrode Mod/Replaced	F/T Lq	10÷100	Ø	Water Leak
12	29-Jun-83	6	CU	MVP	Inst.	150RH	GDC Elec.Flange- MVP Flange	5.00E-08	Dirt on Seal.Resealed.OK	RH150			Leak
13	19-Jul-83	8	CM	MPA	Crit.	Fillet	Duct Scraper Int.Weld-Torus	4.00E+00	D.Scr.Pumped.Later Modified	Fillet	100÷500	Ø	Leak
14	19-Sep-83	1	CM	P.Ch	Inst.	225RH	KL1 Window to P.Ch R/Oblique	1.00E-08	Flange Tightened.Cured.OK	RH225			Leak
15	19-Sep-83	4	CM	MPA	Inst.	Valve	KJ1 Prov.Valve to Torus	2.00E-04	Manual Valve not Shut	Valve	100÷250	Ø	Fail to close
16	19-Sep-83	5	CM	P.Ch	Inst.	225RH	KL1 Window to P.Ch L/Oblique	5.00E-08	Flange Tightened.Cured.OK	RH225			Leak
17	20-Sep-83	2	BL	IVP	Inst.	Butt	IVP Flange Tube to IVP Tube	2.00E-05	Internal Weld.Repaired.OK	Butt			Leak
18	24-Sep-83	5	CM	P.Ch	Op.	Valve	T03 Valve Seat Leak	1.00E+00	Valve Operated out of Sequence	Valve	250÷500	Ø	Seat Leak

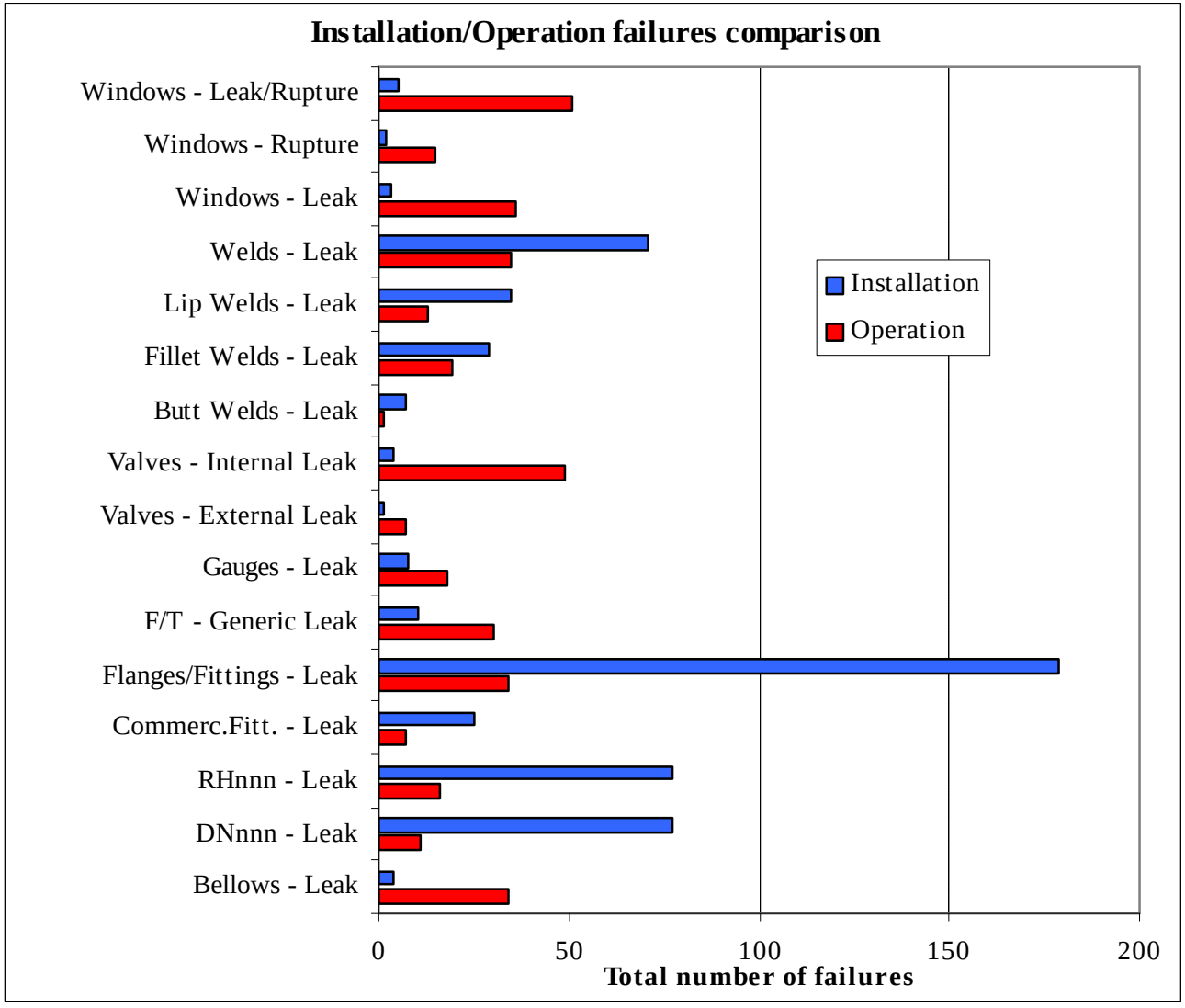
Leaks data set: 616 records

JET VACUUM SYSTEM

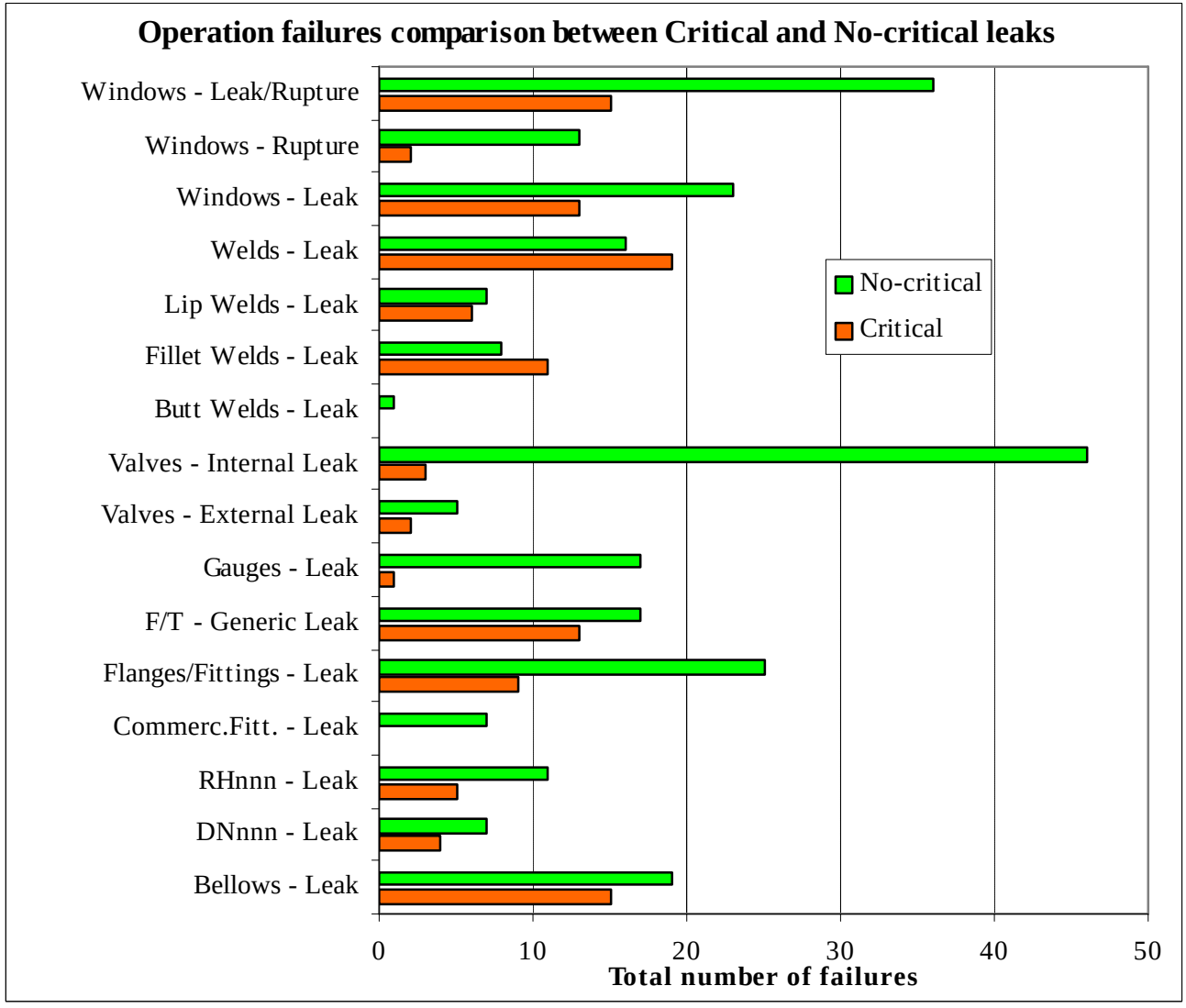
Component	Operating leaks	Installation leaks	Total operation time [h]	N° of components in the system
Bellows	**34** +10[(a)]	**4** +4[(a)]	18 107 520	243
Burst Disks	**1**		189 648	2
Cefilac (DNnnn)	**11**	77 +3[(a)]	26 247 048	462
Bolted Flanges (RHnnn)	**16**	77 +5[(a)]	16 758 816	254
Commercial fittings and flanges	7 +2[(a)]	**25**	15 604 080	236
F/T Cryolines	**2**	**1**	379 296	4
F/T Electrical	**18**		9 169 920	143
F/T Gas lines	**2**	**3**	1 107 168	19
F/T Liquid lines (e.g. cooling water)	**8**	**16**	3 482 688	72
Vacuum Gauges	**18**	**8**	6 276 552	95
Valves	**57** +1[(a)]	**9** +4[(a)]	9 295 128	153
Butt Welds	**1** +1[(a)]	7	41 974 752	686
Fillet Welds	**19** +2[(a)]	**29** +28[(a)]	52 422 576	806
Lip Welds	**13**	**35** +4[(a)]	30 331 656	542
Generic Welds	**35** +12	**71** +32[(a)]	124 728 984	2 034
Windows	**51**	**5**	15 193 992	252
Vacuum Pumps	**0**	**0**	2 858 304	42
Total	**258** +25	**296** +48[(a)]	**249 399 144**	**4 012**

(a) ***Leaks referring to seals and components for which no information about the belonging equipments have been found out (i.e.: total amount of components installed and their operating life)***

JET VACUUM SYSTEM



JET VACUUM SYSTEM



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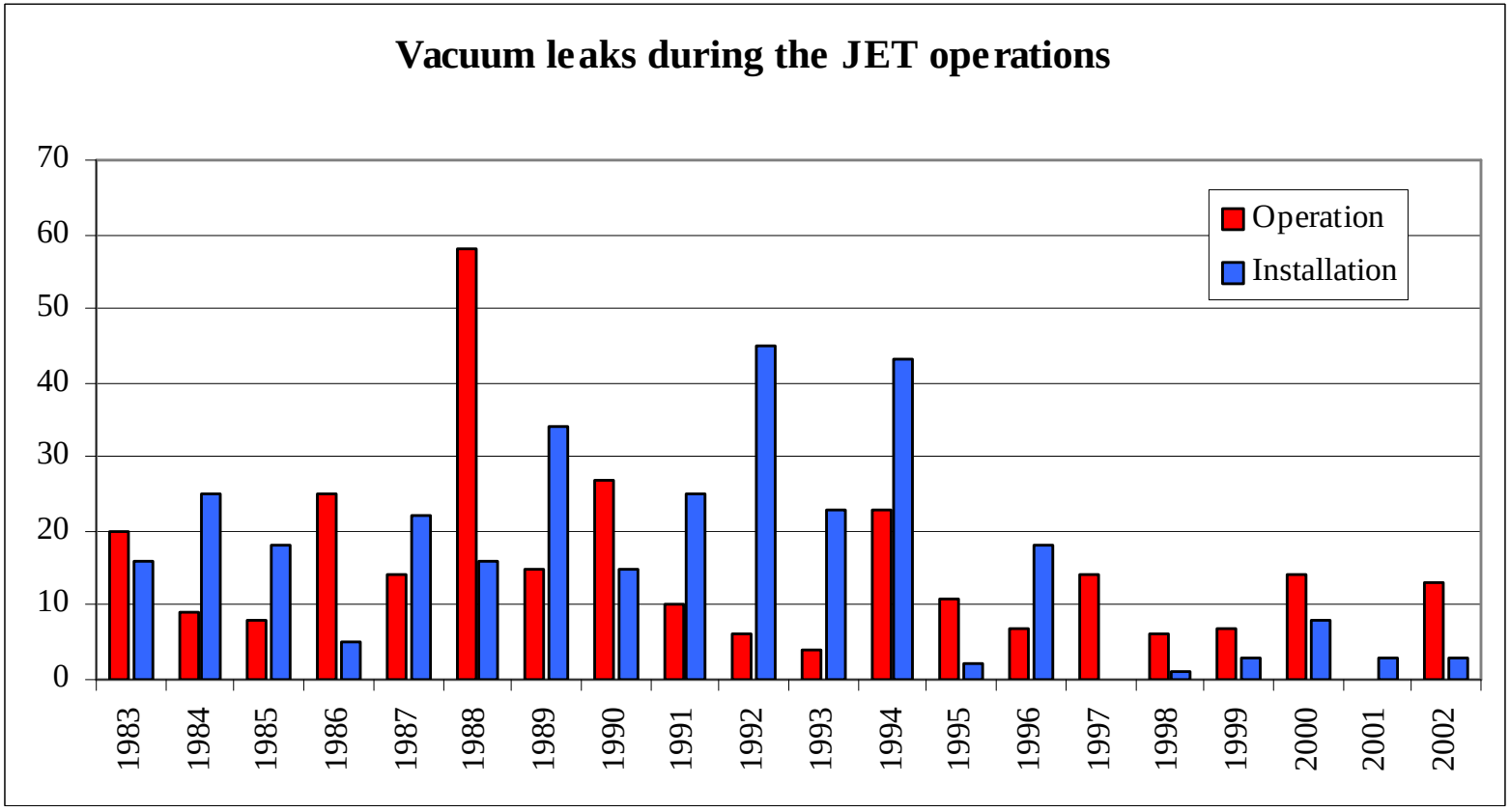

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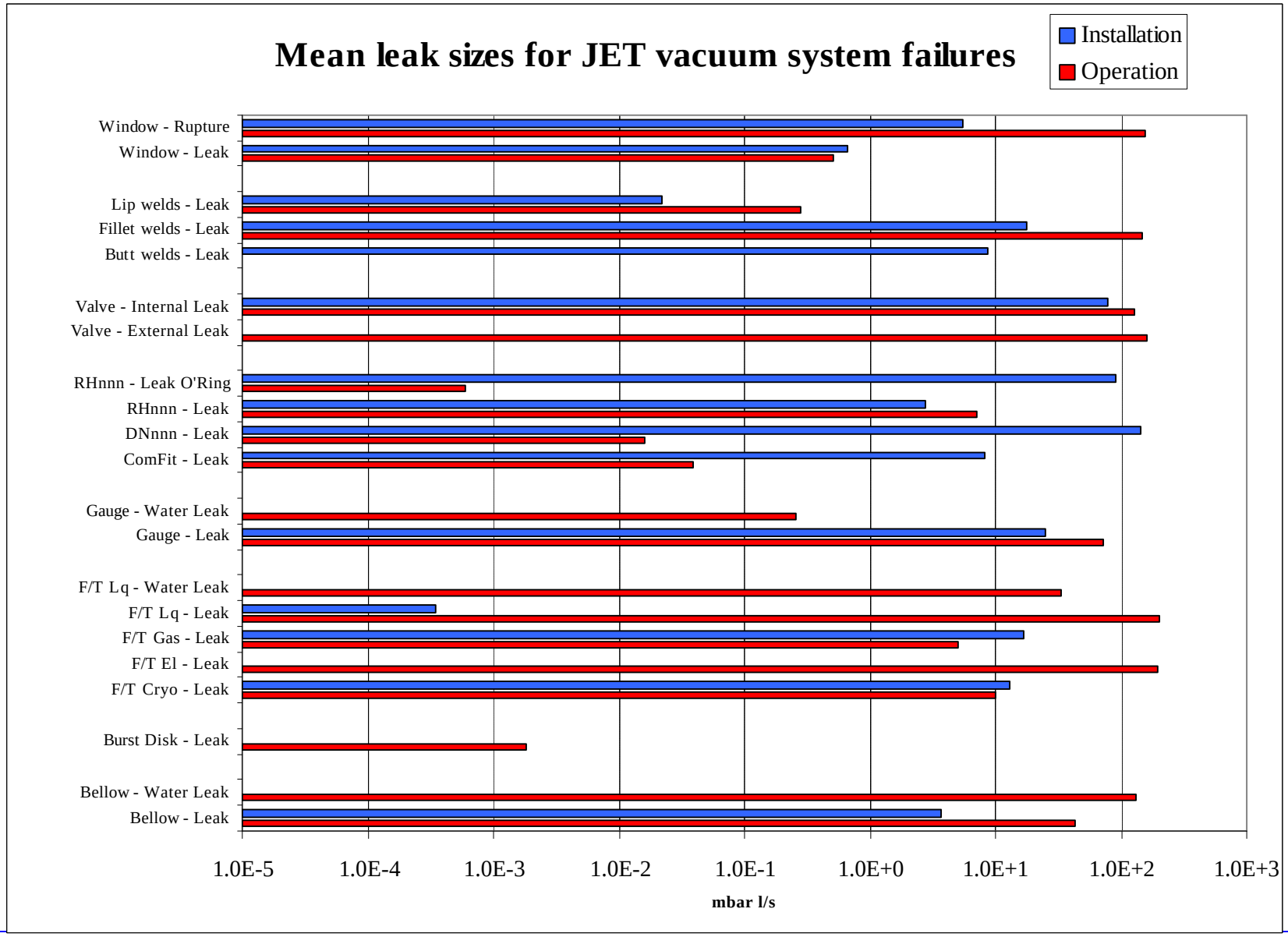
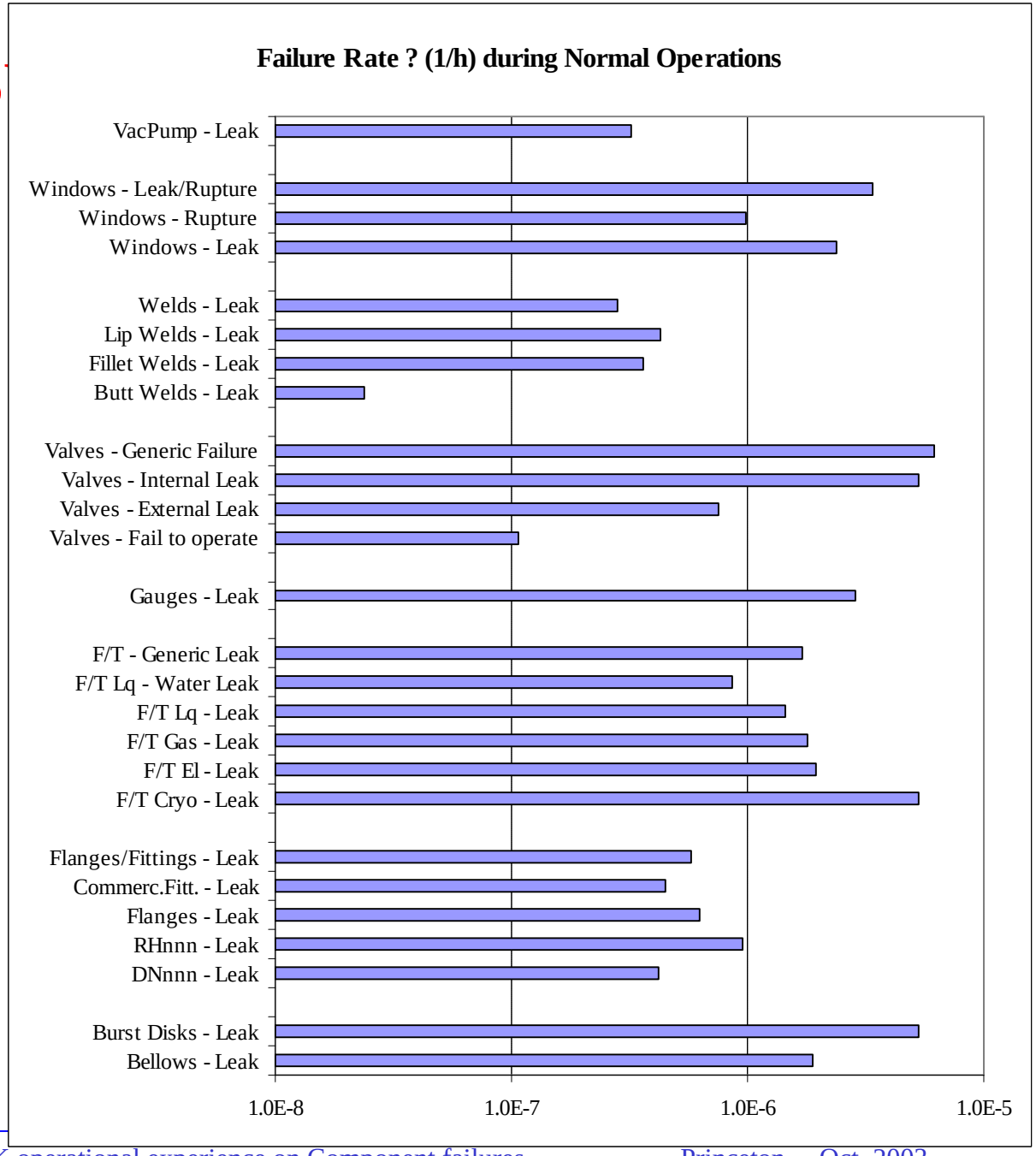
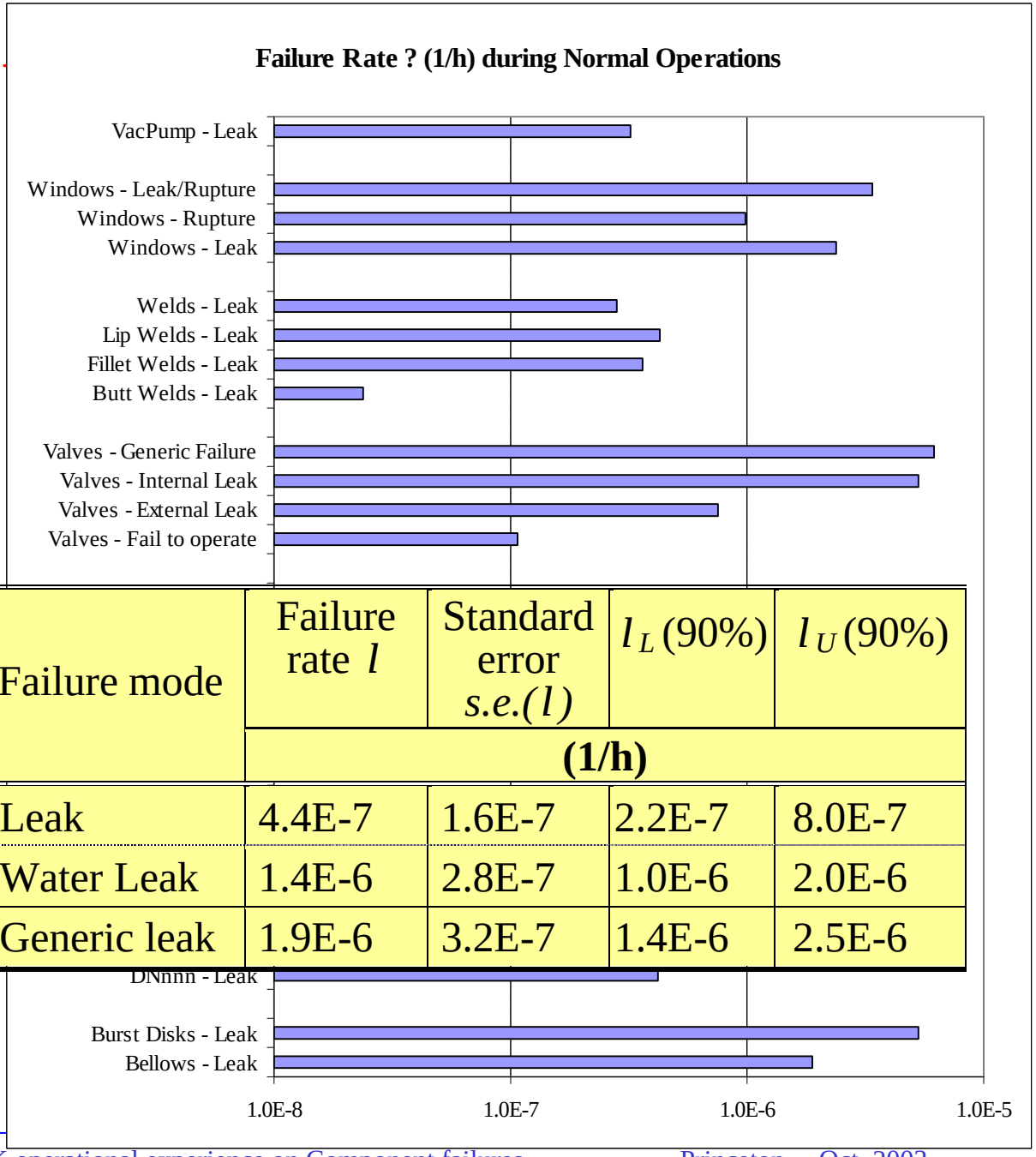


JET VACUUM S

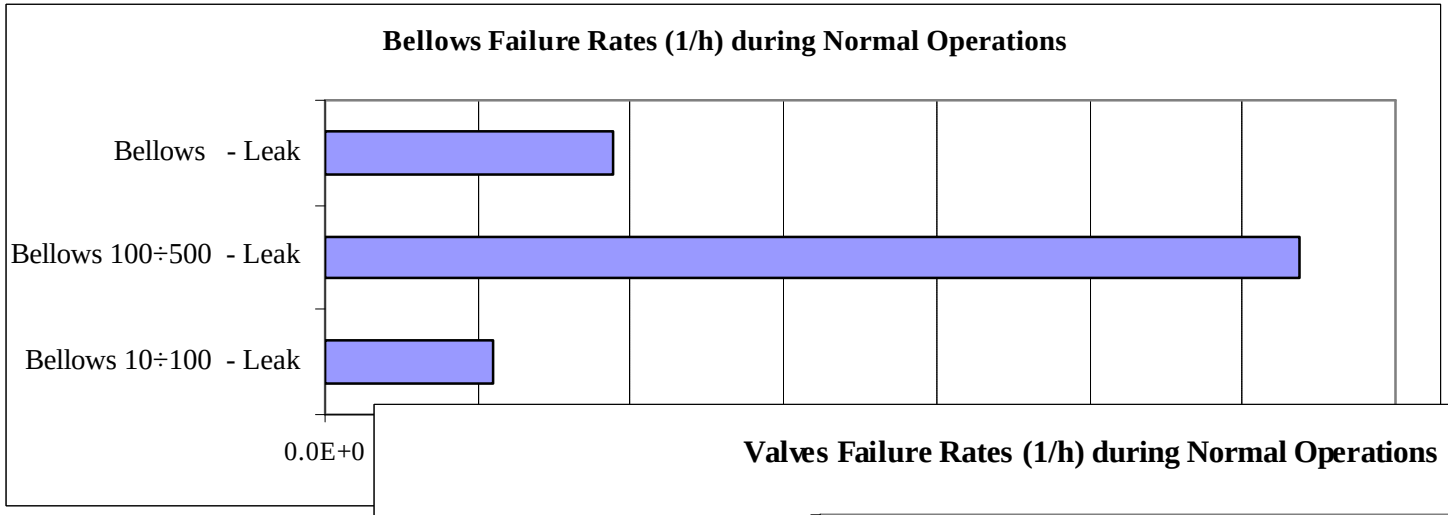

Failure Rate ? (1/h) during Normal Operations
VacPump - Leak
Windows - Leak/Rupture
Windows - Rupture
Windows - Leak
Welds - Leak
Lip Welds - Leak
Fillet Welds - Leak
Butt Welds - Leak
Valves - Generic Failure
Valves - Internal Leak
Valves - External Leak
Valves - Fail to operate
Gauges - Leak
F/T - Generic Leak
F/T Lq - Water Leak
F/T Lq - Leak
F/T Gas - Leak
F/T El - Leak
F/T Cryo - Leak
Flanges/Fittings - Leak
Commerc.Fitt. - Leak
Flanges - Leak
RHnnn - Leak
DNnnn - Leak
Burst Disks - Leak
Bellows - Leak
1.0E-8
1.0E-7
1.0E-6
1.0E-5

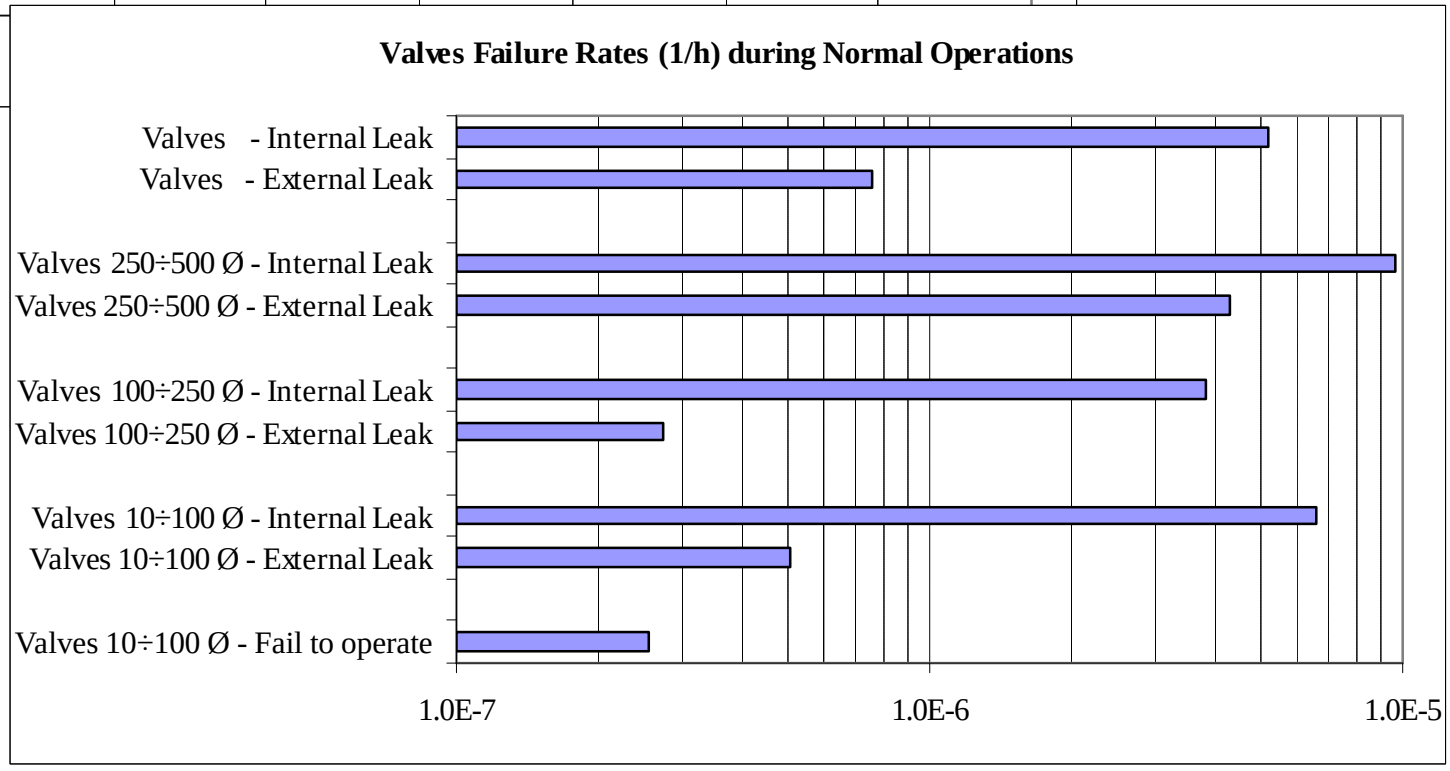
JET VACUUM S



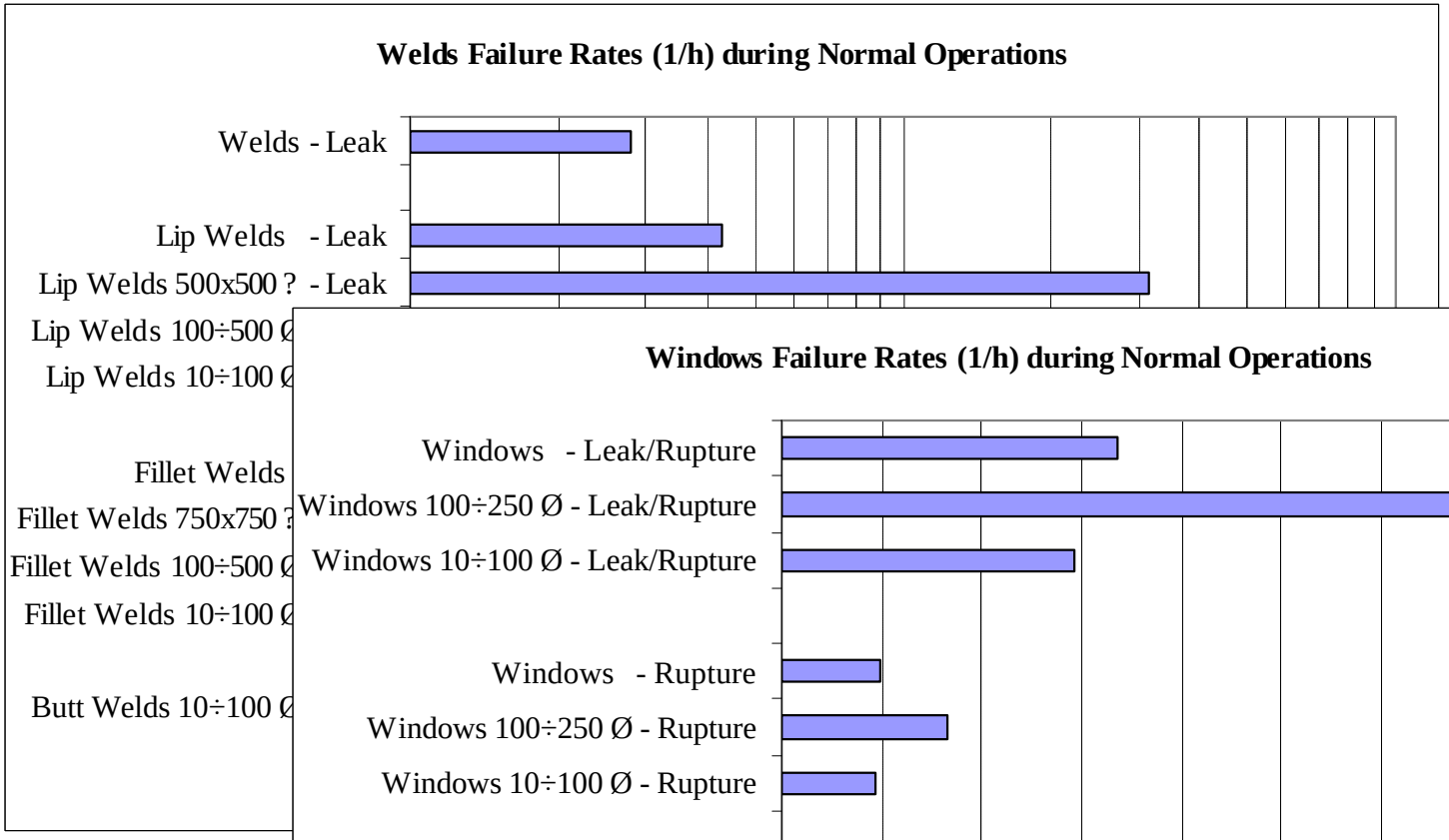
Component	Failure mode	Failure rate l	Standard error $s.e.(l)$	l_L (90%)	l_U (90%)
		(1/h)			
Bellows	Leak	4.4E-7	1.6E-7	2.2E-7	8.0E-7
Bellows	Water Leak	1.4E-6	2.8E-7	1.0E-6	2.0E-6
Bellows	Generic leak	1.9E-6	3.2E-7	1.4E-6	2.5E-6

JET VACUUM SYSTEM

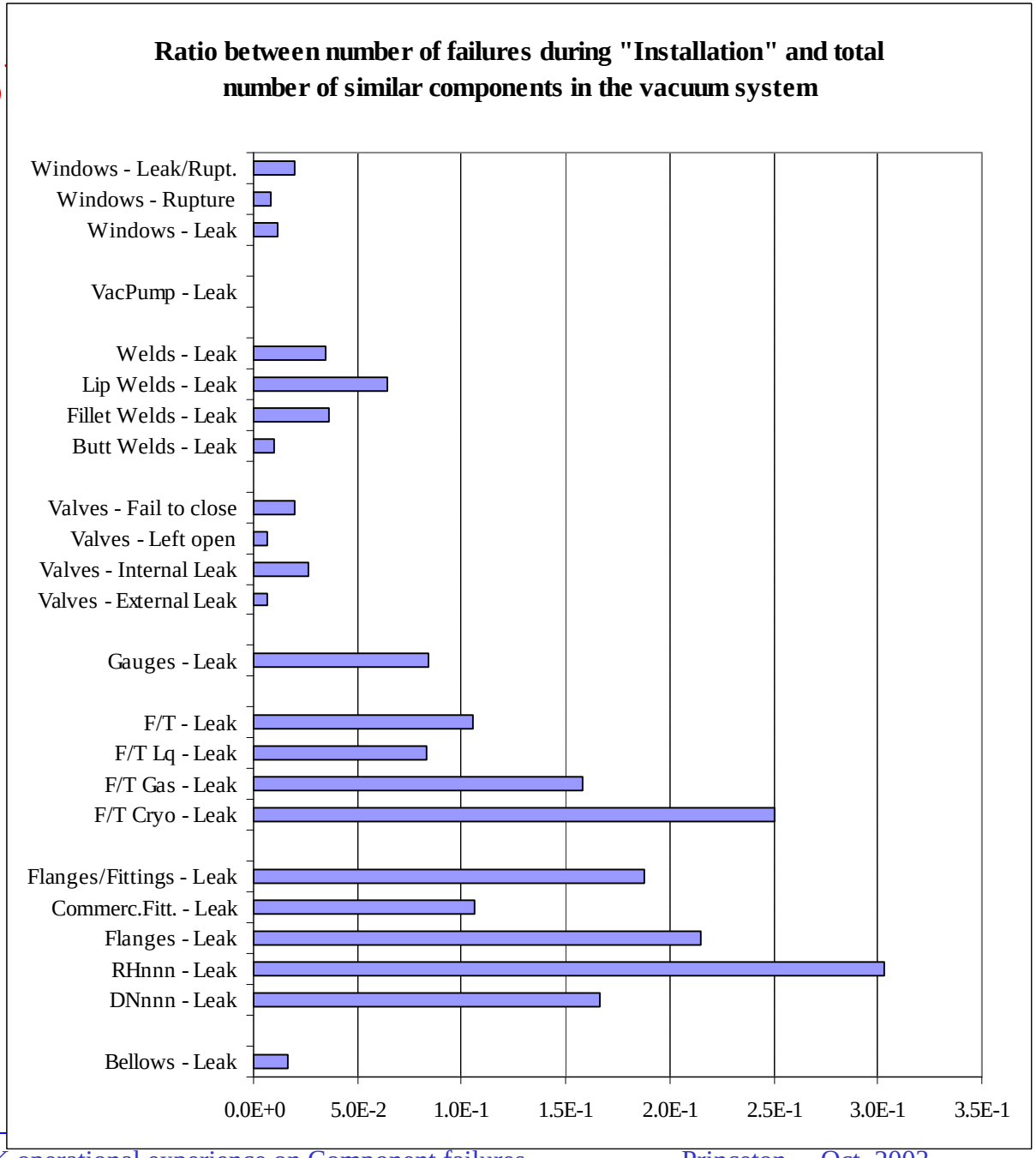




JET VACUUM SYSTEM



JET VACUUM S


Ratio between number of failures during "Installation" and total number of similar components in the vacuum system
Windows - Leak/Rupt.
Windows - Rupture
Windows - Leak
VacPump - Leak
Welds - Leak
Lip Welds - Leak
Fillet Welds - Leak
Butt Welds - Leak
Valves - Fail to close
Valves - Left open
Valves - Internal Leak
Valves - External Leak
Gauges - Leak
F/T - Leak
F/T Lq - Leak
F/T Gas - Leak
F/T Cryo - Leak
Flanges/Fittings - Leak
Commerc.Fitt. - Leak
Flanges - Leak
RHnnn - Leak
DNnnn - Leak
Bellows - Leak
0.0E+0
5.0E-2
1.0E-1
1.5E-1
2.0E-1
2.5E-1
3.0E-1
3.5E-1

TLK

System	Summary description
ZTS	Central Tritium Retention System *(Zentrales Tritium-Rueckhalte-System)*
TRS	Tritium Retention System
TLG	Tritium Storage *(Tritium Lager)*
TTS	Tritium Transfer System
TMT	Tritium Analytical System *(Tritium Mess – Technik)*
ISS	Isotopic Separation System
CAPER	Experiment for recovery of tritium from gaseous waste streams
PETRA	ITER Tritium Plant component tests

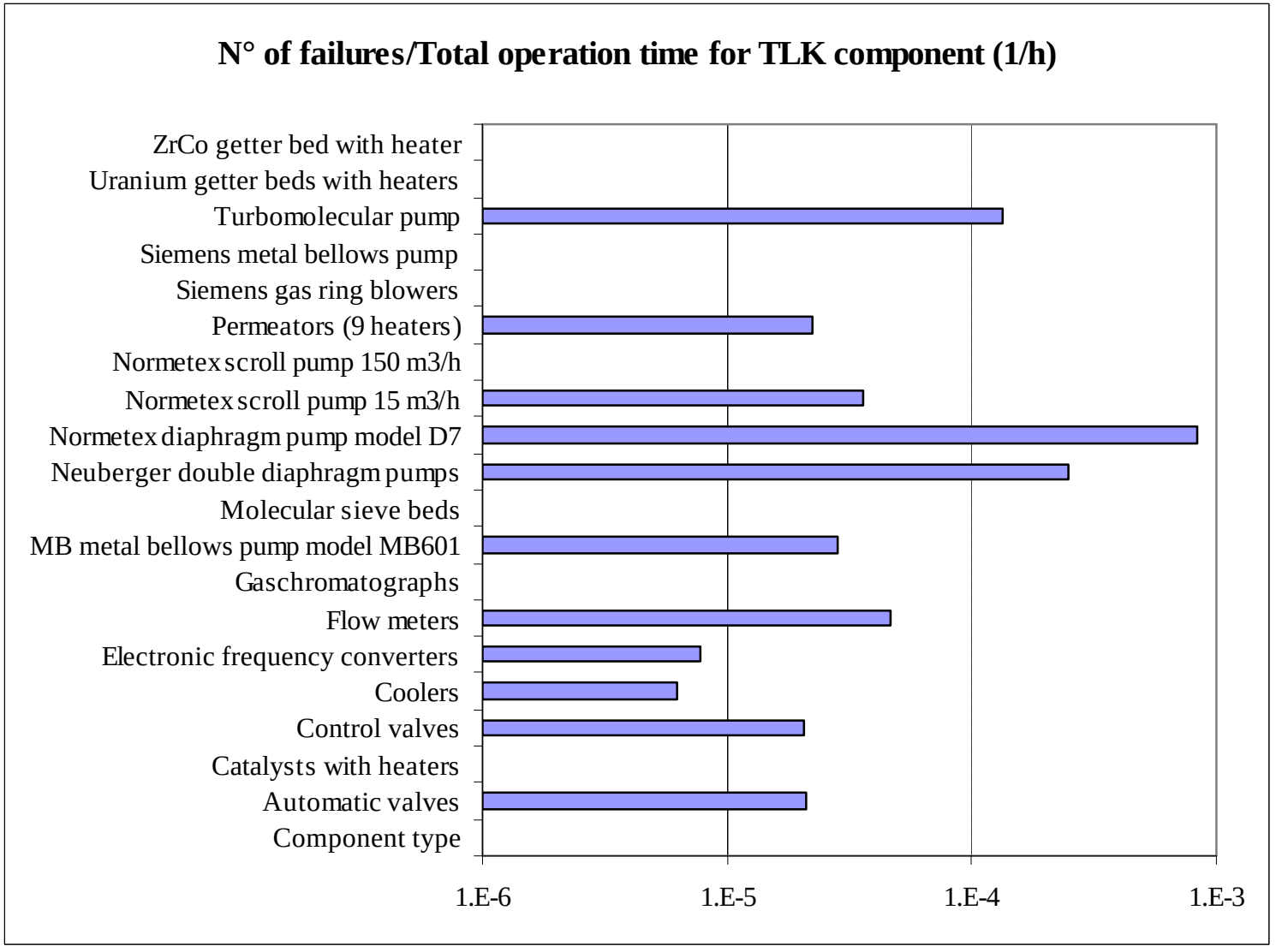
584 Components

Component type	N°
Automatic valves	322
Catalysts with heaters	49
Control valves	31
Coolers	21
Electronic frequency converters	24
Flow meters	16
Gaschromatographs	2
MB metal bellows pump model MB601	13
Molecular sieve beds	42
Neuberger double diaphragm pumps	2
Normetex diaphragm pump model D7	1
Normetex scroll pump 15 m^3/h	9
Normetex scroll pump 150 m^3/h	1
Permeators (9 heaters)	3
Siemens gas ring blowers	24
Siemens metal bellows pump	5
Turbomolecular pump	4
Uranium getter beds with heaters	14
ZrCo getter bed with heater	1

TLK

Component type	Total N° of failures	Total operation time (h)	N° of components
Automatic valves	16	767800	322
Catalysts with heaters	2	2785440	49
Control valves	2	97000	31
Coolers	8	1287720	21
Electronic frequency converters	11	1407720	24
Flow meters	3	64000	16
Gaschromatographs	-	157680	2
MB metal bellows pump model MB601	1	35000	13
Molecular sieve beds	-	2575440	42
Neuberger double diaphragm pumps	4	16000	2
Normetex diaphragm pump model D7	1	1200	1
Normetex scroll pump 15 m^3/h	1	27600	9
Normetex scroll pump 150 m^3/h	-	4000	1
Permeators (9 heaters)	2	90000	3
Siemens gas ring blowers	-	1407720	24
Siemens metal bellows pump	-	13812	5
Turbomolecular pump	1	7400	4
Uranium getter beds with heaters	-	1140	14
ZrCo getter bed with heater	-	60	1

TLK


N° of failures/Total operation time for TLK component (1/h)
ZrCo getter bed with heater
Uranium getter beds with heaters
Turbomolecular pump
Siemens metal bellows pump
Siemens gas ring blowers
Permeators (9 heaters)
Normetex scroll pump 150 m3/h
Normetex scroll pump 15 m3/h
Normetex diaphragm pump model D7
Neuberger double diaphragm pumps
Molecular sieve beds
MB metal bellows pump model MB601
Gaschromatographs
Flow meters
Electronic frequency converters
Coolers
Control valves
Catalysts with heaters
Automatic valves
Component type
1.E-6
1.E-5
1.E-4
1.E-3

CONCLUSION

- **AGHS:** about **130 failures** on a set of **6259 components**, operating for about **156 767 000 hours**, have been pointed out since **1995** up to **January 2002**.
- **Vacuum system :** About **600 failures** on a whole set of **4012 components**, operating for about **249 450 000 hours**, have been pointed out since **March 1983** up to **January 2002**.
- **TLK: 52 failures** on a set of **584 components**, operating for about **10 746 732 hours**, have been pointed out up to **October 2002**.
- Failure rates evaluated are in very **good agreement** with the corresponding ones existing in literature for similar applications. It has to be highlighted that the present set of reliability data is **between the most consistent sets of evaluated data in the field of fusion facilities**, both for the amount of components treated and for the total operating hours. The data here reported could be useful to evaluate **reliability parameters** in support of **safety assessment** and for **availability/reliability analyses** of fusion machines/plants.
- The statistical data will be collected into the "**Fusion Component Failure Rate Database**".

WORK IN PROGRESS

- Collect all the information available about **single component malfunctions and failures** of the **NBI** and **Power Supply Systems** at JET, pointing out causes, consequences, maintenance actions.
- Collect **information useful to evaluate probabilistic values** related to component malfunctions and failures.
- Estimate the main **reliability parameters,** (such as the failure rate and the corresponding standard errors and confidence intervals), associated to the components.
- Point out **practical information on the operating experience** acquired.

Thank you!