



Klystron Maintenance Data in KEKB Injector Linac

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Basic Data of Klystron Life

- KEKB Injector Linac has been operated since 1983, and klystron life data have been accumulated for this period, and been reported in KEK annual report every year.
- In this slide, klystron data from 1993 after the KEKB operation start are used for the evaluation of klystron life and MTBF.
- **Averaged run time for a year was about 7000 hours**, including KEKB, AR and PF injection. More than 7000 hours of klystron high voltage run hours in a year are recorded including the preparation operation.
- **Scheduled maintenance are taken for 3 months (summer) and 2 weeks (winter) in a year and short maintenance are taken once for every 2 to 3 weeks.**
- Klystron replacements are performed mainly in the 3-months maintenance, and replacements due to the sudden failure are performed in short maintenance period.
- Sudden failure of klystron itself was only **one case for these 5 years.**
- 7 emission degradation failures are replaced in long maintenance, and these are predicted by dip-test checking, so these are examples of **preventive maintenance.**



Klystron Life Data

Contribution to long MTBF

Fiscal year of product	Total No. of tubes	Unuse No. of tubes	Living				Av.O.p.tim e (hours)	Failed				Cum ulative operation (hours)	M TBF (hours)
			No. of tubes	STB	Working	No. of tubes		causes			Mean age		
								em ission	w indow	others			
1993	14	1	4	3	1	27,618	9	1	6	2	30,275	382,948	42,550
1994	13	0	4	4	0	31,783	9	2	4	3	18,215	291,068	32,341
1995	23	0	7	1	6	71,158	16	11	2	3	16,737	765,893	47,868
1996	15	0	8	1	7	70,989	7	5	2	0	25,420	745,849	106,550
1998	20	0	12	4	8	52,752	8	2	3	3	35,654	918,258	114,782
1999	15	0	10	1	9	52,630	5	2	3	0	12,568	589,144	117,829
2000	12	0	7	0	7	45,801	5	3	0	2	26,402	452,618	90,524
2001	12	0	12	3	9	26,994	0	0	0	0	-----	323,924	-----
2002	12	1	10	1	9	15,994	1	1	0	0	29,668	189,604	189,604
2003	6	3	3	0	3	16,952	0	0	0	0	-----	50,855	-----
2004	5	4	1	0	1	10,876	0	0	0	0	-----	10,876	-----
2005	4	4	0	0	0	-----	0	0	0	0	-----	0	-----
2006	4	4	0	0	0	-----	0	0	0	0	-----	0	-----
2007	0	0	0	0	0	-----	0	0	0	0	-----	0	-----
2008	0	0	0	0	0	-----	0	0	0	0	-----	0	-----
Total	155	17	78	18	60	42,681	60	27	20	13	23,198	4,721,035	78,684

← Cathode Crisis
 Due to the 1996-product failure of cathode, life was short.

We stop buying of new klystrons due to the long life

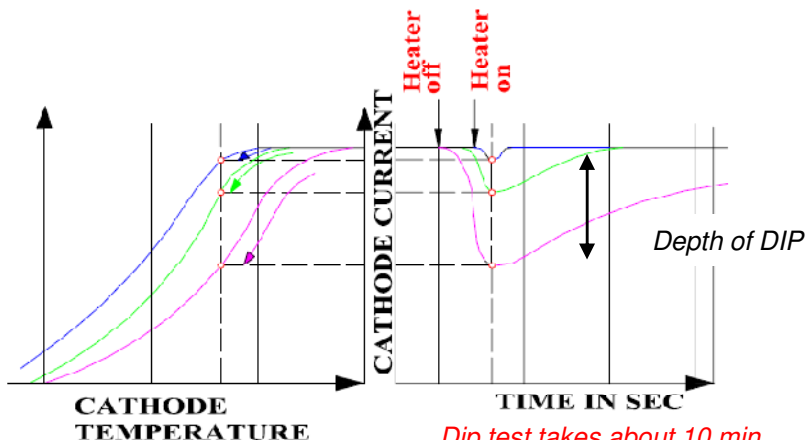
Recent cumulative MTBF data from 19xx to 2004

93-'04	147	9	78	18	60	42,681	60	27	20	13	23,198	4,659,305	77,659
94-'04	133	8	74	15	59	43,496	51	26	14	11	21,949	4,327,212	84,847
95-'04	120	8	70	11	59	44,165	42	24	10	8	22,750	4,047,020	96,358
96-'04	97	8	63	10	53	41,166	26	13	8	5	26,450	3,281,127	126,197
97-'04	82	8	55	9	46	36,828	19	8	6	5	26,829	2,535,278	133,436
98-'04	62	8	43	5	38	32,384	11	6	3	2	20,411	1,617,020	147,002



Prediction of emission degradation

Dip test and Miram plot



Measurement of Miram plot takes 2-3 hours.

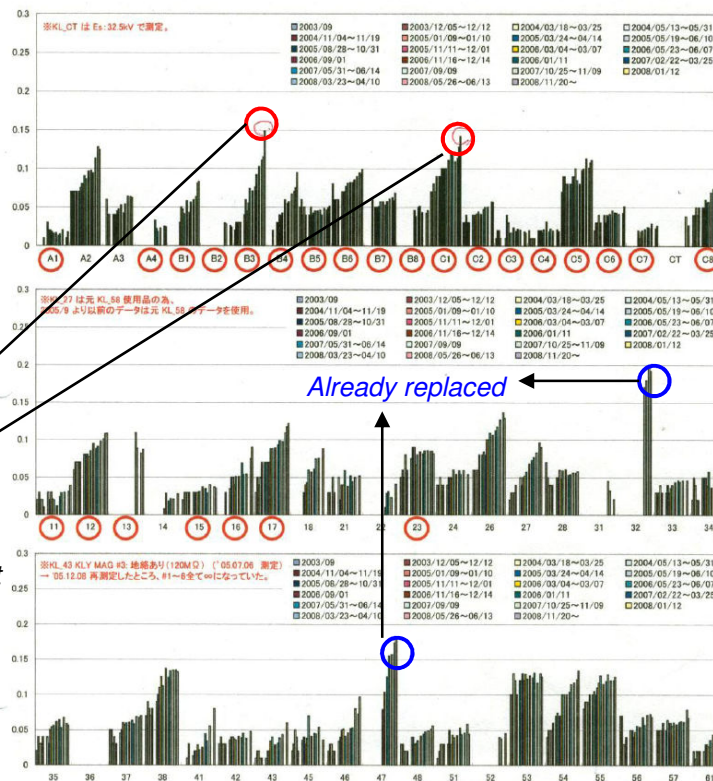
Dip test takes about 10 min.

Miram plot and dip test

Candidate of replacement
If necessary go to Miram plot

Dip tests for cathode activity measurement are performed by sudden heater power-off of 2-3 min. and power-on during The klystron operation. Whole required time for the measurement is about 10 min.. From the historical trend it is possible to judge the cathode degradation.

In KEK, this dip test diagnosis has been important role for the Preventive maintenance of klystron.



Plot of historical dip depth for each Klystron unit



Examples of klystron replacement work in KEK

Accelerator Laboratory

- For these 5 year maintenance, Failures observed during the operation were 4, and the cause due to the klystron was only one due to 'filament open'. Four failed units were replaced at the short maintenance period.
- For cathode degradation, dip tests enabled us to predict the degradation and to replace klystrons in prior to the fatal trouble.
- Causes of other replacements are not due to the klystron causes. KEK's focusing coils have defects for water leak after the long usage of more than 50 to 70 khours.

Year	No. of Replacement	Time of Replacement	Cause of Replacement	Prediction
2005	2	Summer Shut down	Em ission degardation	D ip
	1	Summer Shut down	Mag Failure	
	1	Summer Shut down	No Failure-Unit Move	
	1	Winter Shut down	Em ission degardation	D ip
	1	Short maintenance	Filam ent trouble	●
2006	2	Summer Shut down	Mag Failure	
	1	Summer Shut down	Em ission degardation	D ip
	2	Winter Shut down	Em ission degardation	D ip
	1	Short maintenance	Oil tank trouble	
2007	4	Summer Shut down	Water trouble	
	1	Summer Shut down	Mag Failure	
	1	Winter Shut down	Em ission degardation	D ip
	1	Short maintenance	kly. Window ->WG arc	
2008	1	Summer Shut down	O scillation	Wave Monitor
	1	Summer Shut down	Mag Failure	
2009	5	Summer Shut down	Mag Failure	
	1	Short maintenance	Mag Failure	
	2	Summer Shut down	No Failure-Unit Move	

Sudden trouble during operation



Comparison between SLAC 5045 and KEK 50 MW

- Basically SLAC 5045 and KEK 50 MW show the same tendency.
 - (ex.) Initial klystron manufacturing and operating shakedown took around 5 years.
 - (ex.) Cumulative MTBF has a steady slope increase since 1991. So it is interested in the latest 5 years cumulative MTBF.
- Both klystrons employ the same cathode, i.e., the Scandate cathode of Spectra-Mat Co..
- Reasons for the klystron replacements are similar and general for the klystron operation.
- 5045's operation condition is severer than KEK 50-MW tube: higher repetition rate (120 pps vs 50 pps), higher applied voltage (350kV vs 300kV).
- Causes due to focusing magnet trouble, it is possible to avoid them by employing permanent magnet focusing.
- Causes due to window failure are more predominant for higher output power. Remind that 5045 uses 2 output windows, while 50-MW of KEK uses single windows. High quality ceramic of 99.7% purity and optimized TiN coating seems to prevent the window failure.
- If SLAC uses the preventive maintenance, realistic interrupt with operation might be small.



Summary

- Klystron maintenance data in KEKB injector linac are described in this slide and this shows the evidence of the MTBF of 120khr for the DRFS klystron.
- Operating mode or schedule in KEK's klystrons is similar or a little harder than the expected ILC operation schedule.
- After the resolution of cathode troubles for the 1996 year product, MTBF increase steadily and cumulative MTBF from 1996 products to 2004 products reaches to 126 khrs. If we take MTBF from '97 to '04, 133 khurs. If we take MTBF from '98 to '04, 147 khrs. We didn't need to use the '06 product klystrons and '07 products klystrons. We stopped buying the klystron for these 2 years.
- We shows the way of prediction of emission degradation: dip test and Miram plot. Especially dip test enables us the diagnosis of the cathode activity in very short time and very useful for the predictive maintenance.
- We also show the examples of recent klystron replacement in the scheduled shut down. There are a few troubles for the intrinsic klystron failure which occur suddenly.
- Comparison between the SLAC 5045 and KEK 50-MW, and comments for them are presented.



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