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Memorandum / Note

FAT additional information

Additional information to the FAT report

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Darbos C.**	**16 Oct 2017:signed**	**IO/DG/COO/TED/HCD/ECS**
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Memorandum

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Date: 17 October 2017
Ref. Number: Reference Number
Subject: Instruction to perform FAT for 1st RF Sources (52.RF.13) procured by RF-DA / PA 5.2P3.RF.01

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1. Purpose of this memorandum

This memorandum is in addition to the FAT report (https://user.iter.org/?uid=V7GHGN) which is issued by RFDA for the 1st series gyrotron FAT (RF Source n°13).
Formal approval of the FAT will be given by after reviewing and approving the FAT report and all concerned annexes.

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2. Process description

The FAT procedure is available in this document: https://user.iter.org/?uid=VDYA99
The FAT plan is available in this document: https://user.iter.org/?uid=VDY9FT and has been agreed between parties at the FAT.

The FAT takes place during 1 week in premises of GYCOM, in Nizhny Novgorod, between October 9 and October 13, 2017.

This FAT is focused on gyrotron performances and excludes the sub-system control unit.

3. List of annexes

Annex 1: Protocol FAT-52RF13-01 – Weights of main components
Annex 2: Protocol FAT-52RF13-02 – Dimensions and positions of main components
Annex 3: Protocol FAT-52RF13-03 – Measurement of RF emission power density
Annex 4: Protocol FAT-52RF13-04 – Measurement of X-ray
Annex 5: Protocol FAT-52RF13-05 – Measurement of HE_{11} mode content at MOU output
Annex 6: Protocol FAT-52RF13-06 – List of components & drawing

4. Summary of results (All values are reported in the detailed results)

- Achievement of 5 pulses 1MW 1000s with a duty cycle > 25% (~45%). Measured: Load-911kW, preload-15kW, MOU-35kW; estimated: TL components-35kW (including straight WG, 2 MB, 1 switch and a taper). Cathode voltage between -42 and -42.5kV and cathode current is 42A. Efficiency is more than 50% (even more than 55%).
- Achievement of 10 pulses 1MW 75s with a low duty cycle (<6%), with no conditioning pulses in between. Same parameters (only the filament heating has been slightly modified before beginning the series) but pulse too short to get reliable calorimetric measurements. Output power remains stable.
- Achievement of 20 pulses 1MW 100s with a duty cycle of 25%, with no conditioning pulses in between. Same parameters (only the filament heating has been slightly modified before beginning the series) but still pulse too short to get reliable calorimetric measurements. Output power remains stable.
- Achievement of 20 pulses (partial and complete) 1MW 500s with a duty cycle >25%. Just a few conditioning pulses at the beginning and between 3 first pulses to adjust the filament current. Then, no conditioning pulse was required. Some RF cut-off events (after 300s) and quick restart was not successful. But no conditioning pulse was needed before achieving following 500s pulse.
- Achievement of 3 pulses .8MW 200s at 100Hz, 3 pulses same parameters at 500Hz, 3 pulses same parameters at 1kHz

5. Additional information

- ***Discussion about advantage of conditioning up to 1000s even if not needed for this gyrotron:*** the impact on gyrotron life expectancy is not so important: indeed, it is mainly dictated by number of collector cycles (pulses ~10s) and even if between 4 and 6 weeks are required to achieve 1000s from 200s already performed, number of pulses is not so large compared to the number of pulses required to reach 200s. The advantage is to modify the inner surface of the gyrotron which ensures a more reliable operation at lower pulse duration. Gyrotron operation is then more reliable and very repetitive.

- ***SCU is not available for this tube, therefore there is no control feedback on heater current:*** higher current is set at the beginning of the pulse for long pulse operation (>10s). One test shows that in case of fault, restarting was possible in 30s for 1000s pulse. Quick restart will be studied with final SCU. PID on heater current is necessary for an automatic quick restart.
- ***Ramp-up sequence:*** due to the limit of the MHVPS, an alternate ramp up has been chose in order to avoid reaching the MHVPS threshold at the start: V_b is set 1kV less than the operating value and the missing 1kV is added after 15s to reach the nominal values.
- ***Conditioning between long pulse operation:*** several (~5) pulses of 50ms are performed between 1000s pulses to check cathode current. This can simplified (or even removed?) with heating PID implemented in SCU.
- ***Low duty cycle:*** need to find proper parameters then no need for any conditioning pulse between shots.
- ***CW operation:*** T on MOU flange reaches 70C. Need for implementing additional cooling. Max T required <50C?
- ***Storage conditions:*** When stored, only getter pumps are used to maintain the vacuum inside the gyrotrons. But once every 3 months, the ion pump needs to be switched on with the permanent magnet to check the level of the vacuum.
- ***RF monitor:*** 2 systems are installed, one in the 2^{nd} MB after the MOU and the other directly in the MOU. The interlock system is using the RF monitoring from the MB which seems more reliable in case of RF cut-off; indeed, the quick decrease of the RF signal in the MB corresponds sometimes in an RF increase in the MOU measurement. Further investigation is useful.
- ***Modulation frequency:*** for the cavity, frequencies between 10 and 50Hz are not recommended.
- ***Power has been reduced to .***8Mw for modulation tests because of the MHVS current threshold. Frequencies less than 100Mhz could not be realized due to the trigger for the BPS which was not reliable and fast enough.

6. Additional results and corrective actions

The gyrotron power at the MOU output is inferred from the measurements on the CW load and pre-load and from the estimated losses in the TL components. Measurements on some of these components would be needed to consolidate the value of the output power.

Action 6.1: add calorimetric measurements on the 2 MB and the taper at least, on the switch if possible. These measurements should be performed the following week of the FAT.

The annex 5 shows 2 locations where the X-ray emission is not acceptable: additional shielding is required. On collector top, a lead plate will be added. Around the body, an additional plate cannot directly be installed around the gyrotron, but can be mounted on the support structure. The limit for X-ray is defined at the border of the gyrotron support structure.

Action 6.2: complete the gyrotron shielding and perform new X-ray measurements. This result will be recorded in a minor NC.

7. Conclusion

The gyrotron shows excellent results with very stable repetitive results.

Thanks to the gyrotron team!