

<https://doi.org/10.52676/1729-7885-2026-3-113-121>
UDC 621.039.619; 621.384.8

RESULTS OF THE FIRST EXPERIMENTAL TESTS OF THE RF PLASMA HEATING SYSTEM OF THE KTM TOKAMAK WITH AN EQUIVALENT PLASMA LOAD

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This paper presents the results of the first experimental tests of the ion cyclotron radio-frequency (RF) plasma heating system of the KTM tokamak with an equivalent plasma load. Measurements of the operating parameters of the RF generator and the antenna-feeder system were carried out under conditions approximating plasma operation. The generator circuits were tuned and matched to the load, and the generation characteristics as well as the conditions for stable RF power transmission to the load were investigated. Stable operating regimes of the system and the conditions ensuring stable RF power generation were determined. The test results confirm the functionality of the main components of the RF heating system and demonstrate the possibility of further testing with plasma in the KTM tokamak.

Keywords: *KTM tokamak, RF plasma heating, ion cyclotron heating, antenna module, equivalent plasma load.*

INTRODUCTION

One of the key areas of research in controlled thermonuclear fusion is the study of interactions between plasma radiation and the materials of the tokamak first wall. To support such investigations, the Kazakhstan Material Testing Tokamak (KTM) was established in the Republic of Kazakhstan [1–3]. The facility is intended for studying the behavior of materials under exposure to intense heat fluxes.

The KTM tokamak is equipped with an auxiliary plasma heating system operating in the ion cyclotron resonance frequency range (ICRH) [6]. The ICRH system comprises RF generators, antenna modules (AMs), and an antenna-feeder transmission line for delivering RF power to the plasma. High-power GU-98AM triodes are used as RF power sources [4]. At the nominal RF power level of 8 MW, the discharge duration and divertor heat-flux density are expected to reach 5 s and 20 MW/m², respectively, for plasma currents of 750 kA and plasma densities of 5×10^{19} m⁻³.

Direct operation of the RF heating system with plasma without preliminary tuning and testing may result in abnormal operating conditions and equipment damage. Therefore, prior to plasma-heating experiments, a series of commissioning and verification procedures must be carried out [5,6]. System preparation includes testing the RF generators using equivalent loads.

Previous studies on the KTM tokamak involved testing the RF generator with an equivalent active load (EAL), which enabled preliminary adjustment of the RF power generation and transmission system [7]. The next stage of system preparation requires testing with an equivalent plasma load (EPL), simulating RF power

absorption by the plasma and verifying the performance of the antenna-feeder transmission line under conditions close to those expected during actual operation. Accordingly, the objective of the present work was to prepare and perform the first tests of the RF generator with an equivalent plasma load. To achieve this objective, the following tasks were addressed: confirming stable operation of the RF generator in push-pull mode at a frequency of approximately 13 MHz and verifying proper phase balancing between the generator branches; investigating matching conditions and the need for additional tuning of resonant circuits and phase correction when transitioning from an equivalent active load to an equivalent plasma load; experimentally verifying stable operation with an equivalent plasma load under conditions approximating real plasma interaction; and determining the range of parameters that ensure stable RF generation and efficient RF power transfer from the antenna to the load.

This paper reports the first experimental tests of the KTM tokamak RF plasma heating system with an equivalent plasma load. The operating characteristics of the RF generator and antenna-feeder transmission line are examined, and the parameters ensuring stable RF generation and efficient power transfer to the load are identified.

KTM TOKAMAK RF HEATING SYSTEM

The RF heating system of the KTM tokamak is designed for auxiliary plasma heating through the excitation of ion cyclotron waves. The system provides RF power coupling to the plasma at a frequency of 13 ± 0.5 MHz [8].

The system consists of four identical RF generator modules with a power output of up to 2 MW each, anten-

na modules, and an antenna-feeder transmission line. The total design power of the system is 8 MW with a pulse duration of up to 5 s.

High-power GU-98AM triodes operating in a self-oscillating mode are used as RF power sources. Power is transmitted from the generators to the antenna modules via quarter-wave coaxial transmission lines.

The antenna module (AM) is designed to excite fast magnetosonic waves in the ion cyclotron frequency range, enabling energy transfer to the plasma. The module consists of a symmetric resonant circuit with antiphase excitation of the radiating loop.

The operating frequency of the antenna module is 13 ± 0.5 MHz. The design allows adjustment of the resonant frequency without breaking the vacuum. Figure 1 shows the antenna-module loop equipped with graphite limiters and a boron nitride protective shield.

Experimental Setup and Methods for RF Generator Testing with an Equivalent Plasma Load

Testing of the RF heating system with an EPL represents the next stage of bench testing following experiments with an EAL [7]. Unlike the EAL, the EPL is intended to simulate the complex input impedance of the plasma, including its reactive component, as well as RF-power absorption conditions associated with wave-plasma interaction during RF power transfer from the antenna to the plasma.

The EPL tests are intended to investigate the operating characteristics of the RF generator and the antenna-feeder transmission line under conditions close to those encoun-

tered during plasma operation, including assessment of generation stability, impedance matching, and RF power transfer to the load.

The EPL is a resonant system designed to simulate the plasma impedance in the ion cyclotron resonance frequency range. Unlike an active load, the EPL possesses a pronounced reactive component that determines the matching conditions of the system.

Based on calculations of the geometry and volume of the RF-power absorber, an equivalent plasma load was fabricated for the auxiliary RF heating system of the KTM tokamak.

Figure 2 shows the calculated RF-power absorption coefficient as a function of the conductivity of the working medium. The calculations showed that RF-power absorption approaching 100% can be achieved when the conductivity of the solution is approximately $(1...2) \times 10^{-4}$ S/m.

Figure 3 shows the overall view of the equivalent plasma load and the antenna-module profile made of polymethyl methacrylate (PMMA).

The equivalent plasma load is designed as a rectangular resonator made of 12Cr18Ni10Ti stainless steel, with an end insert made of PMMA that forms an internal profile matched to the geometry of the AM. The internal volume of the EPL is filled with distilled water, which acts as an RF power absorber.

The resonator dimensions ($L_x = 1.85$ m, $L_y = 1.25$ m, $L_z = 1.84$ m) were selected to provide RF-power absorption of 1.94 MW for a solution conductivity of 2×10^{-4} S/m.



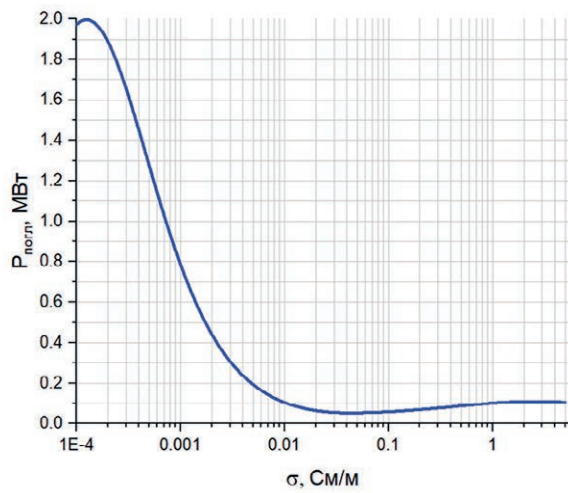
a) AM



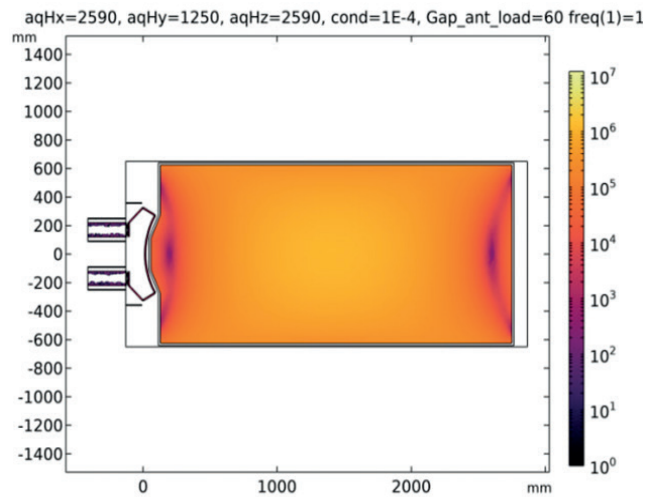
b) AM equipped with limiters and a boron nitride shield

Figure 1. AM of the KTM tokamak RF heating system

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a) Dependence of the absorption coefficient on distilled-water conductivity



b) Distribution of absorbed power density (W/m^3) in the EPL under standing-wave excitation

Figure 2. Calculated absorption coefficient and absorbed power-density distribution in the EPL



a) Overall view of the EPL



b) PMMA profile of the AM in the EPL

Figure 3. Equivalent Plasma Load

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To monitor thermal conditions and evaluate absorbed energy, the design includes provisions for the installation of temperature sensors.

The test procedure includes assembling the RF generator and antenna-feeder transmission line in the same configuration as that used for plasma heating in the KTM tokamak. However, instead of being installed on the tokamak vacuum vessel, the AM is connected to the EPL.

Since reducing the generator anode voltage decreases the output power while having little effect on other key parameters, such as the operating frequency, testing with

the EPL can be carried out under simplified conditions. This makes it possible to perform the experiments without installing the AM inside the tokamak vacuum chamber.

The dielectric properties of the PMMA profile permit operation at voltages of up to 10...15 kV. Therefore, the EPL experiments were conducted at a reduced anode voltage not exceeding 10 kV.

Figure 4 shows a schematic diagram of the test facility, including the RF generator, antenna-feeder transmission line, AM, and EPL.

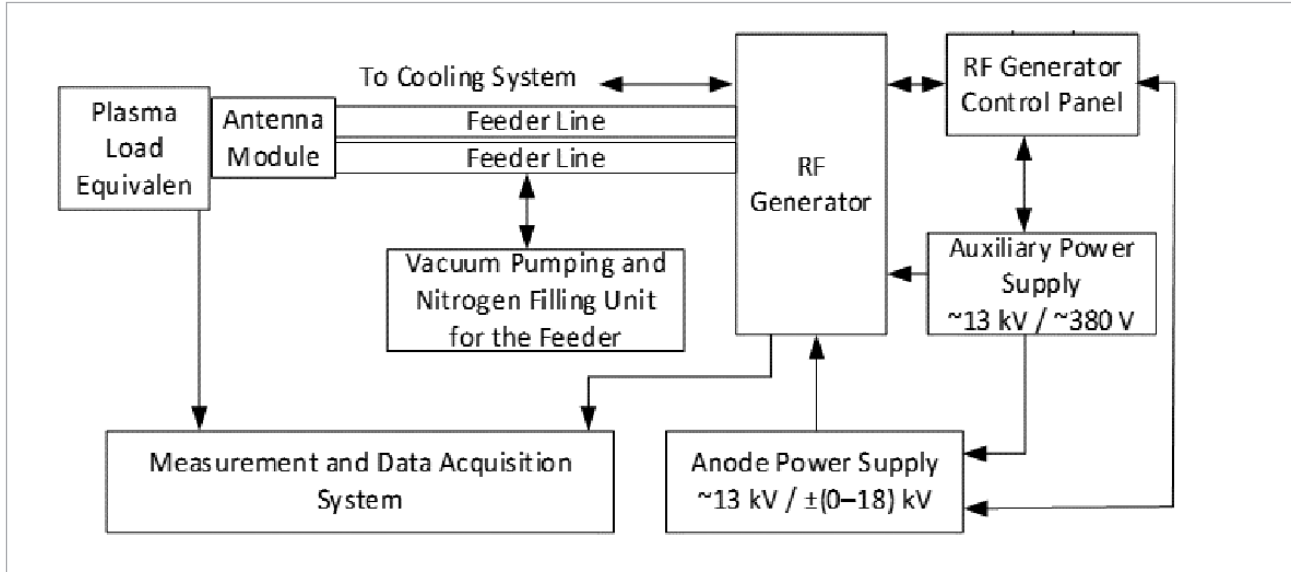


Figure 4. Block diagram of RF generator, transmission line (feeder), and AM testing using an EPL

The tests were carried out using the standard RF generator circuit in the push-pull mode shown in Figure 5. Prior to testing, preliminary tuning of the oscillation fre-

quencies of both generator branches and matching of the resonant-circuit parameters were performed.

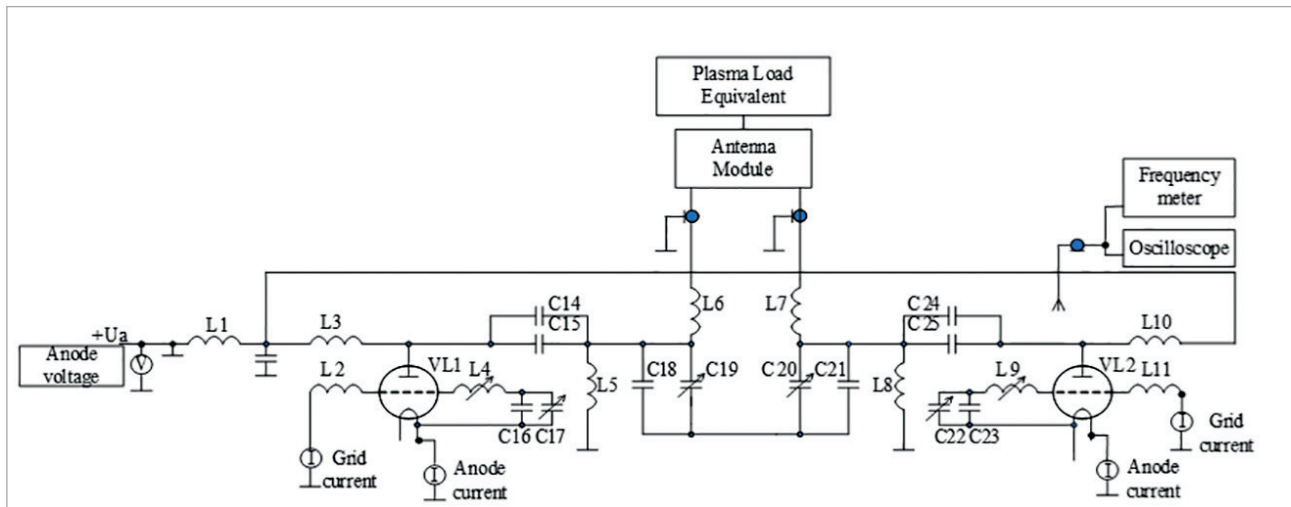
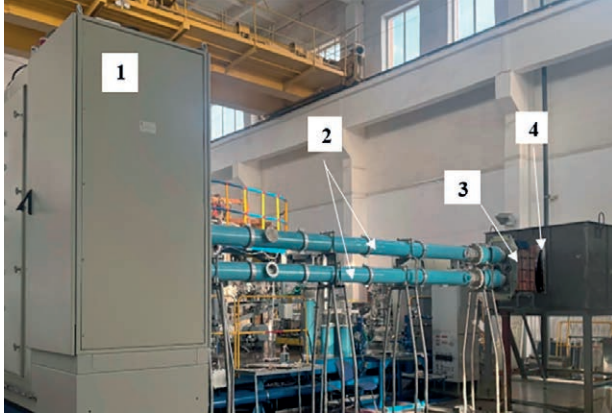


Figure 5. Circuit diagram of the RF generator test setup with the EPL in *push-pull* mode

As part of the preparation, the test facility was assembled by connecting the EPL, AM, feeder line, and RF generator. A general view of the assembled RF system is shown in Figure 6.



1 – RF generator; 2 – feeder line; 3 – AM; 4 – EPL

Figure 6. EPL assembly with the standard feeder line and antenna module

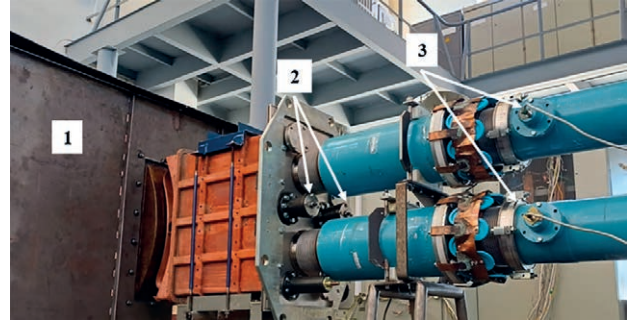
The measurements were carried out using a digital oscilloscope Tektronix THS3024 (bandwidth 200 MHz, real-time sampling rate up to 5 GS/s, four isolated channels, vertical resolution of 8 bits, input impedance of 1 M Ω , and maximum input voltage up to 300 V CAT II) for monitoring voltage waveforms in the RF circuits. The operating frequency was monitored using a frequency counter VC3165 (measurement range up to 1.5 GHz, frequency resolution of 10 Hz, and time base stability of $\pm 2 \times 10^{-6}$) for precise determination of the generator frequency.

The data acquisition system provided real-time recording of the main parameters, including voltage, current, and phase relationships between the generator branches. The measurement uncertainty did not exceed $\pm(0.01 \dots 0.05)\%$ for frequency and $\pm 5\%$ for voltage and current. All measuring instruments were calibrated prior to the experiments in accordance with standard procedures.

TESTING AND ANALYSIS OF THE RF HEATING SYSTEM PERFORMANCE ON THE EPL

The tests were conducted with the RF generator operating in push-pull mode using two GU-98AM power triodes. The system was operated in short-pulse mode with pulse durations of approximately 5 s, while the anode voltage was increased stepwise from ~ 4 kV to ~ 10 kV.

Preliminary tuning of the RF generator and the antenna module (AM) to a frequency of 13 MHz was performed based on calculated parameters and the results of previous experiments using an equivalent active load (EAL). Figure 7 shows the antenna module and the locations of the RF-voltage probes along the feeder line.

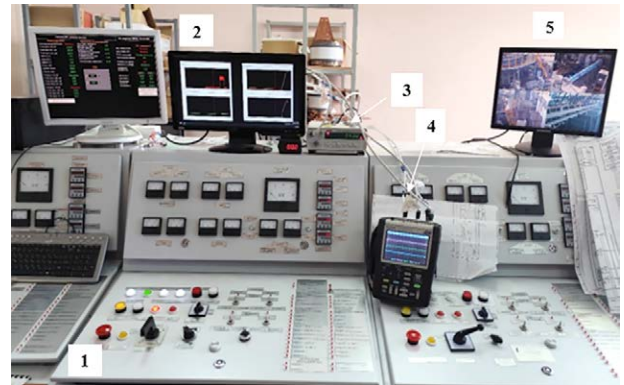


1 – EPL; 2 – AM and vacuum-capacitor drive mechanism; 3 – RF voltage probes

Figure 7. Frequency tuning of the AM and locations of RF voltage probes at the ends of the feeder lines

The operating modes of the RF generator were monitored using standard control panel instruments, including anode voltage, anode current, filament current, and grid current of the generator tubes. In addition, an oscilloscope was used to monitor waveform shape, amplitude, and phase relationship of the signals from the RF voltage probes at the ends of the feeder line, while the generation frequency was measured using a frequency counter.

Figure 8 shows the control panel of the RF generator. During the tests, the parameters of the RF-generator resonant circuits and load-matching elements were adjusted. Tuning was performed by adjusting the capacitances of the anode circuits (C19, C20) and grid circuits (C17, C22), as well as by selecting appropriate values of the grid-circuit inductors L4 and L9 in order to achieve stable oscillation and minimize mismatch between the RF generator and the EPL.



1 – control panel; 2 – data acquisition system; 3 – frequency counter; 4 – oscilloscope; 5 – video surveillance system

Figure 8. RF generator control panel

The preliminary tuning of the RF generator was performed based on parameters obtained earlier during tests on the EAL [7]. These settings ensured stable push-pull operation and were used as initial settings for testing with the EPL.

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During the initial stage of testing with the EPL, asymmetry was observed in the signals from the CH1 and CH2 RF voltage probes on the feeder lines, accompanied by increased noise levels and signal distortion, as shown in Figure 9. This behavior is attributed to the insufficient matching of the system when operating on the EPL, since the tuning parameters obtained with the EAL did not fully ensure the optimal matching under EPL conditions.

The transition from the EAL to the EPL was accompanied by changes in the matching conditions of the antenna-feeder line due to differences in the electrical properties of the loads. Unlike the EAL, which presents a predominantly resistive load, the EPL has a significant reactive impedance component, leading to changes in the

system's resonant operating regime and redistribution of RF voltages and currents in the resonant circuits.

To eliminate the observed asymmetry, additional tuning of the resonant circuits and phase balancing of the RF generator branches were performed. For this purpose, the following modifications were introduced into the triode anode power supply circuits:

- the anode supply decoupling chokes L3 and L10 were divided into sections corresponding to 1/4 and 3/4 of the total inductance;
- an additional capacitor with a capacitance of approximately 1.4 nF was connected at the tap point (three K15U-1A capacitors, 15 kV, 470 pF, 40 kvar, connected in parallel);
- the second terminal of the capacitor was connected to ground (Figures 10 and 11).

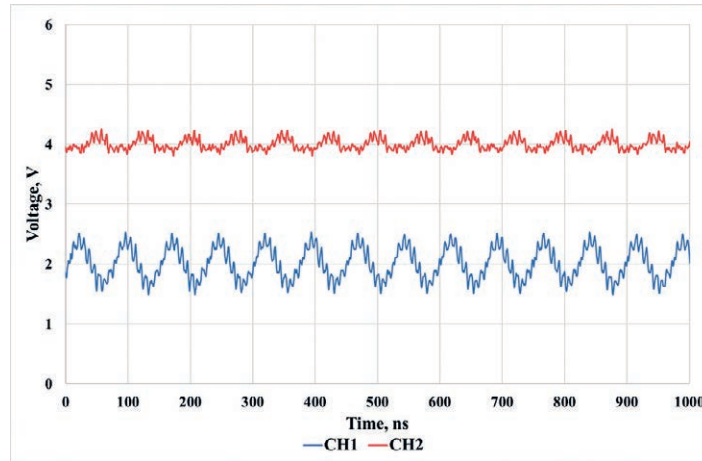


Figure 9. Oscillograms of the signals from RF-voltage probes installed at the ends of the feeder lines

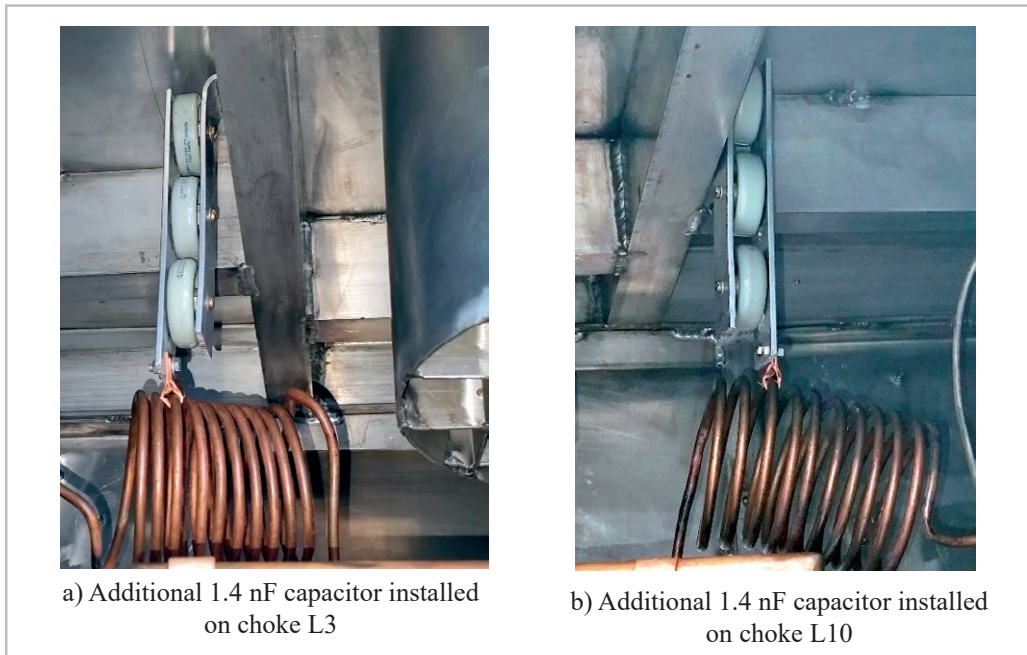


Figure 10. Installation of additional 1.4 nF capacitors

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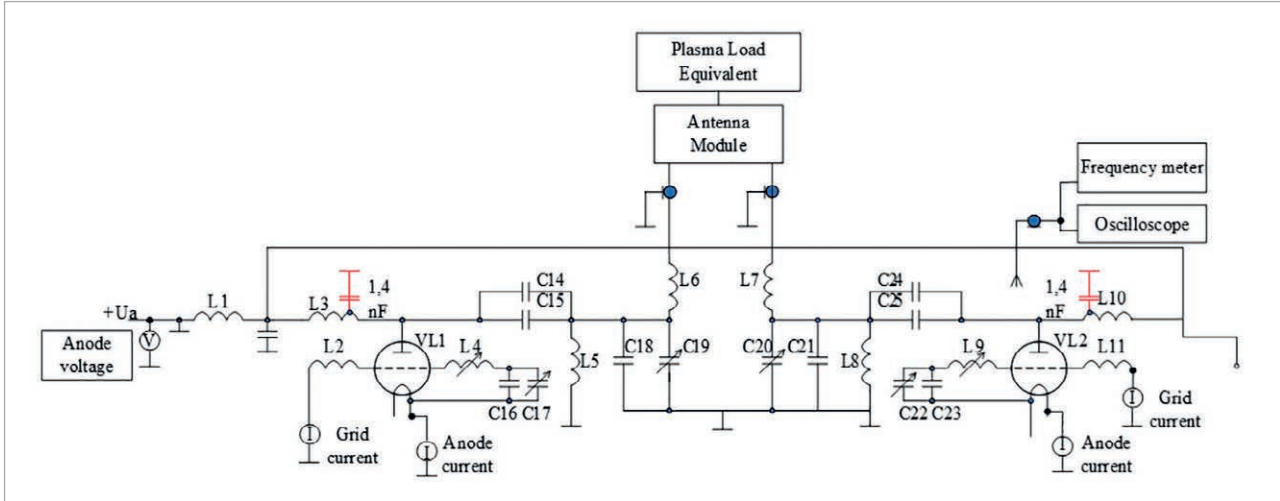


Figure 11. Schematic diagram of the phase-balancing circuit of the RF generator branches with additional 1.4 nF capacitors installed

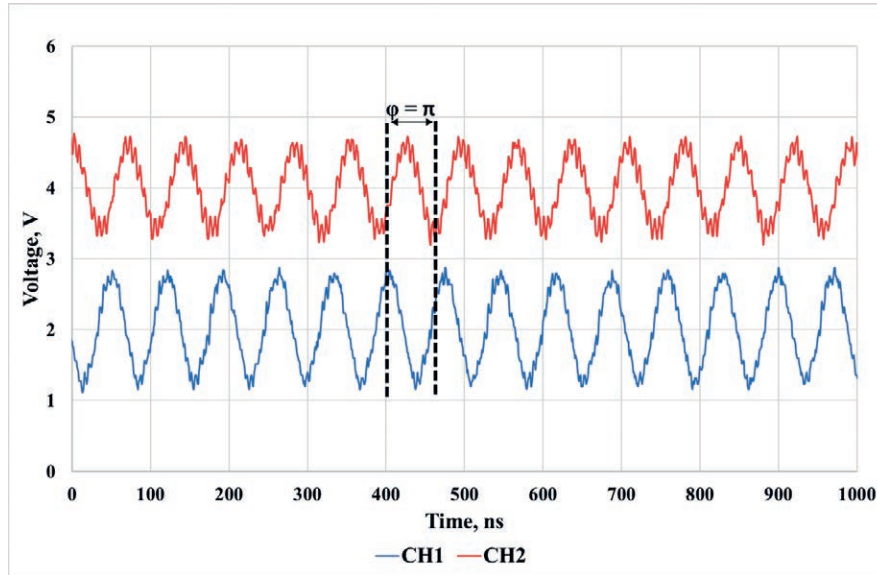


Figure 12. Oscillograms of the signals from RF-voltage probes installed at the ends of the feeder lines

The addition of these components provided phase balancing of the generator arms and improved the stability of the push-pull operating mode. After further tuning of the resonant circuits, stable sinusoidal signals with an oscillation frequency of approximately 13 MHz were obtained. Oscillograms of the CH1 and CH2 signals are shown in Figure 12.

The CH1 and CH2 signals are in antiphase, which corresponds to the calculated push-pull operating mode of the RF generator. The obtained results confirm proper balancing of the RF-generator branches, matching of the resonant-circuit parameters, and stable RF-power transfer to the EPL.

The system was tuned within the following ranges:

- anode capacitance, $C_a = 157...171$ pF;

- grid capacitance, $C_g = 587...621$ pF;

- grid inductance, $L = 0.28$ μ H.

During the tests, the following conditions were achieved:

- stable operation of the RF generator in push-pull mode;
- stable generation frequency at approximately 13 MHz;
- absence of oscillation interruptions and significant parasitic effects;
- proper operation of the antenna-feeder transmission line and the measurement system.

The RF-generator tuning parameters corresponding to stable operation with the EPL are presented in Table 1.

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Table 1. RF-generator tuning parameters for stable operation on the EPL

No.	U Anode (kV)	F (MHz)	Anode circuit capacitance Ca (pF), tubes No. 1 and 2	Grid circuit capacitance Cg (pF), tubes No. 1 and 2	Anode current Ia (A), tubes No. 1 and 2	Grid current Ig (A), tubes No. 1 and 2
1	4	13.1	157/157	621/587	50/50	6/6
2	5	13.1	171/171	621/621	60/55	6/6
3	4,5	13.1	157/157	621/621	50/50	6/6

Based on the test results, the ranges of parameters providing stable oscillation and proper matching of the RF system with the EPL were identified. The main operating parameters of the RF generator during operation with the EPL are presented in Table 2.

Table 2. RF-generator operating parameters with the EPL

Symbol	Description	Unit	Value
If	Filament current	A	1000 ± 100
Ea	Anode voltage	kV	9
Ig	Grid current	A	6-8
Ia	Anode current	A	50-60
f	Operating frequency	MHz	13.0 ± 0.5
t	Pulse duration	s	up to 5

Thus, the EPL test results confirmed the proper operation of the RF generator, the correct tuning of the antenna-feeder transmission line, and the ability to achieve stable oscillation at the design frequency of approximately 13 MHz in push-pull mode. These results indicate that the system is ready for further testing at higher power levels and for the subsequent transition to plasma experiments.

It should be noted that the experiments were conducted at a reduced anode voltage (not exceeding 10 kV) and in the absence of real plasma. Although the equivalent plasma load (EPL) reproduces the complex impedance of the plasma, including its reactive component, it does not fully replicate all plasma-related effects, such as nonlinear wave-plasma interactions and dynamic variations of plasma parameters.

CONCLUSION

This paper presents the results of the first experimental studies of the RF generator of the ion cyclotron resonance heating (ICRH) system of the KTM tokamak using an EPL.

During the tests, stable operation of the RF generator in push-pull mode at a frequency of approximately 13 MHz was achieved at an anode current of 50...60 A and with a pulse duration of up to 5 s. Proper phase balancing of the generator branches was also maintained at a reduced anode voltage level (up to 10 kV).

It was established that the transition from the equivalent active load to the equivalent plasma load changes the matching conditions of the antenna-feeder transmission line and requires additional tuning of the resonant circuits and phase correction.

For the first time, stable operation of the KTM tokamak RF heating system with an equivalent plasma load has

been experimentally demonstrated, enabling reproduction of conditions close to actual plasma interaction. The parameter ranges providing stable oscillation and efficient RF-power transfer to the load have been determined.

The obtained results confirm the operability of the RF system under plasma-relevant conditions and its readiness for further high-power testing and subsequent transition to plasma experiments on the KTM tokamak.

Based on the obtained results and the determined RF-generator tuning parameters, subsequent plasma-heating experiments on the KTM tokamak will be carried out.

The work was carried out within the framework of the scientific and technical program IRN BR23891779, "Scientific and Technical Support of Experimental Research at the Kazakhstan Materials Science KTM Tokamak," with program-targeted funding from the Agency of the Republic of Kazakhstan for Atomic Energy.

The authors express their sincere gratitude to the personnel of the KTM facility and the staff of the Fusion Research Department of the IAE NNC for their assistance in carrying out this work.

REFERENCES:

1. B. Chektybayev, I. Tazhibayeva, E. Batyrbekov, E. Kashykbayev, D. Olkhovik, D. Zarva, S. Zhunisbek, A. Duisen, A. Zhaksybayeva, A. Lee, V. Pavlov, V. Dokuka, R. Khayrutdinov, Improvement of plasma discharge performance at KTM tokamak // Fusion Engineering and Design. – 2024. – Vol. 208. – Art. no. 114684. <https://doi.org/10.1016/j.fusengdes.2024.114684>
2. B. Chektybayev, S. Zhunisbek, I. Tazhibayeva, D. Olkhovik, E. Batyrbekov, D. Zarva, A. Korovikov, A. Lee, V. Pavlov, E. Kashykbayev, A. Zhaksybayeva, A. Duisen Overview of the first experiments at KTM tokamak to obtain plasma discharges // Fusion Engineering and Design. – 2023. – Vol. 194. – Art. no. 113847. ISSN 0920-3796, <https://doi.org/10.1016/j.fusengdes.2023.113847>
3. B. Chektybayev, A. Sadykov, E. Batyrbekov, A. Lee, V. Pavlov, Study of breakdown and plasma formation in the KTM tokamak with the massive conductive vacuum chamber // Fusion Engineering and Design. – 2021. – Vol. 163. – Art. no. 112167. <https://doi.org/10.1016/j.fusengdes.2020.112167>
4. A.V. Gulkin, et al., Optimization and preparation for the start-up of the plasma ICR heating system at the KTM tokamak // Fusion Engineering and Design. – 2024. – Vol. 206. – Art. no. 114596. <https://doi.org/10.1016/j.fusengdes.2024.114596>

5. A.N. Satibekov, et al., Research of the frequency response parameters of the antenna module circuit of the high-frequency plasma heating system of the KTM tokamak // Vestnik. Seriya Fizicheskaya. – 2022. – Vol. 82. – No. 3. <https://doi.org/10.26577/RCPH.2022.v82.i3.09>
6. M.J. Mantsinen et al. Experiments in high-performance JET plasmas in preparation of second harmonic ICRF heating of tritium in ITER // Nucl. Fusion. – 2023. – Vol. 63. – No. 11. – Art. no. 112015. <https://doi.org/10.1088/1741-4326/aceb08>
7. A.V. Gulkin, K. Zhenis, B.Zh. Chektybayev, A.T. Kusainov, V.I. Savkin, S.V. Kotov, D.B. Zarva, S.A. Mukeneva, E.A. Kashikbayev, D.A. Olkhovik, A.M. Gubin, D.V. Getman, Testing of the RF generator of the ICR plasma heating system of the KTM tokamak on an active load equivalent // Vestnik NNC RK. – 2025. – No. 3 (103). – P. 183–191. <https://doi.org/10.52676/1729-7885-2025-3-183-191>
8. Azizov E.A., Gostev A.A., Brykov S.I., Gur'evich S.G., Ivanov V.N., Podymov A.N., Trebich V.D., Frumkin G.A., Gubin A.M., Demidov V.L., Seredenko E.V., Engel'ko V.I., Shapovalov G.V. RF system for additional plasma heating of the KTM tokamak // Induction Heating. – 2011. – No. 1(15). – P. 28–31.

КТМ ТОКАМАГЫ ПЛАЗМАСЫН ЖОҒАРЫ ЖИІЛІКТІ ҚЫЗДЫРУ ЖҮЙЕСІНІҢ ПЛАЗМАЛЫҚ ЖҮКТЕМЕ БАЛАМАСЫНДАҒЫ АЛҒАШҚЫ СЫНАҚ НӘТИЖЕЛЕРІ

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Жұмыста КТМ токамагының плазмасын жоғары жиілікті ион-циклотрондық қыздыру жүйесінің плазмалық жүктеменің эквивалентіндегі алғашқы сынақтарының нәтижелері ұсынылған. Плазмамен жұмыс істеу жағдайларына барынша жақындатылған шарттарда ЖЖ-генератор мен антенна-фидерлік трактінің жұмыс режимдеріне өлшеулер жүргізілді. Генератор тізбектері жүктемемен сәйкестендіріліп, бапталды, генерация параметрлері және ЖЖ-қуатты жүктемеге тұрақты түрде жеткізу шарттары зерттелді. Жүйенің тұрақты жұмыс істеу режимдері және ЖЖ-сәулеленудің тұрақты генерациясын қамтамасыз ететін шарттар анықталды. Сынақ нәтижелері ЖЖ-қыздыру жүйесінің негізгі элементтерінің жұмысқа қабілеттілігін және КТМ токамагының плазмасында одан әрі сынақтар жүргізу мүмкіндігін растайды.

Түйін сөздер: КТМ токамагы, плазманы ЖЖ-қыздыру, иондық-циклотрондық қыздыру, антенналық модуль, плазмалық жүктеме баламасы.

РЕЗУЛЬТАТЫ ПЕРВЫХ ИСПЫТАНИЙ СИСТЕМЫ ВЧ-НАГРЕВА ПЛАЗМЫ ТОКАМАКА КТМ НА ЭКВИВАЛЕНТ ПЛАЗМЕННОЙ НАГРУЗКИ

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В работе представлены результаты первых испытаний системы высокочастотного ионно-циклотронного нагрева плазмы токамака КТМ на эквивалент плазменной нагрузки. Проведены измерения режимов работы ВЧ-генератора и антенно-фидерного тракта в условиях, приближенных к работе на плазму. Выполнена настройка и согласование цепей генератора с нагрузкой, исследованы параметры генерации и условия устойчивой передачи ВЧ-мощности в нагрузку. Определены режимы устойчивой работы системы и условия, обеспечивающие стабильную генерацию ВЧ-излучения. Результаты испытаний подтверждают работоспособность основных элементов системы ВЧ-нагрева и возможность дальнейшего проведения испытаний на плазму токамака КТМ.

Ключевые слова: токамак КТМ, ВЧ-нагрев плазмы, ионно-циклотронный нагрев, модуль антенный, эквивалент плазменной нагрузки.