# Preliminary Results of Wall Conditioning Experiments using High Power ICRH System on SST-1 at Different Toroidal Magnetic Fields

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**Abstract**

Fusion devices require routine operation of wall conditioning in between plasma shots to remove in-vessel impurities. Ion Cyclotron Wall Conditioning (ICWC) is fully compatible with steady-state tokamak in presence of the magnetic field. Here we report the preliminary results of ICRF wall conditioning experiments done on Steady State Superconducting Tokamak (SST-1) using High Power Ion Cyclotron Resonance & Heating (ICRH) System indigenously developed including MW RF generator, High power Tx-Line and Matching Unit (TL&MU), High power Vacuum Transmission Line (VTL) and High power Antenna. In the first stage, conditioned the complete system and antenna by introducing low power RF pulses in the SST-1 machine. It is observed that the conditioning pulse removes gas species from Antenna and VTL. In the second stage, the wall conditioning experiments are conducted at 0.2 - 0.4 T and in the third stage the wall conditioning experiments are conducted at 1.5 T in Helium gas. The diagnostics used are the visible camera, spectroscopy, Residual Gas Analyzer (RGA) etc. more than 600 RF pulses of 150 kW with 0.5 seconds on time and 0.8 Seconds off time were introduced and significant impurity generation is observed from antenna and vacuum vessel. It is observed that RF conditioning at low pressure releases $H_2$ and other gas species. The previous ICWC experiments done on Aditya tokamak show that in presence of toroidal magnetic field and with 15-20 percentage Helium gas in a Hydrogen plasma is found effective in removing wall impurities. The preliminary results on SST1 show that the ICWC in the presence of magnetic field seems to be effective and can be used an alternative method for vessel wall conditioning. In the paper, the above-mentioned experiments and results will be discussed.

## 1. INTRODUCTION

Introduction of RF waves in plasma using Ion Cyclotron Resonance Frequency (ICRF) range has many applications starting from pre-ionization, heating and vessel wall conditioning. In the superconducting tokamak, the normal glow discharge cleaning becomes very difficult and one needs to find alternatives which will work in presence of the toroidal magnetic field. Ion cyclotron waves are one of the prominent candidates for wall conditioning in presence of the steady toroidal magnetic field.

Here we report the preliminary results of ICRF wall conditioning experiments done on Steady State Superconducting Tokamak using indigenously developed High Power Ion Cyclotron Resonance & Heating System which includes MW Radio Frequency generator, High Voltage Power Supply, High power Tx-Line and Matching Unit, High power Vacuum Transmission Line and High power Antenna [1].

## 2. SST-1 ICRH SYSTEM OVERVIEW

A nearly 100-meter long 9-3/16 rigid co-axial copper tx-line carries RF power from RF generator to tokamak SST1 as shown in Fig. 1. The tx-line outer and inner conductors are made of Cu. A series of Double Pole Double Throw (DPDT) switches direct the RF power either towards the IC antenna located in the vacuum vessel or towards fifty Ohm soda water load located in RF generator room. A pre-matching and main matching called Automatic Matching Network (AMN) is placed between the antenna and RF source for matching the RF source impedance (50 Ohm) to antenna-plasma impedance [2]. There are two antennae within one box located at radial port #14 with their associated VTLs mounted on the vacuum vessel which is used for the experiment. The VTL system having Turbo-molecular Pumps (TMPs) to get high vacuum < 5.0e-07 mbar in the vacuum line near the antenna. A VME-based real-time data acquisition and control (DAC) system functioning the smooth operation of the system.

**Experiment parameters:**
-Toroidal Magnetic Field: 1.1 T, 1.5 T & 1.6 T
-Gas: Helium
-VV Pressure: 3.0e-3 ï 2.0e-4 mbar
-Coupled RF Power: 100-110 kW
-Frequency: 24.8 MHz
-RF Pulse: Few milliseconds to few seconds
-No. of RF pulses: > 600

**Diagnostic used:**
-Spectroscopy
-Visible Camera
-Optical Imaging diagnostic
-RGA
-RF diagnostics
-Langmuir probe

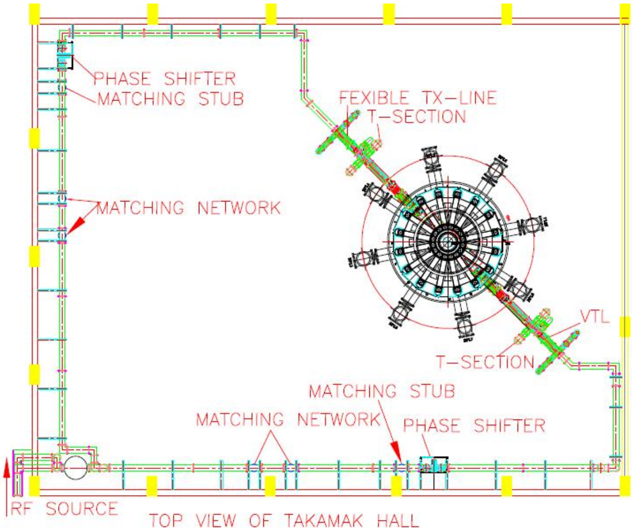
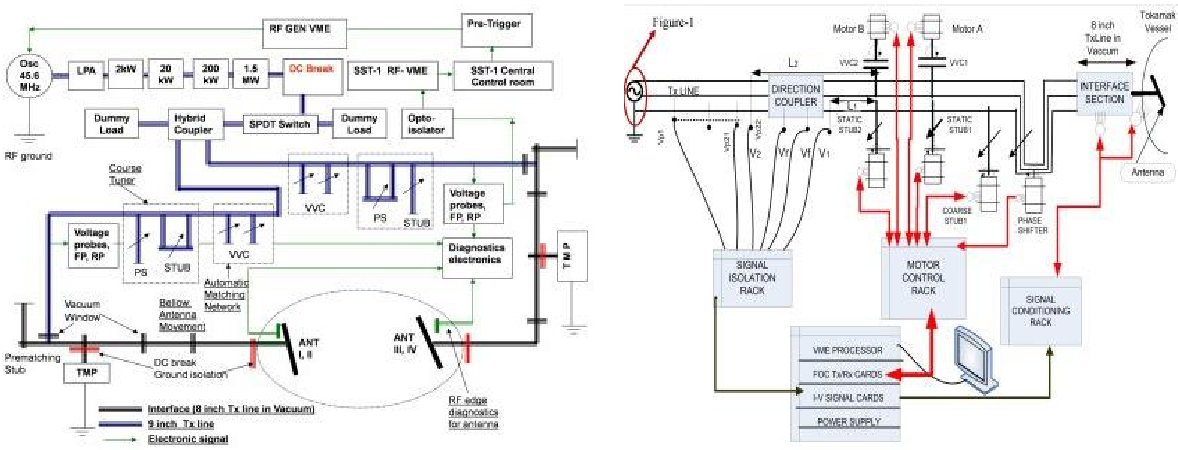



*FIG. 1. ICRF Tx-line layout in SST-1 tokamak*

A simplified block diagram and operation process of complete ICRF system on SST1 is shown in Fig. 2.




*(a) ICRH system block diagram* *(b) ICRH operation process*

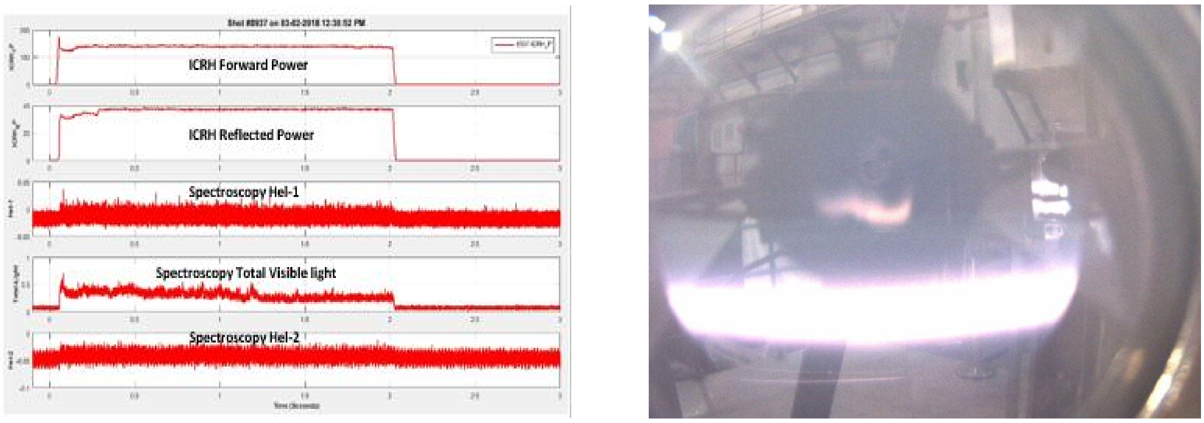
*FIG. 2. (a) The simplified block diagram of the ICRF system & (b) Operation process*

## 3. WALL CONDITIONING EXPERIMENT USING ICRF & RESULTS

Before carrying out the experiment, in the first stage, the tx-line lines, VTLs, and antennae are conditioned by introducing thousands of RF pulses in the range of 5 kW to 150 kW to increase the power handling capacity and is done after tuning the complete system for 24.8 MHz. It has been observed that there is a rise in base pressure from 5.0e-7 to 1.0e-5 mbar during the conditioning RF pulse due to the release of gas species from Antenna and VTL internal surfaces. Finally, the base pressure in the VTLs has been improved up to 1.0e-7 mbar.

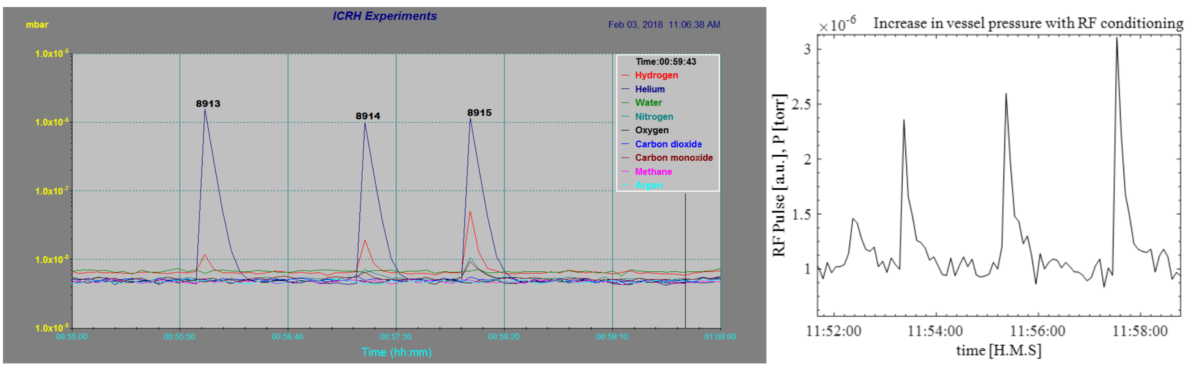
In the second stage, the wall conditioning experiments are conducted at 0.2T/0.4T and in the third stage, the experiments are conducted at 1.5T/1.6T in Helium gas-feed. More than 600 RF pulses of 150 kW at 24.8 MHz with 0.5/1/2 seconds on time and 0.8/1/2 seconds off time were introduced in the pressure range from 3.0e-3 to 2.0e-4 mbar into the machine.

The diagnostics used are the spectroscopy, visible camera, optical imaging, Residual Gas Analyzer (RGA), RF directional coupler and Langmuir probe etc. The Fig. 3(a) shows the forward & reflected RF power and spectroscopy signals (Hel-1, total visible light & Hel-2) and the Fig. 3(b) shows an image of ICRF discharge during RF power injection. Relative levels of gas species have been measured using RGA. The Fig. 4 shows (a) the RGA signals due to the release of different gas species and (b) increase in Vacuum Vessel (VV) pressure.




*(a) Spectroscopy signals* *(b) RF produced discharge*

*FIG. 3. (a) Spectroscopy and ICRF power signals (b) RF produced discharge at 1.5T*




*(a) RGA signals* *(b) VV pressure*

*FIG. 4. (a) RGA signals recorded during RF power injection (b) increase in VV pressure*

## 4. SUMMARY

It is observed that ICRF conditioning at low pressure releases Helium, Hydrogen and other gas species and long duration pulses of seconds are more effective in the wall conditioning. The previous experiments done on Aditya tokamak show that in presence of toroidal magnetic field the ICRF wall conditioning releases wall impurities [3]. The preliminary results on SST-1 show that the ICWC in the presence of the magnetic field seems to be effective and can be used as an alternative method for vessel wall conditioning.

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