Commissioning of the Pegasus-III Experiment

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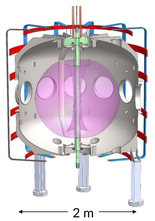
Pegasus-III Experiment

The Pegasus-III Experiment is a Dedicated US Platform for Solenoid-Free Startup Development

Pegasus-III Mission: Solve the ST startup challenge by comparing, contrasting, and investigating synergistic effects of non-solenoidal current drive techniques using power plant relevant technology

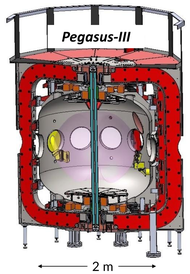
- Compare, contrast, and combine solenoid-free startup concepts in dedicated facility[1]
  - Local helicity injection (LHI)
  - Coaxial helicity injection (CHI), both transient and sustained
  - RF assist and sustainment (EBW, ECH, ECCD)
- Goal: develop validated physics and technology basis for MA startup

Pegasus



Parameter	Pegasus	Pegasus-III
I_{TF}	0.288 MA	1.15 MA
N_{TF}	12	24
ψ_{sol} (mWb)	40	0
R_{inner} [cm]	5.5	7.0
TF Conductor Area [cm^2]	13.2	72
$B_{T,max}$ [T] at R_0~0.4 m	0.15	0.58
B_T Flattop [ms]	25	50-100
A	1.15	1.18

Pegasus-III

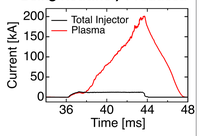


- Significant upgrades performed to provide capability for this mission
  - Ohmic solenoid removed from system
  - Upgraded TF magnet assembly capable of withstanding forces of 4x field
  - Active divertor coils
  - Upgraded/expanded power supplies and new stored energy
  - Next generation LHI, CHI, and RF capabilities
  - Expanded diagnostic set

Status: Pegasus-III is Operating

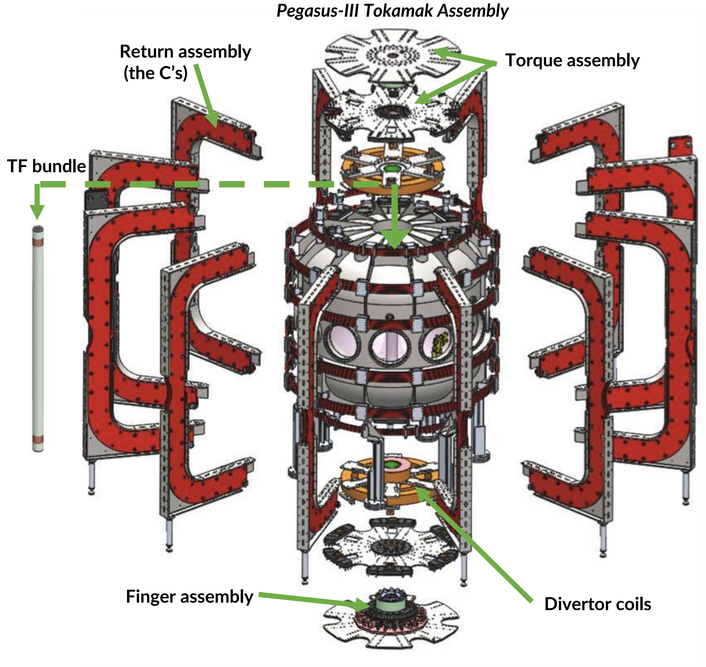
- Assembly of Pegasus-III completed
- Commissioning of Pegasus-III completed
  - Tested power supplies[2] and magnets
  - Installed in-vessel diagnostics[3]
- Conditioned vacuum vessel and LHI injectors
- Commenced plasma operations in July 2023
  - Operating routinely with $B_t \leq 0.3$ T and $I_p \leq 0.20$ MA
  - Plasma diagnostics continue to be brought online
- Performing experiments to accomplish stated mission

Pegasus-III LHI Plasmas Being Routinely Produced



All Major Pegasus-III Upgrade Sub-Assemblies Have Been Assembled and Commissioned

Pegasus-III Tokamak Assembly



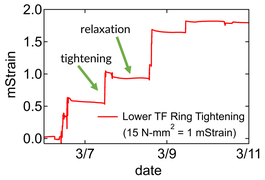
Pegasus-III Tokamak Assembled in Experimental Hall



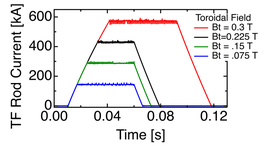
Centerstack Assembly

- All components assembled – TF bundle, return assembly, torque assembly, finger assembly, and divertor coils
  - Fasteners torqued to specifications
- Finger assembly compression monitored
  - Multi-day process of tightening
  - Achieved desired ≤30 N/mm^2
- Inductance and resistance of magnet measured
  - Agrees with analytic computation
- TF magnet tested to 0.3 T
  - No change in strain observed during operation[3]
  - No change in strain when operated in conjunction with other magnets

TF Magnet Finger Assembly Tightening Achieved Desired Pressure



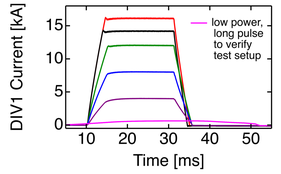
TF Magnet Successfully Commissioned up to 0.3 T



Divertor Coil Commissioning Protocol

- New divertor coil triplets (upper & lower) allow CHI operation[1]
- Low power shot to verify connections
- Measure deflection of mounting plate and compare to model
- Increase coil current to maximum
  - DIV1, DIV2, DIV3, & DIV4 coils to ±16 kA
  - EF1 and EF8 to ±8 kA
- Operate DIV1, DIV2, & EF1 and DIV3, DIV4, & EF8 together
- Mounting plate structure flex ≤0.5 mm, agreement with model
- EF8 failed testing and will not be operated
  - CHI scenarios adjusted to account for unused coil

DIV1 Coil Commissioned Successfully



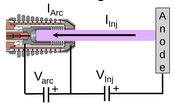
LHI Systems Commissioned

- LHI system consists of four 4-cm^2 injectors and independent power supplies[2,4]
- Multi-level buck converter (MLBC) used for advanced LHI $V_{inj}(t)$ and buck converter used for V_{arc}
- Injector system operational with 4 kA of arc current and > 3.6 kA of bias current for each injector (≥14 kA total to date)
- All injectors conditioned to $V_{inj} \geq 800$ V and operational

LHI Bias Supply Commissioning Protocol

- Demonstrate fault condition control
- Tune PID parameters
- Increase bank voltage and current demand for 10 ms pulse to 4 kA maximum
- Demonstrate 4 kA - 50 ms pulse
- Commission each bias and arc supply
  - Separately and all 8 together
- Condition injectors to ~800 V

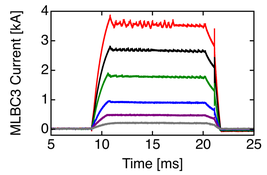
Schematic of Local Helicity Injector Used on Pegasus-III



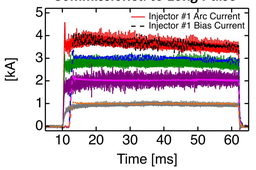
Pair of 4-cm^2 injectors installed in vessel



Single MLBC Bias Supply Commissioning



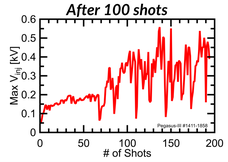
All 8 Bias and Arc Power Supplies Commissioned to Long Pulse



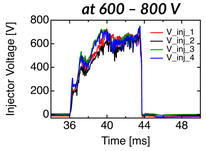
Local Helicity Injector Conditioning

- Voltage handling determined by gas load and extracted current
- Typical operations ≥ 600 V on all four injectors

Conditioning Progress Evident After 100 shots



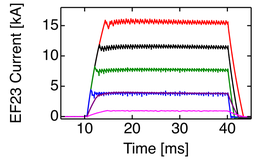
Routine Operation Achieved at 600 – 800 V



Equilibrium Field (EF) Coils Commissioning Protocol

- Low power shot to check connections
- Increase power supply bank voltage
- Tune PID feedback coefficients
- Increase coil current to maximum
  - +16 kA for EF23 and EF67 coil sets
  - ± 8 kA for EF45 coil set
- Operate all coils together and with the TF
  - Monitored strain and no change observed

EF23 Coil Commissioned Successfully



References: [1] J.A. Reusch, *et al.*, YP11.00029; [2] M.W. Bongard *et al.*, YP11.00031; [3] M.D. Nornberg, *et al.*, YP11.00035 ; [4] A.C. Sontag, *et al.*, YP11.00032

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