ASME PTC 47: Performance Test Codes for IGCC Plants

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History & Status of PTC 47

- No performance test code existed for IGCC power generation plants
- 1993 ASME approved formation of a Committee to develop a Code (PTC 47) to determine overall IGCC power plant performance
- 30 members have contributed to the Code over last 10 yrs.
- 16 current members involved with Code completion
- 1st draft of PTC 47 now being reviewed by industrial community
Overview of PTC 47 Features

- **Purpose of Code** is to provide testing procedures to determine:
  - Power Output & thermal efficiency of IGCC plants at specified operating conditions
  - Flows & properties of export syngas & steam in multiple-product IGCC plants
- **Code is limited to** combined-cycle power-generation systems using gas & steam turbines
- **Code covers a defined range of** primary fuel characteristics
- **Test results can be used to compare performance against plant design rating**
- **Code does not provide a basis for comparing the performance against different plant designs**
For “electric power only” plants, Code provides procedures for determining:
  - Corrected net power
  - Corrected net heat rate
  - Corrected heat input
For plants that also export synthesis gas and/or process steam, Code provides procedures for determining:
  - Corrected net power
  - Corrected heat Input
  - Export syngas flow, press., temp., compos., HV
  - Export steam flow, press., temp., and quality.
Testing Methodology:

- Measure thermal inputs & useful outputs entering and leaving the boundary of IGCC plant
- Correct measurements to compensate for differences between test conditions & rating point
- Compare corrected results to plant performance at rating point

Accuracy of measurements is essential to test process, so instruments and measurement methods are selected to reduce overall test uncertainty
<table>
<thead>
<tr>
<th>Corrected Values</th>
<th>Power Only</th>
<th>Multiple Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input fuel flow:</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>Solid Fuels</td>
<td>3 %</td>
<td>3 %</td>
</tr>
<tr>
<td>Liquid &amp; Gaseous Fuels</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Input fuel heating value</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Export syngas temperature</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>3°C (5°F)</td>
<td>3°C (5°F)</td>
</tr>
<tr>
<td><strong>Export syngas pressure (abs.)</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>½%</td>
<td>½%</td>
</tr>
<tr>
<td><strong>Export syngas composition</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Export syngas volumetric flow</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Export syngas heating value</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Export steam temperature</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>3°C (5°F)</td>
<td>3°C (5°F)</td>
</tr>
<tr>
<td><strong>Export steam pressure (abs.)</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>½%</td>
<td>½%</td>
</tr>
<tr>
<td><strong>Export steam flow</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Power plant thermal efficiency: Solid Fuels</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>Liquid &amp; Gaseous Fuels</td>
<td>3.5%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>1.5%</td>
<td></td>
</tr>
<tr>
<td><strong>Power plant electrical output</strong></td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>
Test Uncertainties for solid fuel plants are higher due to uncertainty of solid fuel flow feeders.

Code requires pre-test & post-test uncertainty analyses to estimate limit of error of test results.

Measurement uncertainty is determined using calculation procedures from PTC 19.1.

Test tolerances are contractual adjustments but not part of the Performance Test Code.
Fuel Flexibility

- Code is designed to provide accurate results whether the primary fuel is a solid, liquid, or gas
  - Solid fuel flow measurement (difficult due to solid material variability), requires frequent calibration against reference
  - Liquid fuel flow measured using flow meters (PTC 47 provides lab test repeatability criteria)
  - Gaseous fuel flow measured using orifices or turbine flow meters
PTC 47 written to accommodate wide range of IGCC plant configurations:
- Gasifiers: entrained flow, fluidized bed, or moving bed
- ASU: inside, outside Code test boundary, or not applicable (air-blown gasification systems)
- Plant heat rejection: inside or outside Code test boundary
- Cogeneration: process steam or other forms of thermal energy in addition to electric power
- Poly-Production Facilities: producing more than two products (export syngas, electric power, process steam)
Resolved PTC 47 Technical Issues

- **Inlet Air or Ambient Air?**
  - PTC 47 requires measurements to determine: $T_{db}$, $P_{atmos}$, & Specific Humidity at inlets to compressors and heat rejection equipment

- **HHV or LVH?**
  - For PTC 47 tests, HV may be reported either as LHV or HHV, but fuels, product gases, and syngas must all be reported with consistent terms

- **Correction Factors or Simulation Models?**
  - PTC 47 allows correction factor methods for individual variables or correction algorithms in multivariate computer models, when available
Using PTC For IGCC Test

- PTC 47 is organized into 6 main sections
  - Section 1 defines scope of Code and acceptable level of uncertainty
  - Section 2 contains definitions
  - Section 3 provides testing guidelines
  - Section 4 describes essential measurements & instrumentation
  - Section 5 defines required calculations
  - Section 6 organizes the test report

- Pre-Test Activities
  - Pre-test run in advance to calculate preliminary results
  - Perform uncertainty analysis w/standard deviations observed during pre-test trial run
  - Use analysis results to determine measurement accuracy required to meet overall test uncertainty
Using PTC For IGCC Test

- Operational Stability During Testing

**Typical Stabilization Times and Test Run Duration**

<table>
<thead>
<tr>
<th>Type of Gasifier</th>
<th>Stabilization</th>
<th>Test Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrained Flow</td>
<td>24 Hours</td>
<td>4 Hours</td>
</tr>
<tr>
<td>Fluidized Bed</td>
<td>24 Hours</td>
<td>4 Hours</td>
</tr>
<tr>
<td>Moving Bed</td>
<td>24 Hours</td>
<td>4 Hours</td>
</tr>
</tbody>
</table>

- Test runs are limited to 4 Hrs. to minimize the performance effect of daily inlet air temp. cycling
Using PTC For IGCC Test

- **Permissible Deviations From Design**
  - Variation in test conditions need to be maintained within specific criteria to limit overall test uncertainty

- **Recommended Test Sequence**
  - Test complete IGCC Plant first per Code to confirm performance levels
  - If performance shortfall, test IGCC subsystems per appropriate codes to isolate problem:
    - PTC 47.1 – ASU
    - PTC 47.2 – Gasification Block
    - PTC 47.3 – Fuel Gas Cleaning
    - PTC 47.4 – Power Block
  - Subsystem testing should be conducted separately to accommodate any boundary constraints
  - For highly integrated IGCC plants, total plant operation may need to be operated to evaluate individual subsystems
PTC 47 Status Update:

- The Code establishes methodologies for performance testing complete IGCC plants with guidelines comparable to other fossil plant technologies.
- The Code documentation will serve as resource for testing a wide range of IGCC plant configurations using a consistent set of calculations.
- Several test procedural issues addressing the complexity of IGCC systems have been resolved.
- The Code document will cover all important issues related to IGCC performance validation testing.