

ASME PTC PM-2010
(Revision of PTC PM-1993)

Performance Monitoring Guidelines for Power Plants

Performance Test Codes



**The American Society of
Mechanical Engineers**

ASME
SETTING THE STANDARD

INTENTIONALLY LEFT BLANK

ASME PTC PM-2010
(Revision of PTC PM-1993)

Performance Monitoring Guidelines for Power Plants

Performance Test Codes



**The American Society of
Mechanical Engineers**

ASME
SETTING THE STANDARD

Date of Issuance: April 30, 2010

The next edition of this Guide is scheduled for publication in 2015. There will be no addenda or written interpretations of the requirements of this Guide issued to this edition.

ASME is the registered trademark of The American Society of Mechanical Engineers.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not approve, rate, or endorse any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which preclude the issuance of interpretations by individuals.

No part of this document may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

Copyright © 2010 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All rights reserved
Printed in U.S.A.

CONTENTS

Foreword.....	vii
Committee Roster	viii
Correspondence With the PTC PM Committee.....	x
Introduction.....	xi
Section 1 Fundamental Concepts.....	1
1-1 Object and Scope	1
1-2 Overview.....	1
1-3 Definitions and Description of Terms.....	17
Section 2 Program Implementation.....	22
2-1 Program Planning.....	22
2-2 Instrumentation	33
2-3 Performance Monitoring Implementation and Diagnostics	58
2-4 Incremental Heat Rate.....	131
2-5 Performance Optimization	145
Section 3 Case Studies/Diagnostic Examples.....	177
3-1 Air Heater Plugging Due to Failed Sootblower	177
3-2 Boiler Example	179
3-3 Temperature Calibrations.....	180
3-4 Capacity Loss Investigation Due to Fouling of Feedwater Flow Nozzle (Nuclear Plant)	184
3-5 Unit Capacity and ID Fan Capacity Due to Air Heater Leakage.....	189
3-6 Loss of Extraction Flow.....	191
3-7 Question and Answer Session: A Nuclear Plant Diagnostic Problem.....	193
3-8 Application of Turbine Test Data for Problem Identification.....	195
3-9 Condenser Tube Fouling Problem	196
3-10 Feedwater Partition Plate Bypass Problem.....	199
3-11 Air-Heater Passage Problem.....	200
3-12 Deposition in High-Pressure Turbine.....	201
3-13 Pulverizer Coal-Mill Fineness Problem.....	202

Figures

1-2.6-1	Typical Plant Losses.....	5
1-2.6-2	Typical Losses for a Gas-Turbine-Based Combined Cycle Plant	6
1-2.6-3	Heat Balance for Turbine Cycle of Typical Pressurized Water Reactor Nuclear Plant	7
1-2.6-4	Mass Flows Through Steam and Feedwater System for Typical Pressurized Water Reactor Plant.....	8
1-2.6-5	Energy Distribution for a Typical Pressurized Water Reactor Nuclear Plant.....	8
1-2.6-6	Typical Boiler Losses	9
1-2.6-7	Typical Cycle Losses.....	10
1-2.6-8	Typical Turbine/Generator Losses	11
1-2.6-9	Computed Variation of Unburned Carbon With Excess Air	12
1-2.6-10	Effect of O ₂ and Coal Fineness on Unit Heat Rate	13
1-2.6-11	Effect of Stack Gas Temperature on Unit Heat Rate	13
1-2.6-12	Boiler Loss Optimization.....	14
2-2.3.1-1	Primary Flow Section for Welded Assembly.....	37
2-2.3.1-2	Inspection Port	37
2-2.4-1	Basic Pressure Terms From ASME PTC 19.2.....	40
2-2.4-2	General Uncertainties of Pressure-Measuring Device From PTC 6 Report	40
2-2.4.5-1	Effect of Pressure and Bias Errors on HP Turbine Efficiency	42
2-2.4.5-2	Effect of Pressure and Bias Errors on IP Turbine Efficiency	43
2-2.5.1-1	TC Drift Study of Six Thermocouples Cycled 210 days to 300 days.....	44
2-2.5.2-1	Drift of Ice Point Resistance of 102 PRTDs Cycled 810 days.....	45
2-2.5.3-1	Effect of Temperature Bias and Error on HP Turbine Efficiency.....	46
2-2.5.3-2	Effect of Temperature Bias and Error on IP Turbine Efficiency	46
2-3.6.2.1-1	Performance Curves to Characterize Boiler Losses — Example for a Coal-Fired Unit	63
2-3.6.2.3-1	Heat Rate Logic Tree — Main Diagram.....	64
2-3.6.2.3-2	Illustration of Decision Tree Concept for Investigating Performance Parameter Deviations	65
2-3.8.4.1-1	Pulverizer Capacity Curve	81
2-3.8.4.1-2	Arrangement for Sampling Pulverized Coal.....	82
2-3.8.4.1-3	Graphical Form for Representing Distribution of Sizes of Broken Coal.....	83

2-3.8.6.1-1	Sampling Direct-Fired Pulverized Coal-Sampling Stations (Dimensions Are “Percent of Pipe Diameter”)	89
2-3.9.4.3-1	Typical DCA and TTD Versus Internal Liquid Level.....	105
2-4.2-1	Input/Output Curves for the Two Typical Thermal Units	131
2-4.2-2	Input/Output Relationships for a 2 × 1 Combined Cycle Facility	132
2-4.2-3	Incremental Heat Rate for Steam Turbine With Sequential Valve Operation	132
2-4.3.1-1	Optimum Load Division by Equal Incremental Heat Rate.....	135
2-4.4-1	Example of Heat Rate Not Monotonically Increasing in a 2 × 1 Configuration	137
2-4.4-2	Incremental Curve Shape	138
2-4.4-3	Illustration of Development of Incremental Heat Rate Information From Basic Plant Measurements.....	139
2-4.4-4	Heat Rate and Incremental Heat Rate Versus Load Fossil Unit.....	141
2-4.4-5	Heat Rate and Incremental Heat Rate Versus Load Bias Error.....	141
2-4.4-6	Heat Rate and Incremental Heat Rate Versus Load Combined Bias and Random Error	142
2-4.6.1-1	Combined Cycle Heat Rates Versus Ambient Temperature	144
2-4.6.2-1	Combined Cycle Input/Output Relationships.....	144
2-4.6.2-2	Combined Cycle Incremental Heat Rates Versus Ambient Temperature	145
3-1.1-1	Air Heater Exit Gas Temperature 2-Week Trends.....	177
3-1.3-1	Air Heater Differential Pressure 2-Week Trends	178
3-3.2-1	Three RTDs: Readings Collected at Five Temperatures	181
3-3.2-2	Fit of RTD Data.....	182
3-3.2-3	Histogram of RTD A.....	182
3-3.2-4	Distribution of Errors for the Three RTDs	182
3-3.2-5	Fits of RTDs A, B, and C in Open Circuit	183
3-3.2-6	Fits of RTDs A, B, and C Using the Calendar–Van Dusen Eq. (3-3.2) for Calibration.....	183
3-3.3-1	Fits With and Without Replicate Data.....	184
3-4.1.1-1	Logic Tree for Case Study: Capacity Loss Investigation	186
3-4.1.2-1	Decision Tree for Capacity Loss Due to Suspected Fouling of the Feedwater Flow Nozzle	187
3-4.1.3-1	Power Design Heat Balance for Case Study	188

3-5.2-1	Flue Gas Analyzer Measurements at Locations Along the Gas Path.....	190
3-6.3-1	Generator-Output and Heat Rate Deviation.....	191
3-6.3-2	Change in Performance Profile Over Significant Cycle Positions.....	192
3-7-1	Variations of Fourth-Stage Pressure	193
3-7-2	Similarities Between Predicted and Measured Pressure Changes	194
3-8.3-1	Turbine Pressure Profiles.....	196
3-13.3-1	Adjusted Inverted Cone	203

Tables

1-2.6-1	Off-Design Conditions' Approximate Effect on Actual Heat Rate	11
1-2.6-2	Value of Turbine Section Efficiency Level Improvement on a Unit Heat Rate of 10,000 Btu/kWh	12
1-2.6-3	Sensitivity of Heat Rate to Various Parameters for a Typical Pressurized Water Reactor Nuclear Power Plant	14
2-3.6.2.2-1	Diagnostic Chart of Turbine Loss Characteristics	62
2-3.6.2.2-2	Steam Surface Condenser Diagnostics	63
2-3.16-1	Matrix of Cycle Interrelations.....	124
2-4.3-1	Incremental Rates for the Two Generating Units in Fig. 2-4.3-1	133
2-4.3-2	Relative Incremental Costs Associated With a Combined Cycle Facility.....	134
2-4.3.1-1	Impact of Load Division on Plant Economy.....	135
3-5.2-1	Air Heater Leakage	189
3-10.1-1	Test Results of Four High-Pressure Heaters	199
3-12.2-1	Reconciliation of Load Change Based on Change in Performance Parameters	202
3-13.3-1	Measurements Taken at the Outage.....	203
3-13.3-2	Calculated Cone and Feedpipe Areas	204
3-13.3-3	Resulting Gap Clearances and Leaks	204

Nonmandatory Appendix

A	Thermodynamics Fundamentals.....	205
---	----------------------------------	-----

FOREWORD

Since the original publication of these Guidelines in 1993, then limited to steam power plants, the field of performance monitoring (PM) has undergone considerable expansion. PM has gained in importance as the lifetime of equipment and power plants have been lengthened and greater demands on extending it by careful monitoring — rather than its replacement by new equipment — has become the tendency in the power industry. The techniques themselves have also been transformed, largely by the emergence of electronic data acquisition as the dominant, though not exclusive, method of obtaining the necessary information. Manual methods remain but as specialized applications. Based on the realization of the changes that have taken place it was deemed necessary to update the document itself.

The new realities of engineers and other plant personnel concerned with PM are reflected in the revised organization of the new Guide. This consists of three parts which are considered to have equal importance as regards the reader. Part 1 “Fundamental Considerations” stresses, not only by its contents but also by its separate editorial status, the importance of considering the essentials of PM prior to the specifics of the actual application. All too often lack of experience or need for rapid delivery of results has led to implementation without due thought being given to the basic needs, potential benefits and likelihood of tradeoffs of the PM program. The distinction here is in the emphasis given to the underlying importance of basic considerations.

Part 2 “Program Implementation” is a thoroughly revised and updated text of the main body of the 1993 Guide. Readers familiar with the original edition will find some of the material familiar but much that is new. The concepts of PM implementation and diagnostics have been brought into closer conjunction as is the case in contemporary practice rather than as two wholly separate aspects of monitoring activity. Similarly, the importance of cycle interrelationships have now been thoroughly recognized and so the distinction given to it in 1993 was no longer necessary; it has become an accepted part of PM implementation, in practice and in the structure of this revised Guide.

Part 3 “Case Studies/Diagnostic Example” is wholly new. Since 1993 a large amount of experience and historical data has been accumulated and a selection is here presented. The importance of Part 3 goes beyond the illustrative although the various actual situations briefly described were chosen for their applied significance. In a larger sense, Part 3 illustrates the immense scope and variety of PM and, it is hoped, thereby makes clear the need to carefully consider the specifics of each monitoring situation. There are few general rules and many aspects particular to the plant, equipment and process to be considered. Plant’s technical staffs are encouraged to learn from the experience of their predecessors in the field of monitoring and carefully scrutinize these recommendations and details as guidance to establish an optimal PM program.

This edition was approved by the Performance Test Codes Standards Committee on December 8, 2008.

ACKNOWLEDGMENTS

This revision of PTC PM Performance Monitoring Guidelines for Power Plants is dedicated to the memory of Fred H. Kindl, who passed away while this revision was in progress. Mr. Kindl was an outstanding engineer who significantly promoted the importance of power plant performance activities, a faithful member of the Committee, and a major contributor to the content of these Guidelines.

ASME PTC COMMITTEE

Performance Test Codes

(The following is the roster of the Committee at the time of approval of this Document.)

STANDARDS COMMITTEE OFFICERS

M. P. McHale, *Chair*

J. R. Friedman, *Vice Chair*

J. H. Karian, *Secretary*

STANDARDS COMMITTEE PERSONNEL

P.G. Albert, General Electric Co.

R. P. Allen, Consultant

J. M. Burns, Burns Engineering

W. C. Campbell, Southern Company Services

M. J. Dooley, Sigma Energy Solutions

J. R. Friedman, Siemens Power Generation, Inc.

G. J. Gerber, Consultant

P. M. Gerhart, University of Evansville

T. C. Heil, The Babcock & Wilcox Co.

R. A. Henry, Sargent & Lundy

J. H. Karian, The American Society of Mechanical Engineers

D. R. Keyser, Survice Engineering

S. J. Korellis, Electric Power Research Institute

M. P. McHale, McHale & Associates, Inc.

P. M. McHale, McHale & Associates, Inc.

J. W. Milton, P.E. Energy

S. P. Nanni, The Babcock & Wilcox Co.

A. L. Plumley, Plumley Associates

R. R. Priestley, General Electric

A. Rabensteine, Environmental Systems Corp.

J. A. Silvaggio, Jr., Siemens Demag Delaval

W. G. Steele, Jr., Mississippi State University

J. C. Westcott, Mustan Corp.

W. C. Wood, Duke Energy

PTC PM COMMITTEE — PERFORMANCE MONITORING

J. W. Milton, *Chair*

T. L. Toburen, *Vice Chair*

G. Osolobe, *Secretary*

J. K. August, Core Inc.

K. M. Brandt, General Physics Corporation

R. R. Des Jardins, General Physics Corporation

J. F. Elliott, South Carolina Electric & Gas

P. D. Friedman, University of Massachusetts–Dartmouth

C. T. Gitchell, Howden Buffalo, Inc.

J. M. Harmon, Alstom Power Inc.

R. A. Johnson, Mississippi Power Company

J. C. Kim, IBECONS International

S. J. Korellis, Electric Power Research Institute

D. C. McLaughlin, General Physics Corporation

J. W. Milton, RRI Energy, Inc.

S. R. Piezuch, Black & Veatch Corporation

S. Soufi, SMS Energy-Engineering, Inc.

K. S. Sunder Raj, Power & Energy Systems Services, Inc.

T. L. Toburen, T2E3

CORRESPONDENCE WITH THE PTC PM COMMITTEE

General. ASME Codes are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Guide may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, PTC Standards Committee
The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

Proposing Revisions. Revisions are made periodically to the Guide to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Guide. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Guide. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal including any pertinent documentation.

Attending Committee Meetings. The PTC Standards Committee holds meetings or telephone conferences, which are open to the public. Persons wishing to attend any meeting or telephone conference should contact the Secretary of the PTC Standards Committee or check our Web site <http://www.asme.org/codes/>.

INTRODUCTION

This document contains guidelines for performance monitoring and optimization. These guidelines establish procedures for monitoring power plant performance parameters in a routine, ongoing, and practical manner.

These guidelines do not constitute or supersede any of the Performance Test Codes. They constitute a set of nonmandatory guidelines to promote performance monitoring activities.

The guidelines provide methods and procedures to monitor power plant and equipment performance and to validate, process, and analyze the data in order to improve or optimize unit or plant thermal efficiency, capacity, economic dispatch, operator awareness, and cycle component diagnostics, as well as to provide information for engineering studies, preventive or predictive maintenance, and planning purposes concerning equipment maintenance, replacements, or upgrades.

It is not the intent of this document that the instructions it contains be used for acceptance or official testing of new or existing power plants, systems, and components.

INTENTIONALLY LEFT BLANK

PERFORMANCE MONITORING GUIDELINES FOR POWER PLANTS

Section 1 Fundamental Concepts

1-1 OBJECT AND SCOPE

1-1.1 Object

The object of these guidelines is to provide information to implement and utilize a performance monitoring and optimization program effectively. These guidelines are not intended to become mandatory for power plant performance monitoring, nor do they include all or override any safety considerations.

In performance monitoring of diverse items of power plant equipment, the uncertainty level of results may range from very small to quite large, depending on the given situation. It is important for the engineer to evaluate uncertainty and take appropriate action for meeting goals. Useful references include PTC 19.1 Test Uncertainty and the related Performance Test Codes.

1-1.2 Scope

The scope of these guidelines includes fossil-fueled power plants, gas-turbine power plants operating in combined cycle, and the balance-of-plant portion including interface with the nuclear steam supply system of nuclear power plants. The guidelines include performance monitoring concepts, a description of various methods available, and means for evaluating particular applications.

The guidelines provide procedures for validation and interpretation of data, determination of performance characteristics and trends, determination of sources of performance problems, analysis of the performance in relation to the process, determination of losses due to degradation, possible corrective actions, and performance optimization.

The guidelines provide the necessary information for implementing a performance monitoring program, using either an automated or a manual data acquisition system, or both.

1-2 OVERVIEW

1-2.1 Definition of Performance Monitoring

Performance monitoring is an overall, long-term effort to measure, sustain, and improve the plant and/or unit thermal efficiency, capacity, dispatch cost, emissions control, and maintenance planning. The program can be implemented for multiple reasons such as cost reduction, capacity improvement, and/or reliability improvements. The decision to implement a performance-monitoring program should be based on plant and fleet requirements and available resources. This includes personnel knowledgeable of the process, the instrumentation, the data collection medium, and the required analysis and interpretation techniques.

For the purpose of this document, the term “monitoring” refers to an overall, long-term, continuing program. It can range from periodic testing of individual components to on-line monitoring of all cycle components. The term “testing” refers to a specific part of the performance monitoring program.

These guidelines cover a broad range of performance monitoring techniques oriented toward power plants. They seek to advise plant personnel on how to effectively monitor the efficiency and condition of the equipment throughout its lifetime. They also extend beyond monitoring itself into the areas of information evaluation and application toward corrective action.