

# THE STRUCTURAL DESIGN OF AIR AND GAS DUCTS FOR POWER STATIONS AND INDUSTRIAL BOILER APPLICATIONS

AIR AND GAS DUCT STRUCTURAL DESIGN COMMITTEE OF THE  
ENERGY DIVISION OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Ronald L. Schneider, Chairman

Daniel S. Blackwood

Victor A. Bochicchio

Robert F. Bucelwicz

Joseph G. Clark

M. Roy Hogan

Robert W. Jacks

Ronald B. Johnson

Paul A. Kokosinski

Timothy S. Laughlin

Thomas G. Longlais

James Newell

Rodney K. Simonetti

Michael Stieffermann

Kenneth M. Tamms

Walter Van Dyke

Raymond M. Warren

Haim Weinstein

James S. Whitcraft

**ASCE** *American Society  
of Civil Engineers*

1801 ALEXANDER BELL DRIVE  
RESTON, VIRGINIA 20191-4400

This is a preview. [Click here to purchase the full publication.](#)

## ABSTRACT

This document, *The Structural Design of Air & Gas Ducts for Power Stations & Industrial Boiler Applications*, has been created to assist structural engineers when performing the structural analysis and design of ductwork. Air and gas ducts for fossil fuel power stations and industrial boiler applications are unique structures. Considering that ductwork structural analysis and design is not currently referenced or governed by any national code or design standard, this publication presents the structural engineer with current approaches for the structural analysis and design of air and flue-gas ductwork. Included are sections on: 1) Material selection, behavior and performance; 2) design loads, loading combinations and allowable stresses; 3) thermal considerations; 4) vibration considerations; 5) structural arrangement and behavior; 6) toggle duct behavior and expansion joint considerations; 7) overall duct structural analysis and design methods; and 8) design considerations for local elements of the structure, such as stiffeners, internal braces, connections, turning vanes, and other flow distribution devices. This document also discusses drawing and specification content, fabrication and construction techniques and considerations, duct support methods, and special considerations regarding the design of duct support structures. Finally, it talks about field maintenance examinations and inspections for the purpose of preventative maintenance or condition assessment.

### Library of Congress Cataloging-in-Publication Data

The structural design of air and gas ducts for power stations and industrial boiler applications / Air and Gas Duct Structural Design Committee of the Energy Division of the Air and Gas Duct Structural Design Committee.  
p. cm.

Includes bibliographical references and index.

ISBN 0-7844-0112-8

1. Power plants—Equipment and supplies. 2. Steam-boilers. 3. Air ducts—Design and construction. 4. Flue gases. I. American Society of Civil Engineers. Air and Gas Duct Structural Design Committee.

TJ164.S87 1995

95-24709

621.31'2—dc20

CIP

The material presented in this publication has been prepared in accordance with generally recognized engineering principles and practices, and is for general information only. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application.

The contents of this publication are not intended to be and should not be construed to be a standard of the American Society of Civil Engineers (ASCE) and are not intended for use as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document.

No reference made in this publication to any specific method, product, process or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE.

ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor.

Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

Photocopies. Authorization to photocopy material for internal or personal use under circumstances not falling within the fair use provisions of the Copyright Act is granted by ASCE to libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$2.00 per article plus \$.25 per page copied is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923. The identification for ASCE Books is 0-7844-0112-8/95 \$2.00 + \$.25. Requests for special permission or bulk copying should be addressed to Permissions & Copyright Dept., ASCE.

Copyright © 1995 by the American Society of Civil Engineers,  
All Rights Reserved.

Library of Congress Catalog Card No: 95-24709

ISBN 0-7844-0112-8

Manufactured in the United States of America.

## PREFACE

This ASCE Special Publication has been created by a select committee of structural and mechanical engineers who are extremely experienced in the structural analysis and design of air and flue-gas ductwork for power stations and large industrial boiler applications.

The need for this document was identified in 1991 by the ASCE Fossil Power Committee under the chairmanship of Thomas Longlais. Tom obtained the authorization of the ASCE through the Energy Division to create the Task Committee assigned to produce this Special Publication. Subsequently, the ASCE Task Committee on the Structural Design of Air & Gas Ducts was created late in 1991 under my chairmanship. My first, and most important task, was to form a working committee of qualified individuals from various sectors of the power and boiler industries. I believed that the best committee would consist of representatives from all facets of the ductwork industry: owners, consulting engineers, equipment suppliers and duct suppliers. I tried to recruit individuals from these types of representative major companies that perform the structural analysis and design of ducts. The committee started out in January of 1992 with about 25 members, but gradually shrunk to a working group of 19. All of these individuals put a considerable amount of work into this effort and I thank them all.

### **Air & Gas Duct Structural Design Committee**

Ron Schneider	*	Gilbert/Commonwealth Engineers
Dan Blackwood		Southern Company Services
Vic Bochicchio		Zurn Balcke-Durr, Inc.
Bob Bucelwicz		Boston Edison Co.
Joe Clark	*	ABB Combustion Engineering Systems
Roy Hogan	*	ABB Environmental Systems
Bill Jacks		Tennessee Valley Authority
Ron Johnson	*	Babcock & Wilcox
Paul Kokosinski	*	Public Service Electric & Gas
Tim Laughlin	*	Sargent & Lundy Engineers
Tom Longlais		Sargent & Lundy Engineers
Jim Newell		Stone & Webster Engineering Corp.
Rod Simonetti	*	Gilbert/Commonwealth Engineers
Mike Stiefermann	*	Central Electric Company
Ken Tamms		American Electric Power
Walt Van Dyke	*	Foster Wheeler Energy Corp.
Ray Warren	*	Warren Engineering
Heim Weinstein		Public Service Electric & Gas
Jim Whitcraft	*	Bechtel Power Corp.

The most significant and time consuming contributions were made by the individuals who actually authored the various sections of this ASCE Special Publication. These individuals are noted on the previous page with an asterisk after their name. They all deserve a special thanks for their commitment and hard work.

In addition, many of the task committee members obtained important help from other engineers and designers within their organizations. I give my thanks to all of them. Some of the more significant contributors to the success of this ASCE Special Publication were: Daniel Biss, David Wagner, Timothy Frymoyer, and Kenneth Bauer from Gilbert/Commonwealth and Edward Hanko from Sargent & Lundy.

Ronald L. Schneider  
ASCE Member  
June 1995

**American Society of Civil Engineers  
Special Publication**

**The Structural Design  
of Air & Gas Ducts for  
Power Stations & Industrial Boiler Applications**

**CONTENTS**

	<u>Page</u>
1 INTRODUCTION . . . . .	1
1.1 Statement of Intent and Expected Use of this Document . . . . .	3
1.2 Limitations and Scope of this Document . . . . .	5
1.3 Ductwork Systems Descriptions . . . . .	7
1.4 Glossary/Definitions . . . . .	17
1.5 Descriptions of Major Ductwork Equipment . . . . .	26
1.6 Descriptions of Ductwork Accessories . . . . .	30
2 DUCTWORK ARRANGEMENT AND BEHAVIOR . . . . .	33
2.1 Overview . . . . .	35
2.2 Interfaces with Equipment . . . . .	37
2.3 Thermal Expansion . . . . .	45
2.4 Supports . . . . .	54
2.5 Duct Geometries . . . . .	66
2.6 Internal Trusses and Struts . . . . .	70
2.7 Effects of the Arrangement on Loads . . . . .	74
3 STRUCTURAL MATERIAL - SELECTION, APPLICATIONS AND PROPERTIES . . . . .	81
3.1 Introduction . . . . .	83
3.2 Availability of Materials . . . . .	83
3.3 Material Properties . . . . .	84
3.4 Material Selection . . . . .	92
3.5 Bolts . . . . .	95
3.6 Welding Electrodes . . . . .	95
3.7 Ductwork Protection . . . . .	96
3.8 Hanger Elements . . . . .	99

# STRUCTURAL DESIGN OF AIR & GAS DUCTS

	<b>Page</b>
<b>4 SERVICE CONDITIONS AND DESIGN LOADS.....</b>	<b>101</b>
4.1 Service Conditions.....	103
4.2 Design Loads .....	109
<b>5 LOADING COMBINATIONS AND ASSOCIATED DESIGN STRESSES .....</b>	<b>119</b>
5.1 Design Stress Considerations.....	121
5.2 Recommended Analysis and Design Approach .....	124
5.3 Load Definitions and Considerations.....	124
5.4 Loading Combinations .....	125
<b>6 PLATE DESIGN AND STIFFENER LOCATION CONSIDERATIONS .....</b>	<b>129</b>
6.1 Introduction .....	131
6.2 Rectangular Duct Plate Design .....	132
6.3 Plate and Stiffener Composite Action .....	140
6.4 Circular Ductwork Plate Design .....	142
6.5 Other Considerations .....	145
<b>7 DUCTWORK GLOBAL STRUCTURAL ANALYSIS .....</b>	<b>149</b>
7.1 Introduction .....	151
7.2 Global Approach .....	152
7.3 Structural Model Considerations .....	159
<b>8 STRUCTURAL ELEMENT DESIGN .....</b>	<b>171</b>
8.1 General Considerations.....	173
8.2 Rectangular Ducts .....	174
8.3 Internal Trusses and Struts for Rectangular Ducts .....	185
8.4 Circular Ducts .....	193
8.5 Lateral External Tie Elements .....	197
<b>9 STRUCTURAL DESIGN OF FLOW DISTRIBUTION DEVICES ..</b>	<b>199</b>
9.1 Function of Flow Distribution Devices .....	201
9.2 Flow Layout and Structural Considerations .....	203
9.3 Support Considerations .....	205
9.4 Structural Analysis .....	205
9.5 Structural Design .....	210

<b>10</b>	<b>DRAWING, FABRICATION AND CONSTRUCTION TECHNIQUES AND CONSIDERATIONS</b>	<b>213</b>
10.1	General Considerations	215
10.2	Drawings and Specifications	223
10.3	Fabrication	228
10.4	Welding	230
10.5	Shop Inspection	233
10.6	Surface Preparation	234
10.7	Handling and Shipping	235
10.8	Erection	238
<b>11</b>	<b>INSULATION AND LAGGING</b>	<b>241</b>
11.1	Introduction	243
11.2	Purpose of Insulation and Lagging	243
11.3	Types of Insulation and Lagging	245
11.4	Affects of Insulation and Lagging on the Structural Design of Ducts	247
11.5	Methods of Installation and Quality of the Work	249
11.6	Construction Details	253
<b>12</b>	<b>MAINTENANCE EXAMINATION OF EXISTING DUCT SYSTEMS</b>	<b>259</b>
12.1	Factors that Influence the Need for Structural Examinations	261
12.2	Field Examination Techniques	265
12.3	Potential Damage Areas	273
12.4	Examination Data, Evaluation and Disposition	278
	<b>APPENDIX I - REFERENCES</b>	<b>283</b>
	<b>INDEX</b>	<b>289</b>





# STRUCTURAL DESIGN OF AIR & GAS DUCTS

## LIST OF FIGURES

### Page

Figure 1.1	Typical Pressurized System Ductwork Arrangement for a Coal-Fired Power Plant . . . . .	9
Figure 1.2	Typical Balanced Draft System Ductwork Arrangement for a Coal-Fired Power Plant . . . . .	10
Figure 1.3	Typical Ductwork Arrangement for a Combined Cycle Power Plant . . . . .	11
Figure 1.4	Typical Air Duct Arrangement for a Fluidized-Bed Boiler . . .	12
Figure 1.5	Typical Air Duct Arrangement for a Pulverized Coal-Fired Boiler . . . . .	14
Figure 1.6	Typical Pressure Profile for a Coal-Fired Power Plant . . . . .	16
Figure 1.7	Typical Toggle Duct Arrangement . . . . .	18
Figure 2.1	Damper Types . . . . .	40
Figure 2.2	Preferred Damper Location Relative to an Expansion Joint . .	41
Figure 2.3	Example of a Dead Leg Duct Section . . . . .	42
Figure 2.4	Example of the Effect of Expansion Joint Placement on Loads . . . . .	46
Figure 2.5	Typical Arrangement with a Toggle Duct Section . . . . .	47
Figure 2.6	Typical Duct Anchor and Guide Arrangement . . . . .	48
Figure 2.7	Locating the Anchor Point at the Center of Mass . . . . .	49
Figure 2.8	Typical Guided Bottom Support Detail . . . . .	50
Figure 2.9	Virtual Anchor Point . . . . .	50
Figure 2.10	Typical Spherical Slide Bearing Plate Assembly . . . . .	51
Figure 2.11	Initial Offset of Bottom Support to Reduce Eccentricity . . . .	53
Figure 2.12	Example of Support Steel Framing Which Allows Friction Forces to Cancel . . . . .	55
Figure 2.13	Example of an Indeterminate Duct Section . . . . .	57
Figure 2.14	Example of a Determinate Duct Section . . . . .	59
Figure 2.15	Effect of Hanger Rotation . . . . .	61
Figure 2.16	Example of the Proper Arrangement of Supports at Different Elevations . . . . .	64
Figure 2.17	Typical Rectangular Duct Construction . . . . .	67
Figure 2.18	Internal Truss at a Duct Branch . . . . .	71
Figure 2.19	Internal Struct. . . . .	72
Figure 2.20	Typical Flexible and Inflexible Truss Arrangements . . . . .	73
Figure 3.1	Coefficient of Thermal Expansion Versus Temperature . . . . .	85
Figure 3.2	Modulus of Elasticity Versus Temperature . . . . .	86
Figure 3.3	Yield Strength Ratio Versus Temperature . . . . .	86
Figure 3.4	Ultimate Strength Ratio Versus Temperature . . . . .	88

## **LIST OF FIGURES (cont.)**

	<u><b>Page</b></u>
Figure 4.1 Typical Locations of Ash Accumulation . . . . .	112
Figure 4.2 Effect of Unbalanced Pressure Forces on Ductwork and Its External Supports . . . . .	116
Figure 6.1 Example of Poor Duct Support Arrangements . . . . .	133
Figure 6.2 Sample Rectangular Duct Stiffener Framing . . . . .	135
Figure 6.3 Large Deflection Theory Behavior . . . . .	136
Figure 6.4 Example of Circular Duct Loading Considerations . . . . .	144
Figure 7.1 Typical Path for Dead Load . . . . .	154
Figure 7.2 Typical Path for Wind Load . . . . .	155
Figure 7.3 Typical External Support Structure . . . . .	156
Figure 7.4 Typical Support Model . . . . .	159
Figure 7.5 Effective Area Considered for Duct Stiffness . . . . .	160
Figure 7.6 Equivalent Wind Load for Model Analysis . . . . .	163
Figure 8.1 Stiffener Composite Section . . . . .	175
Figure 8.2 Typical Stiffener to Plate Connections . . . . .	176
Figure 8.3 Example Stiffener Arrangement . . . . .	178
Figure 8.4 Typical Stiffener Loading Conditions . . . . .	179
Figure 8.5 Example of a Stiffener Stress Profile Calculation Sheet . . . . .	181
Figure 8.6 Duct to Hopper Interface . . . . .	182
Figure 8.7 Examples of Stiffener Connections . . . . .	185
Figure 8.8 Typical Truss Connection . . . . .	186
Figure 8.9 Typical Hanger Rod Support Arrangements . . . . .	192
Figure 8.10 Typical Bottom Support Arrangements . . . . .	193
Figure 8.11 Local Stresses in Circular Rings . . . . .	194
Figure 8.12 Typical Circular Duct Support Hanger Arrangements . . . . .	195
Figure 8.13 Typical Bottom Supported Circular Duct Arrangement . . . . .	195
Figure 8.14 Typical Circular Duct Saddle Support . . . . .	196
Figure 9.1 Typical Flow Distribution Device Configurations . . . . .	202
Figure 9.2 Dynamic Thrust on Turning Vanes . . . . .	208
Figure 10.1 Common Shipping Trailer Dimensions . . . . .	218
Figure 10.2 Typical Rail Shipping Widths . . . . .	219
Figure 10.3 Typical Field Splices for Ducts . . . . .	222
Figure 10.4 Duct Cross Section Bowing Tolerance . . . . .	230
Figure 10.5 Typical Temporary Bracing Schemes . . . . .	237

## STRUCTURAL DESIGN OF AIR & GAS DUCTS

### LIST OF FIGURES (cont.)

	<u>Page</u>
Figure 11.1 Typical External Insulation Attached to the Duct Plate . . . . .	250
Figure 11.2 Typical External Insulation Attached to Duct Stiffeners . . . . .	251
Figure 11.3 Typical Internal Insulation Details . . . . .	252
Figure 11.4 Typical Insulation Detail at Expansion Joints . . . . .	254
Figure 11.5 Alternate Insulation Detail at Expansion Joints . . . . .	254
Figure 11.6 Typical Hopper Crotch Insulation Detail . . . . .	255

### LIST OF TABLES

	<u>Page</u>
Table 3.1 Typical Allowable Creep Stresses for Steels Common to Ductwork Applications . . . . .	90
Table 4.1 Air and Gas Duct EXAMPLE Pressures and Temperatures for a Pressurizer Coal-Fired Power Plant . . . . .	105
Table 4.2 Air and Gas Duct EXAMPLE Pressures and Temperatures for a Balanced Draft Coal-Fired Power Plant . . . . .	106
Table 4.3 Air and Gas Duct EXAMPLE Pressures and Temperatures for Pressurized and Balanced Draft Industrial Boilers . . . . .	107
Table 4.4 Flyash Density Ranges . . . . .	112
Table 10.1 Shipping Cost Factors . . . . .	216
Table 12.1 Structural Maintenance Examination - Equipment Checklist . . . . .	267