

High Density Data Centers

Case Studies and Best Practices

© 2008, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org).
For personal use only. Additional reproduction, distribution, or transmission in either print or
digital form is not permitted without ASHRAE's prior written permission.

*This publication was prepared in cooperation with TC 9.9, Mission Critical Facilities,
Technology Spaces, and Electronic Equipment.*

**Any updates/errata to this publication will be posted on the
ASHRAE Web site at www.ashrae.org/publicationupdates.**

© 2008, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org).
For personal use only. Additional reproduction, distribution, or transmission in either print or
digital form is not permitted without ASHRAE's prior written permission.

High Density Data Centers



**American Society of Heating, Refrigerating
and Air-Conditioning Engineers, Inc.**

© 2008, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org).
For personal use only. Additional reproduction, distribution, or transmission in either print or
digital form is not permitted without ASHRAE's prior written permission.

ISBN 978-1-933742-32-8

Second imprint ©2008 American Society of Heating, Refrigerating
and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329
www.ashrae.org

All rights reserved.
Printed in the United States of America

Printed on 30% post-consumer waste using soy-based inks.

Cover courtesy of Joe Lombardo of DLB Associates.

ASHRAE has compiled this publication with care, but ASHRAE has not investigated, and ASHRAE expressly disclaims any duty to investigate, any product, service, process, procedure, design, or the like that may be described herein. The appearance of any technical data or editorial material in this publication does not constitute endorsement, warranty, or guaranty by ASHRAE of any product, service, process, procedure, design, or the like. ASHRAE does not warrant that the information in the publication is free of errors, and ASHRAE does not necessarily agree with any statement or opinion in this publication. The entire risk of the use of any information in this publication is assumed by the user.

No part of this book may be reproduced without permission in writing from ASHRAE, except by a reviewer who may quote brief passages or reproduce illustrations in a review with appropriate credit; nor may any part of this book be reproduced, stored in a retrieval system, or transmitted in any way or by any means—electronic, photocopying, recording, or other—without permission in writing from ASHRAE.

Library of Congress Cataloging-in-Publication Data

High density data centers : case studies and best practices.
p. cm. — (ASHRAE Datacom Series)

Summary: "Provides the reader a series of data center case studies and best practices that demonstrate how high density loads can be cooled using a number of different approaches and includes a breadth of data center ventilation schemes and shows how they are deployed to cool high density IT equipment"—Provided by publisher.

Includes bibliographical references and index.
ISBN 978-1-933742-32-8 (softcover)

1. Office buildings--Design and construction--Case studies. 2. Office buildings--Air conditioning--Case studies. 3. Electronic data processing departments--Equipment and supplies--Protection--Case studies. 4. Data processing service centers--Equipment and supplies--Protection--Case studies. 5. Electronic digital computers--Cooling--Case studies. 6. Data libraries--Protection--Case studies. I. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

TH4311.H54 2008
725'.23--dc22

2008006301

ASHRAE STAFF

SPECIAL PUBLICATIONS

Christina Helms
Editor

Cindy Sheffield Michaels
Associate Editor

James Madison Walker
Assistant Editor

Michshell Phillips
Administrative Assistant

PUBLISHING SERVICES

David Soltis
Group Manager

Tracy Becker
Graphic Applications Specialist

Jayne Jackson
Publication Traffic Administrator

PUBLISHER

W. Stephen Comstock

Contents

| | |
|---|-----|
| Acknowledgments | vii |
| Chapter 1 Introduction | 1 |
| Chapter 2 Raised-Access Floor Case Studies | 7 |
| 2.1 Raised-Access Floor with Perimeter Modular CRACs | 7 |
| 2.1.1 Case Study 1—National Center for Environmental Prediction (NCEP) | 7 |
| 2.1.2 Case Study 2—IBM Test Facility in Poughkeepsie (2004) | 23 |
| 2.1.3 Case Study 3—San Diego Supercomputer Center | 40 |
| 2.1.4 Case Study 4—IBM Test Facility in Poughkeepsie (2005) | 56 |
| 2.2 Raised-Access Floor with AHUs on Subfloor | 66 |
| 2.2.1 Case Study 5—Lawrence Livermore National Lab Data Center | 66 |
| 2.3 Raised-Access Floor Supply/Ceiling Return | 74 |
| 2.3.1 Case Study 6—NYC Financial Services Data Center | 74 |
| 2.4 Raised-Access Floor with Heat Exchangers Adjacent to Server Racks | 87 |
| 2.4.1 Case Study 7—Georgia Institute of Technology Data Center | 87 |
| 2.4.2 Case Study 8—Hewlett-Packard Richardson DataCool™ Data Center | 95 |

vi | Contents

| | | |
|---|--|------------|
| 2.5 | Raised-Access Floor with Underfloor Supply/Ducted Ceiling Return | 112 |
| 2.5.1 | Case Study 9—Oracle Data Center | 112 |
| Chapter 3 Non-Raised-Access Floor Case Studies | | 127 |
| 3.1 | Non-Raised-Access Floor with Row Cooling | 127 |
| 3.1.1 | Case Study 10—Cedars-Sinai Medical Center Data Center | 127 |
| 3.2 | Non-Raised-Access Floor with Ceiling Supply | 137 |
| 3.2.1 | Case Study 11—Lawrence Berkeley National Lab. | 137 |
| Chapter 4 Best Practices | | 157 |
| 4.1 | Data Center—New Builds | 157 |
| 4.1.1 | Ventilation Designs | 158 |
| 4.1.2 | Raised-Access Floor Plenum Height | 160 |
| 4.1.3 | Room Ceiling Height | 162 |
| 4.1.4 | Underfloor Blockages | 163 |
| 4.1.5 | CRAC Placement and Configuration | 164 |
| 4.2 | Accommodating Future Data Center Growth | 165 |
| 4.3 | Raised-Access Floor Data Center | 166 |
| 4.3.1 | Perforated Tile Layout and Configuration | 166 |
| 4.3.2 | Rack and Rack Layout-Related Effects | 168 |
| 4.4 | Localized Cooling | 170 |
| 4.5 | Non-Raised-Access Floor Data Center | 171 |
| 4.6 | Data Center Energy Management and Efficiency | 171 |
| References and Bibliography | | 175 |
| Abbreviations and Acronyms | | 183 |
| Index | | 185 |

Acknowledgments

The information in this book was produced with the help and support of the corporations, academic institutions, and organizations listed below:

| | |
|-------------------------------------|--------------------------------|
| American Power Conversion | JDA Consulting Engineers |
| Bellsouth | Lawrence Berkeley National Lab |
| Cedar Sinai Medical Center | Microsoft |
| Citigroup | Minick Engineering |
| Cushman and Wakefield | Opengate Data Systems |
| DLB Associates Consulting Engineers | Oracle |
| Emerson | Panduit |
| Georgia Institute of Technology | Rumsey Engineers |
| Hewlett Packard | San Diego Supercomputer Center |
| IBM | Ted Jacob Engineering Group |

ASHRAE TC9.9 wants to particularly thank the following people:

- **John Bean, Christian Belady, Jack Glass, Jason Kutticherry, Oleg Levchok, Rhonda Johnson, Bret Lehman, Mukesh Khattar, Joe Prisco, Madhusudan Iyengar, and Roger Schmidt** for their participation as chapter leads and for writing and performing final edits of their chapters.
- **Dr. Roger Schmidt** of IBM, Chair of TC9.9, for his vision and leadership in the creation of this book.
- **Joe Lombardo** for the book cover design.

In addition TC9.9 would like to thank Will Dahlmeier, Mike Mangan, and Don Beaty of DLB Associates, Inc., and the following people for substantial contributions to the individual case studies in the book:

Case 1: Thanks to Bob Wasilewski and Tom Juliano of DLB Associates, Inc. for aiding in the measurements, and thanks to Donna Upright and Duane Oetjen

viii | **Acknowledgments**

of IBM for their complete support in performing these measurements while the data center was in full operation.

Case 2: Thanks to Bob Wasilewski and Tom Juliano of DLB Associates, Inc., for their aid in the measurements, and thanks to Donna Upright and Duane Oetjen for their complete support in performing these measurements while the data center was in full operation.

Case 3: Thanks to Dr. Roger Schmidt, Dr. Hendrik Hamann, Dane Miller, and Harald Zettl for their help with collection and interpretation of the data. The characterization and paper would not have been possible without their contribution. The author also thanks the staff of SDSC, especially Mike Datte and Jeff Filliez, for their full cooperation in allowing IBM to study the data center and publish the results.

Case 4: Thanks to Donna Upright and Duane Oetjen for their complete support in performing these measurements in Poughkeepsie while the data center was in full operation.

Case 5: Thanks to Steve Holt at Livermore for helping with the data collection at the Livermore site.

Case 6: Thanks to Gerhard Haub and Patrick Calcagno of Cushman and Wakefield and Ryan Meadows and Ed Koplín of JDA Consulting Engineers for their assistance with field measurements and analysis.

Case 7: Thanks to Dr. Bartosz Ilkowski at the Georgia Institute of Technology, Bret Lehman of IBM, Stephen Peet of BellSouth, and Steve Battenfeld of Minick Engineering for their contributions to both the design and documentation of this high density case study. Thanks also to Sam Toas and Rhonda Johnson of Panduit for their contributions in the areas of temperature measurement and results documentation.

Case 8: Thanks to Jonathan Lomas for field data collection and Scott Buell for CFD modeling and graphics.

Case 9: Thanks to Lennart Stahl of Emerson, a great collaborator on the project, and to the supporting executives, Paul Perez of HP and Thomas Bjarnemark of Emerson. Thanks also to Chandrakant Patel, Cullen Bash, and Roy Zeighami for all their technical support and contributions.

Case 10: Thanks to Dr. Mukesh Khattar, Mitch Martin, Stephen Metcalf, and Keith Ward of Oracle for conceptual design and implementation of the hot-air containment at the rack level, which permitted use of variable-speed drives on the CRACs while preventing mixing of hot and cold air in the data floor; Mark Redmond of Ted Jacob Engineering Group for system engineering and specifications; and Mark Germagian, formerly of Wright Line and now with Opengate Data Systems, for building server racks with hot-air containment.

Case 11: Thanks to Bill Tschudi of Lawrence Berkeley National Laboratory and Peter Rumsey of Rumsey Engineers for contributing this case study, which was performed as part of a broader project for the California Energy Commission.