NIST NCSTAR 1-1I

Federal Building and Fire Safety Investigation of the World Trade Center Disaster

Post-Construction Modifications to Fire Protection, Life Safety, and Structural Systems of World Trade Center 7

Raymond A. Grill
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NIST National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce

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U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

Technology Administration
Michelle O'Neill, Acting Under Secretary for Technology

National Institute of Standards and Technology
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ABSTRACT

This report was prepared to support the analysis of building and fire codes and standards of the National Institute of Standards and Technology World Trade Center (WTC) Investigation. This report was prepared to support the overall objective of determining how and why WTC 7 collapsed. The purpose of this report is to document modifications and/or repairs of the fire protection, life safety, and structural framing systems of WTC 7.

Keywords: Beams, building modifications, cover plates, fire alarm, fire protection, fire safety, fire sprinklers, floor slab openings, high-rise buildings, life safety, means of egress, pressurization, structural framing, tenant alterations, voice communication, web openings, wide-flange T-sections, World Trade Center.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronyms

ASTM	ASTM International
BCNYC	Building Code of the City of New York (Local Law No. 76)
HVAC	heating, ventilating, and air conditioning
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
PANYNJ	Port Authority of New York and New Jersey
WTC 1	World Trade Center 1 (North Tower)
WTC 2	World Trade Center 2 (South Tower)
WTC 7	World Trade Center 7

Abbreviations

ft	foot
in.	inch
WT15x74	American Institute of Steel Construction/ASTM standard abbreviation for a box (tube) beam of cross section 15 in. by 74 in.
WT24x55	American Institute of Steel Construction/ASTM standard abbreviation for a wide flange beam of cross section 24 in. flange and 55 in. web.

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GLOSSARY

active fire protection – A means to help prevent the loss of life and property from fire by extinguishing, suppressing, or controlling a fire through functional systems. Sprinkler systems, fire alarm systems, and smoke control systems are examples of active fire protection.

area of refuge – A floor area to which egress is made through a horizontal exit or supplemental vertical exit.

combustible – A material that is not determined to be noncombustible.

damper – A device installed in heating, ventilating, and air conditioning ductwork used to prevent the spread of fire and/or smoke. Dampers are provided to maintain a fire resistance rating of the assembly being penetrated.

detector – An initiation device that automatically detects a change in state, such as presence of smoke, high temperature, or abnormal rate of temperature rise.

fire alarm system – A system, automatic or manual, arranged to give a signal indicating a fire emergency and initiate the appropriate response.

fire resistance rating – The time in hours that materials or their assemblies will withstand fire exposure as determined by a fire test.

fireproofing – Materials or assemblies used to provide a fire resistance rating to a building component.

firestop – A solid or compact, tight closure to retard the spread of flames or hot gases within concealed spaces.

initiation device – A system component that originates a change-in-state signal in the fire alarm system. An initiation device begins the life safety processes, such as evacuation; heating, ventilating, and air conditioning shut down; elevator recall, etc.

manual fire alarm box – A manually operated initiation device that originates a change-in-state signal in the fire alarm system.

means of egress – A continuous and unobstructed path of vertical and horizontal travel from any point in a building to a public way. The means of egress consist of the exit access, the exit, and the exit discharge.

noncombustible – A material that, in the form in which it is used in construction, will not ignite and burn when subjected to fire. However, any material which liberates flammable gas when heated to any temperature up to 1,380 ºF for 5 min shall not be considered noncombustible.

notification appliance – A fire alarm system component such as a bell, horn, speaker, or strobe that provides audible, tactile, or visible outputs, or any combination thereof.

passive fire protection – Fire protection features that are incorporated into the building construction or building materials that do not rely on active fire protection methods to limit fire ignition, fire growth, or material failure. Fire separations and divisions, sprayed-on fire proofing, and enclosing structural members with noncombustible materials are examples of passive fire protection.

smoke and heat venting – A process used to move products of combustion to the outdoor air.

PREFACE

Genesis of This Investigation

Immediately following the terrorist attack on the World Trade Center (WTC) on September 11, 2001, the Federal Emergency Management Agency (FEMA) and the American Society of Civil Engineers began planning a building performance study of the disaster. The week of October 7, as soon as the rescue and search efforts ceased, the Building Performance Study Team went to the site and began its assessment. This was to be a brief effort, as the study team consisted of experts who largely volunteered their time away from their other professional commitments. The Building Performance Study Team issued its report in May 2002, fulfilling its goal "to determine probable failure mechanisms and to identify areas of future investigation that could lead to practical measures for improving the damage resistance of buildings against such unforeseen events."

On August 21, 2002, with funding from the U.S. Congress through FEMA, the National Institute of Standards and Technology (NIST) announced its building and fire safety investigation of the WTC disaster. On October 1, 2002, the National Construction Safety Team Act (Public Law 107-231), was signed into law. The NIST WTC Investigation was conducted under the authority of the National Construction Safety Team Act.

The goals of the investigation of the WTC disaster were:

- To investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster.
- To serve as the basis for:
  - Improvements in the way buildings are designed, constructed, maintained, and used;
  - Improved tools and guidance for industry and safety officials;
  - Recommended revisions to current codes, standards, and practices; and
  - Improved public safety.

The specific objectives were:

1. Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft and why and how WTC 7 collapsed;
2. Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response;
3. Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1, 2, and 7; and
4. Identify, as specifically as possible, areas in current building and fire codes, standards, and practices that warrant revision.

NIST is a nonregulatory agency of the U.S. Department of Commerce's Technology Administration. The purpose of NIST investigations is to improve the safety and structural integrity of buildings in the United States, and the focus is on fact finding. NIST investigative teams are authorized to assess building performance and emergency response and evacuation procedures in the wake of any building failure that has resulted in substantial loss of life or that posed significant potential of substantial loss of life. NIST does not have the statutory authority to make findings of fault nor negligence by individuals or organizations. Further, no part of any report resulting from a NIST investigation into a building failure or from an investigation under the National Construction Safety Team Act may be used in any suit or action for damages arising out of any matter mentioned in such report (15 USC 281a, as amended by Public Law 107-231).

Organization of the Investigation

The National Construction Safety Team for this Investigation, appointed by the then NIST Director, Dr. Arden L. Bement, Jr., was led by Dr. S. Shyam Sunder. Dr. William L. Grosshandler served as Associate Lead Investigator, Mr. Stephen A. Cauffman served as Program Manager for Administration, and Mr. Harold E. Nelson served on the team as a private sector expert. The Investigation included eight interdependent projects whose leaders comprised the remainder of the team. A detailed description of each of these eight projects is available at http://wtc.nist.gov. The purpose of each project is summarized in Table P–1, and the key interdependencies among the projects are illustrated in Fig. P–1.

Table P–1. Federal building and fire safety investigation of the WTC disaster.

Technical Area and Project Leader	Project Purpose
Analysis of Building and Fire Codes and Practices; Project Leaders: Dr. H. S. Lew and Mr. Richard W. Bukowski	Document and analyze the code provisions, procedures, and practices used in the design, construction, operation, and maintenance of the structural, passive fire protection, and emergency access and evacuation systems of WTC 1, 2, and 7.
Baseline Structural Performance and Aircraft Impact Damage Analysis; Project Leader: Dr. Fahim H. Sadek	Analyze the baseline performance of WTC 1 and WTC 2 under design, service, and abnormal loads, and aircraft impact damage on the structural, fire protection, and egress systems.
Mechanical and Metallurgical Analysis of Structural Steel; Project Leader: Dr. Frank W. Gayle	Determine and analyze the mechanical and metallurgical properties and quality of steel, weldments, and connections from steel recovered from WTC 1, 2, and 7.
Investigation of Active Fire Protection Systems; Project Leader: Dr. David D. Evans; Dr. William Grosshandler	Investigate the performance of the active fire protection systems in WTC 1, 2, and 7 and their role in fire control, emergency response, and fate of occupants and responders.
Reconstruction of Thermal and Tenability Environment; Project Leader: Dr. Richard G. Gann	Reconstruct the time-evolving temperature, thermal environment, and smoke movement in WTC 1, 2, and 7 for use in evaluating the structural performance of the buildings and behavior and fate of occupants and responders.
Structural Fire Response and Collapse Analysis; Project Leaders: Dr. John L. Gross and Dr. Therese P. McAllister	Analyze the response of the WTC towers to fires with and without aircraft damage, the response of WTC 7 in fires, the performance of composite steel-trussed floor systems, and determine the most probable structural collapse sequence for WTC 1, 2, and 7.
Occupant Behavior, Egress, and Emergency Communications; Project Leader: Mr. Jason D. Averill	Analyze the behavior and fate of occupants and responders, both those who survived and those who did not, and the performance of the evacuation system.
Emergency Response Technologies and Guidelines; Project Leader: Mr. J. Randall Lawson	Document the activities of the emergency responders from the time of the terrorist attacks on WTC 1 and WTC 2 until the collapse of WTC 7, including practices followed and technologies used.

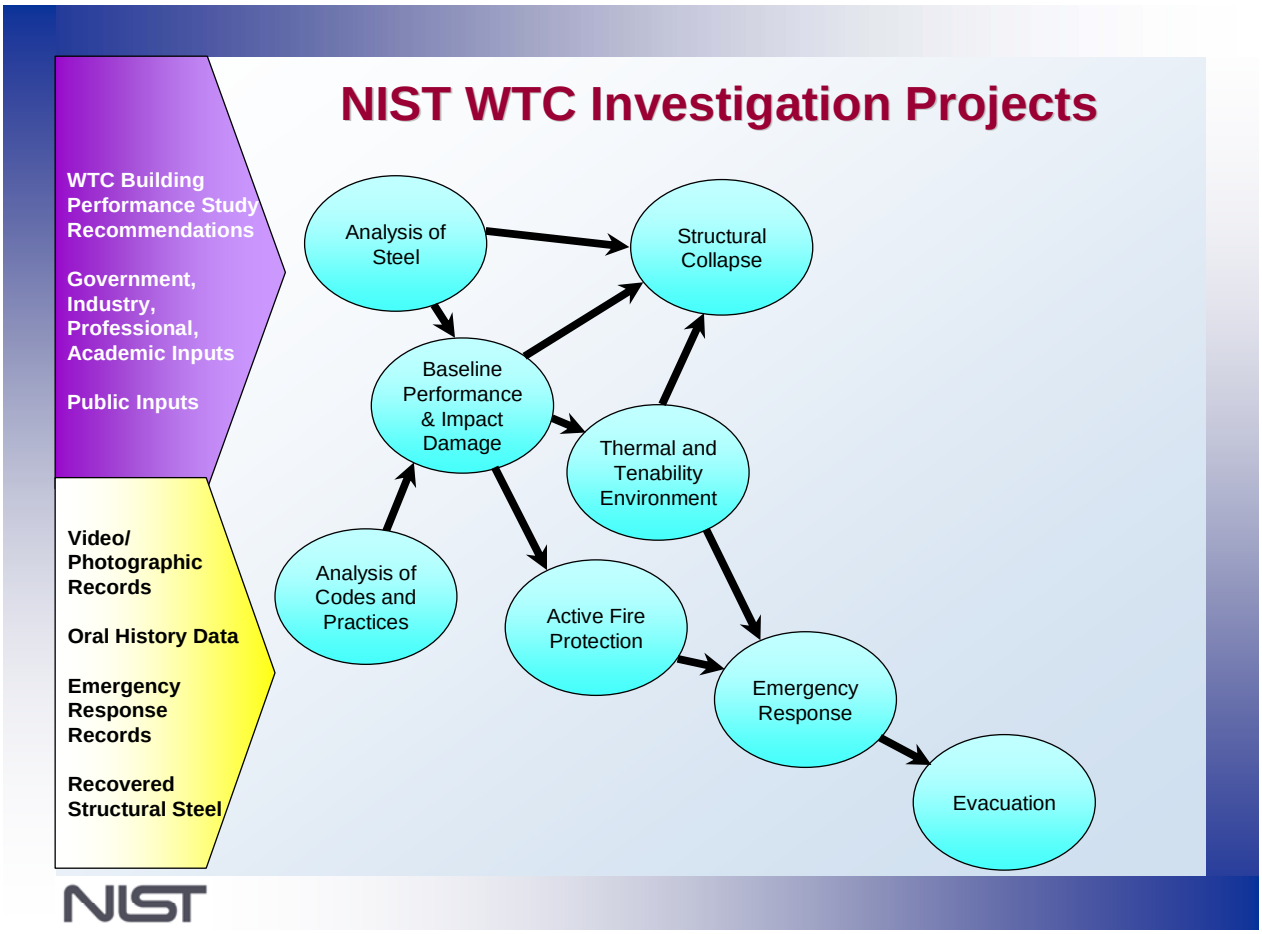

Figure P–1. The eight projects in the federal building and fire safety investigation of the WTC disaster.

National Construction Safety Team Advisory Committee

The NIST Director also established an advisory committee as mandated under the National Construction Safety Team Act. The initial members of the committee were appointed following a public solicitation. These were:

- Paul Fitzgerald, Executive Vice President (retired) FM Global, National Construction Safety Team Advisory Committee Chair
- John Barsom, President, Barsom Consulting, Ltd.
- John Bryan, Professor Emeritus, University of Maryland
- David Collins, President, The Preview Group, Inc.
- Glenn Corbett, Professor, John Jay College of Criminal Justice
- Philip DiNenno, President, Hughes Associates, Inc.

- Robert Hanson, Professor Emeritus, University of Michigan
- Charles Thornton, Co-Chairman and Managing Principal, The Thornton-Tomasetti Group, Inc.
- Kathleen Tierney, Director, Natural Hazards Research and Applications Information Center, University of Colorado at Boulder
- Forman Williams, Director, Center for Energy Research, University of California at San Diego

This National Construction Safety Team Advisory Committee provided technical advice during the Investigation and commentary on drafts of the Investigation reports prior to their public release. NIST has benefited from the work of many people in the preparation of these reports, including the National Construction Safety Team Advisory Committee. The content of the reports and recommendations, however, are solely the responsibility of NIST.

Public Outreach

During the course of this Investigation, NIST held public briefings and meetings (listed in Table P–2) to solicit input from the public, present preliminary findings, and obtain comments on the direction and progress of the Investigation from the public and the Advisory Committee.

NIST maintained a publicly accessible Web site during this Investigation at http://wtc.nist.gov. The site contained extensive information on the background and progress of the Investigation.

NIST's WTC Public-Private Response Plan

The collapse of the WTC buildings has led to broad reexamination of how tall buildings are designed, constructed, maintained, and used, especially with regard to major events such as fires, natural disasters, and terrorist attacks. Reflecting the enhanced interest in effecting necessary change, NIST, with support from Congress and the Administration, has put in place a program, the goal of which is to develop and implement the standards, technology, and practices needed for cost-effective improvements to the safety and security of buildings and building occupants, including evacuation, emergency response procedures, and threat mitigation.

The strategy to meet this goal is a three-part NIST-led public-private response program that includes:

- A federal building and fire safety investigation to study the most probable factors that contributed to post-aircraft impact collapse of the WTC towers and the 47-story WTC 7 building, and the associated evacuation and emergency response experience.
- A research and development (R&D) program to (a) facilitate the implementation of recommendations resulting from the WTC Investigation, and (b) provide the technical basis for cost-effective improvements to national building and fire codes, standards, and practices that enhance the safety of buildings, their occupants, and emergency responders.

Table P–2. Public meetings and briefings of the WTC Investigation.

Date	Location	Principal Agenda
June 24, 2002	New York City, NY	Public meeting: Public comments on the *Draft Plan* for the pending WTC Investigation.
August 21, 2002	Gaithersburg, MD	Media briefing announcing the formal start of the Investigation.
December 9, 2002	Washington, DC	Media briefing on release of the *Public Update* and NIST request for photographs and videos.
April 8, 2003	New York City, NY	Joint public forum with Columbia University on first-person interviews.
April 29–30, 2003	Gaithersburg, MD	NCST Advisory Committee meeting on plan for and progress on WTC Investigation with a public comment session.
May 7, 2003	New York City, NY	Media briefing on release of *May 2003 Progress Report.*
August 26–27, 2003	Gaithersburg, MD	NCST Advisory Committee meeting on status of the WTC investigation with a public comment session.
September 17, 2003	New York City, NY	Media and public briefing on initiation of first-person data collection projects.
December 2–3, 2003	Gaithersburg, MD	NCST Advisory Committee meeting on status and initial results and release of the *Public Update* with a public comment session.
February 12, 2004	New York City, NY	Public meeting on progress and preliminary findings with public comments on issues to be considered in formulating final recommendations.
June 18, 2004	New York City, NY	Media/public briefing on release of *June 2004 Progress Report.*
June 22–23, 2004	Gaithersburg, MD	NCST Advisory Committee meeting on the status of and preliminary findings from the WTC Investigation with a public comment session.
August 24, 2004	Northbrook, IL	Public viewing of standard fire resistance test of WTC floor system at Underwriters Laboratories, Inc.
October 19–20, 2004	Gaithersburg, MD	NCST Advisory Committee meeting on status and near complete set of preliminary findings with a public comment session.
November 22, 2004	Gaithersburg, MD	NCST Advisory Committee discussion on draft annual report to Congress, a public comment session, and a closed session to discuss pre-draft recommendations for WTC Investigation.
April 5, 2005	New York City, NY	Media and public briefing on release of the probable collapse sequence for the WTC towers and draft reports for the projects on codes and practices, evacuation, and emergency response.
June 23, 2005	New York City, NY	Media and public briefing on release of all draft reports for the WTC towers and draft recommendations for public comment.
September 12–13, 2005	Gaithersburg, MD	NCST Advisory Committee meeting on disposition of public comments and update to draft reports for the WTC towers.
September 13–15, 2005	Gaithersburg, MD	WTC Technical Conference for stakeholders and technical community for dissemination of findings and recommendations and opportunity for public to make technical comments.

- A dissemination and technical assistance program (DTAP) to (a) engage leaders of the construction and building community in ensuring timely adoption and widespread use of proposed changes to practices, standards, and codes resulting from the WTC Investigation and the R&D program, and (b) provide practical guidance and tools to better prepare facility owners, contractors, architects, engineers, emergency responders, and regulatory authorities to respond to future disasters.

The desired outcomes are to make buildings, occupants, and first responders safer in future disaster events.

National Construction Safety Team Reports on the WTC Investigation

A final report on the collapse of the WTC towers is being issued as NIST NCSTAR 1. A companion report on the collapse of WTC 7 is being issued as NIST NCSTAR 1A. The present report is one of a set that provides more detailed documentation of the Investigation findings and the means by which these technical results were achieved. As such, it is part of the archival record of this Investigation. The titles of the full set of Investigation publications are:

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EXECUTIVE SUMMARY

The purpose of this report is to identify the repairs and/or modifications made to the fire protection, life safety, and structural framing systems of World Trade Center (WTC) 7 from initial occupancy to September 11, 2001. Documentation for more than 120 tenant alterations to WTC 7 was located and reviewed. Fire protection, life safety, and structural framing systems for these alterations are summarized in this report.

The fire protection and life safety systems were modified to accommodate new tenant layouts. As walls were removed, added, and relocated, the requirements for the fire protection and life safety systems changed. As wall layouts were modified, fire sprinkler and fire alarm devices were relocated. Fire and smoke dampers were installed as required by the Building Code of the City of New York (BCNYC). Life safety requirements of the BCNYC, such as travel distance requirements, were analyzed. A list is provided of the tenant alterations that modified the fire protection and life safety systems.

Most of the structural modifications were done to accommodate tenant requirements. Horizontal members of the floor framing system were strengthened due to increased loading from high-density files. Strengthening of these beams and girders was achieved by welding cover plates to the bottom flanges, the underside of the top flanges, or both. In some cases, new beams were introduced to carry a portion of the new load.

Floor slabs were completely removed on the east side of the building to accommodate trading floors for Salomon Brothers, Inc., but were subsequently replaced when the trading floors were moved to another location. Columns in this area, which had twice the unsupported length after the slab removal, were reinforced. Other openings were cut into a few floor levels to accommodate new stairways connecting adjoining floors.

Web openings were cut through some beams and girders to allow passage of ductility work. In some cases, the beams or girders had to be reinforced in order to increase capacity.

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Chapter 1
INTRODUCTION

Over the life of World Trade Center (WTC) 7, enhancements to the fire protection, life safety, and structural framing systems were made. Tenant alterations, fires, revised building code provisions, and new technology all were the reasons for the enhancements of the systems. Changes made to these systems ultimately affected the building performance. Thus, in order to analyze the performance of WTC 7 in response to the attacks of September 11, 2001, it is crucial to have the most current configuration of the systems installed. The purpose of this report is to identify the repairs and/or modifications made to the fire protection, life safety, and structural framing systems of WTC 7 from initial occupancy to September 11, 2001.

1.1 FIRE PROTECTION AND LIFE SAFETY

Tenant alteration projects included modifications of the fire protection and life safety systems within WTC 7. Tenant spaces were modified to accommodate new floor layouts as tenants moved in and out. New wall layouts, changed occupancy use, and mission continuity objectives in tenant spaces introduced different code requirements.

Tenant alterations performed in WTC 7 included typical business occupancy modifications to the fire protection and life safety systems. A typical office alteration included rearranging walls to accommodate the desired layout of the tenant while maintaining proper fire separations and divisions from other tenants within the building. Fire and smoke dampers were installed in the heating, ventilating, and air conditioning systems where penetrations of fire rated walls occurred. The base building wet pipe sprinkler system was modified by the addition and/or relocation of sprinkler heads and branchlines in the tenant space as called for in National Fire Protection Association (NFPA) 13 and the Building Code of the City of New York (BCNYC) requirements for minimum spacing from these walls. Hydraulic calculations were performed to justify the pipe sizes of the branch lines as necessary. Documentation indicates that calculations were conducted back to the floor control valve assembly of each floor where system pressures were previously known. Fire alarm and voice communication systems were installed in accordance with NFPA 72 and the BCNYC requirements within each tenant space, again to maintain minimum spacing from relocated walls. Although documentation does not exist for each project, an egress analysis was generally performed to verify that travel distances and other means of egress requirements in the BCNYC were not exceeded. Providing exit and emergency lighting within the tenant space, which was required by the BCNYC, was also included in the tenant alteration project. The system modifications were submitted to the Port Authority of New York and New Jersey (PANYNJ or Port Authority) for approval or were approved using the self-certification process established by the PANYNJ. Tenant Construction Review Manuals, provided by the PANYNJ Engineering Department, were used for establishing minimum design criteria and design details.

Whenever work was done in the WTC buildings, a project number was assigned by the Port Authority under which all contracts, drawings, and correspondence was filed. These numbers are typically of the format W(yy)-1234 (where yy is the year initiated and 1234 is a four-digit number). This report includes

these numbers as references to individual projects, and files retained by the Port Authority are identified by these numbers.

1.2 STRUCTURAL FRAMING

Most of the structural modifications were done to accommodate tenant requirements. These generally involved strengthening the horizontal members of the floor framing system due to increased loading from high-density files (see Table 3–1 in Chapter 3). Strengthening of the beams and girders was achieved by welding cover plates to the bottom flanges and/or to the underside of the top flanges. In some cases, deficiencies were remedied by introducing a new beam between existing beams to reduce the tributary load on the deficient beams. In other cases, wide-flange T-sections were welded directly to the underside of deficient girders.

Floor slabs were completely removed on the east side of the building to accommodate the trading floors for Salomon Brothers, Inc., but were subsequently replaced when the trading floors were moved to another location (Cantor 1989). The only framing members that remained on these floors from the original design were the columns and the girders that were part of the lateral-force-resisting system. The columns, which had twice the unsupported length after the slab removal, were reinforced in this area. Other openings were cut into a few floors to accommodate new stairways connecting adjoining floors. New framing members were introduced where needed.

Web openings were cut through some beams and girders to allow passage of utility ductwork. These openings were typically reinforced with plates. In some cases, an inverted T-section was welded to the bottom flange of the existing beam to increase the capacity of the beam in the area of the opening. Shallow notches were cut in the top and bottom flanges of some of the beams to accommodate ductwork. To make up for lost capacity, plates were introduced just under the top flanges and just above the bottom flanges.

Other minor modifications were made, including the installation of supports for folding partitions.

The remainder of this report identifies the specific major modifications and repairs that were made to the fire protection, life safety, and structural framing systems of WTC 7.

1.3 REFERENCES

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Chapter 2
MODIFICATIONS TO FIRE PROTECTION AND LIFE SAFETY SYSTEMS

The fire protection and life safety modifications of World Trade Center (WTC) 7 are listed in Table 2–1. Most of the tenant alterations followed the typical business occupancy modification summary previously identified in Chapter 1 of this report. Tenant alterations with additional modifications or modifications that varied from the typical modification summary of Chapter 1 are noted in the last column of Table 2–1. The year and floor location of the alteration are also given to provide a history of the floor or portion thereof. Tenant alteration documentation was not located for all floors, and thus, not every floor is identified in Table 2–1.

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems.

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W98-1734	1	Core	1998	Office of Emergency Management	Typical, including Inergen system for fuel tanks
W-7005	2, 4	Northeast	1989	Salomon Brothers, Inc.	Typical
W00-7108	3	Core	2000	Salomon Smith Barney	Typical
W-8006	3	Southeast	1990	Tobacco Shop	Typical
W95-7140	3	Northeast	1995	Salomon Brothers, Inc.	Typical
W98-7195	3	Lobby	1998	WTC 7	Egress analysis
W00-7004	4, 29–37, 39–44, 47	Various	2002	Salomon Smith Barney	Various modifications, mostly utilities and structural but includes new halon system (34th floor)
W95-7109	7	Entire	1995	American Express Bank	Typical
W98-1734	7	South	1998	Office of Emergency Management	Removal of sprinklers from generator room
W98-7230	7	Core	1999	Silverstein Properties	Typical
W99-7175	7	Northeast	1999	American Express	Typical

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems (continued).

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W93-7233	7, 8	Entire	1994	American Express	Typical
W01-7131	7, 8, 13	Northwest	2001	Unknown	Typical
W00-7143	8	Northwest	2000	American Express	Typical
W94-7187	8	West	1995	American Express Bank Check Processing Department	Typical
W94-7176.02	9, 10	Entire	1994	Ambassador Construction Project	Typical
W-8005	10–12	Various	1990	Spicer and Oppenheimer	Typical
W92-7056	11, 12	Entire	1992	Securities Exchange Commission	Typical
W00-7185	13	Southeast	2000	Standard Chartered	Typical
W92-7056	13	North	1992	Securities Exchange Commission	Typical
W97-7202	13	Northeast	1997	Salomon Brothers, Inc.	Typical
W99-7137	13	Northeast	1999	Standard Chartered	Typical
W96-7183, W97-7150	14–16	Various	1996, 1997	Insurance Services Office	Typical
W-8004, W-8013, W95-7110	14–17	Entire	1990, 1993, 1995	Insurance Services Office	Typical
W-7002	15	Southeast	1988	Cameron and Colby	Typical
W-8004	18	Southwest	1990	Insurance Services Office	Typical
W-8009	18	Core	1991	Silverstein	Typical
W92-7150	18	Northeast	1992	Equal Employment Opportunity Commission	Typical

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems (continued).

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W96-7189	18	South	1996	Insurance Services Office	Typical
W98-7203	18	West	1998	ISO 2	Typical
W-8010	19	East	1991	Hartford Insurance Group	Typical
W96-7118	19	West	1996	National Association of Insurance Commissioners	Typical
W97-7101	19	North	1997	ITT Hartford	Typical
W95-7153	20	Entire	1995	Hartford Insurance Group	Typical
W-8010	20, 21	Entire	1991	Hartford Insurance Group	Typical
W95-7179, W95-7205	21	East	1995, 1995	ITT Hartford	Typical
W96-7150	21	Southwest	1996	ITT Hartford	Typical
W97-7129	21	West	1997	Salomon Brothers, Inc.	Typical
W97-7135	21	Core	1997	ITT Hartford	Typical
W94-7107	22	Entire	1994	Federal Home Bank of New York	Typical, including new pre-action system
W98-7109	22	Southwest	1998	Federal Home Loan Bank of New York	Typical
W98-1734	23	Entire	1998	Office of Emergency Management	Typical, including new pre-action system
W-8003	24, 25	Entire	1989	Department of Treasury – IRS	Typical
W95-7163	26, 27	Entire	1995	Standard Chartered	Typical
W93-7160, W93-7138, W93-7246	28	Entire	1993	Salomon Brothers, Inc.	Typical
W94-7180	28	Northeast	1994	Salomon Brothers, Inc.	Typical

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems (continued).

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W96-7185	28	Various	1996	Salomon Brothers, Inc.	Typical
W97-7173, W97-7186	28	Various	1997, 1997	Salomon Brothers, Inc.	Typical
W99-7168	28–32, 34	Core	1999	Salomon Smith Barney	Typical
W00-7194	29	Southeast	2000	Hartford Insurance	Typical
W93-7148	29	Entire	1993	Salomon Brothers, Inc.	Typical
W97-7172	29	East	1997	Salomon Brothers, Inc.	Typical
W00-7122	30	Core	2000	Salomon Smith Barney	Typical, including new pre-action system
W94-7141	30	East	1994	Salomon Brothers, Inc.	Typical
W94-7207	30	East	1994	Salomon Brothers, Inc.	Typical
W97-7132	30	Southeast	1997	Salomon Brothers, Inc.	Typical
W97-7152	30	Southeast	1997	Department of Defense	Typical
W00-7127	31	Core	2000	Salomon Smith Barney	Typical, including new pre-action system
W00-7128	32	Core	2000	Salomon Smith Barney	Typical, including new pre-action system
W00-7225	32	Entire	2000	Salomon Smith Barney	Typical
W93-7155	33	Southwest	1993	Salomon Brothers, Inc.	Typical
W93-7212	33	South	1994	Salomon Brothers, Inc.	Typical
W99-7160	33	Southwest & Core	1999	Salomon Smith Barney	Typical
W99-7161	33	Core	1999	Salomon Smith Barney	Typical, including new pre-action systems

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems (continued).

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W93-7137, W93-7157, W93-7207, W93-7237, W94-7134, W94-7230	34	Entire	1993, 1993, 1993, 1993, 1994, 1994	Salomon Brothers, Inc.	Typical
W97-7119	34	South	1997	Salomon Brothers, Inc.	Typical
W93-7151	35	Southeast	1993	Salomon Brothers, Inc.	Typical
W93-7231	35	Southeast	1994	Salomon Brothers, Inc.	Typical
W94-7195	35	Southwest	1994	Salomon Brothers, Inc.	Typical
W-7005	35,44	Entire	1989	Salomon Brothers, Inc.	Typical, including egress analysis for assembly space
W00-7139	36	East	2000	Salomon Smith Barney	Typical
W96-7196	36	Various	1996	Salomon Brothers, Inc.	Typical
W99-7122	36	Northeast	1999	Salomon Smith Barney	Typical
W99-7144	36, 39	Core	1999	Salomon Smith Barney	Typical, including new pre-action systems
W99-7148	36–43	Core	1999	Salomon Smith Barney	Typical, including new pre-action systems
W00-7188	37	Entire	2000	Salomon Smith Barney	Typical
W99-7134	37	Entire	1999	Salomon Smith Barney	Typical
W00-7224	38	Northeast	2000	Salomon Smith Barney	Typical
W94-7102	38	Entire	1994	Salomon Brothers, Inc.	Typical
W96-7179	38	North	1996	Salomon Brothers, Inc.	Typical
W97-7167	38	Northeast	1997	Salomon Brothers, Inc.	Typical

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems (continued).

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W00-7202	39	Entire	2000	Salomon Smith Barney	Typical
W93-7102	39	Entire	1993	Salomon Brothers, Inc.	Typical, includes egress analysis for auditorium
W95-7173	39	Core	1995	Salomon Brothers, Inc.	Typical
W96-7120	39	Northeast	1996	Salomon Brothers, Inc.	Typical
W97-7138	39	Northeast	1997	Salomon Brothers Inc.	Typical
W99-7119	39	Northeast	1999	Salomon Smith Barney	Typical
W99-7127	39–46	East	1999	Salomon Smith Barney	Typical
W99-7172	40	Entire	1999	Salomon Smith Barney	Typical
W93-7118	41	Northwest	1993	Salomon Brothers, Inc.	Typical
W96-7140	41	West	1996	Salomon Brothers, Inc.	Typical
W97-7142	41	Core	1997	Salomon Brothers, Inc.	Typical
W97-7153	41	North	1997	Salomon Brothers, Inc.	Typical
W99-7177	41	Entire	1999	Salomon Smith Barney	Typical
W99-7178	42	Entire	1999	Salomon Smith Barney	Typical
W99-7178	42	Entire	1999	Salomon Smith Barney	Typical
W00-7111	43	Entire	2000	Salomon Smith Barney	Typical, including new pre-action system
W01-7111	44	Entire	2001	Salomon Smith Barney	Typical, including new pre-action systems
W95-7195	45	North	1995	Salomon Brothers, Inc.	Typical

Table 2–1. Summary of modifications to WTC 7 fire protection and life safety systems (continued).

TAA No.	Floor(s)	Location on Floor	Year	Tenant	Systems Modified
W99-7120	45	West	1999	Salomon Smith Barney	Typical
W99-7194	45	East	1999	Salomon Smith Barney	Typical
W93-7167, W93-7168	46	Entire	1993, 1993	Salomon Brothers, Inc.	Typical
W97-7196	46	South	1997	Salomon Brothers, Inc.	Typical
W00-7203	47	Northeast	2000	Salomon Smith Barney	Typical
W93-7221	47	Northeast	1994	Salomon Brothers, Inc.	Typical
W97-7140	47	East	1997	Salomon Brothers, Inc.	Typical
W00-7202	39	Entire	2000	Salomon Smith Barney	Typical
W93-7102	39	Entire	1993	Salomon Brothers, Inc.	Typical, includes egress analysis for auditorium
W95-7173	39	Core	1995	Salomon Brothers, Inc.	Typical

Key: TAA, Tenant Alteration Application.

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Chapter 3
STRUCTURAL MODIFICATIONS DUE TO TENANT ALTERATIONS

Structural modifications due to tenant alterations are listed in Table 3–1. Included is a brief description of the work that was performed with respect to the modifications. In most cases, members were reinforced to accommodate floor loads that were greater than the loads for which these members were originally designed.

In all of the cases cited in Table 3–1, structural calculations were included on the check of the existing structural members and on the design of new structural members. In the documents related to the 1988 modifications, there were comments made by the Tenant Construction Review Unit of the Port Authority of New York and New Jersey (PANYNJ or Port Authority) in regard to the project submittal. Also included were responses from the structural engineer to the Port Authority on these comments. Similar documents are available for the modifications made in 1999 on the 40th floor, which include a copy of the Tenant Construction or Alteration Application that was submitted to the Port Authority on behalf of the tenant.

Table 3–1. Modifications made due to tenant alterations.

Date	Floor(s)	Tenant	Structural Engineer	Description of Modification	Reference Work Order Number
1988	38	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Bottom and top cover plates were added to the existing W24x55 beams along column lines 37 and 40, and bottom cover plates were added to the existing W24x55 beams along column lines 30 and 35 to support new hanger loads.	W-7004 PANYNJ (Newark)
1989	24	General Auditing Office	Office of Irwin G. Cantor	Bottom cover plates were added to the existing W21x44 beam on column line 45 and the two adjacent W21x44 beams to the west of column line 45 to support additional load due to new file storage. The existing W36x135 girder framing between columns 76 and 79, which supported these beams, was also reinforced with a bottom cover plate.	W-8003 PANYNJ (Newark)

Table 3–1. Modifications made due to tenant alterations (continued).

Date	Floor(s)	Tenant	Structural Engineer	Description of Modification	Reference Work Order Number
1989	47	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Bottom cover plates were added to the existing W16x31 beam along column line 2, the W16x26 beam along column line 3, and the W14x22 beams along column lines 4 and 5 to support additional mechanical equipment. The W33x130 girder on column line 56, which supported these beams, was reinforced with bottom and top cover plates.	W-7004 PANYNJ (Newark)
1990	11, 12	Spicer & Oppenheimer	Office of Irwin G. Cantor	Bottom cover plates were added to eight existing beams and girders in the northwest corner of the building on the 11th floor to support larger live loads. Similarly, bottom cover plates were added to three existing beams between column lines 48 and 49 and the girder between columns 70 and 73 on the 12th floor.	W-8005 PANYNJ (Newark)
1991	19	ITT Hartford	Office of James Ruderman	Bottom cover plates were added to existing W24x55 and W24x76 beams to support new files and shelves. Exact location of these beams could not be determined from the documentation.	W-8010 PANYNJ (Newark)
1992	12	Securities Exchange Commission	Office of Irwin G. Cantor	Bottom cover plates were added to eleven existing beams in the northwest corner of the building to support legal files. A new W12x19 beam was also added between two of the existing beams.	W92-7056 PANYNJ (Newark)
1992	18, 19	Equal Employment Opportunity Commission	Office of Irwin G. Cantor	Bottom cover plates were added to existing W24 beams on the 18th floor on column lines 31, 32, and 33 to support larger live loads.	W92-7150
1993	28	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Eight additional shear studs were added to an existing W16x26 beam located in the mechanical/electrical room to support new equipment loads.	W93-7138 PANYNJ (Newark)
1993	7, 8	American Express Bank	Office of James Ruderman	A new W12x14 beam located on the west side of the building between column lines 7 and 8 was added on the 8th floor to support a new concrete masonry unit wall.	W93-7233 PANYNJ (Newark)

Table 3–1. Modifications made due to tenant alterations (continued).

Date	Floor(s)	Tenant	Structural Engineer	Description of Modification	Reference Work Order Number
1994	7–29	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Bottom cover plates were added to 22 existing beams between columns 5 and 25 on the south side of the building on each floor between levels 7 and 29 to support larger live loads. Similarly, bottom cover plates were added to eight beams on the east side of the building between column lines 31 and 37 on each of these floors.	W93-7232
1995	20	ITT Hartford	The Cantor Seinuk Group	Bottom cover plates were added to the existing W16x26 beams along column lines 23 and 25 to support new filing cabinets. Similarly, WT sections were welded to the bottom of the existing W16x26 beams that framed in between the above-mentioned beams. WT sections were welded to the bottom of the existing W16x26 beam east of column line 18 and the W16x26 beam on column line 19 to support new filing cabinets. Similarly, a bottom cover plate was added to the existing W16x26 beam east of column line 19.	W95-7153
1999	37	Salomon Smith Barney	Gilsanz Murray Steficek	A new W16x40 beam was added between two existing W14x22 beams along column lines 76 and 77 to support a new high-density filing system.	W99-7134 PANYNJ (Newark)
1999	13	The Standard Chartered Bank	The Cantor Seinuk Group	Ten additional shear studs were added to an existing W24x55 beam to support additional loads from a new file room and a new UPS/LAN room. Exact location of this beam could not be determined from the documentation.	W99-7137-02 PANYNJ (Newark)
1999	40	Salomon Smith Barney	Gilsanz Murray Steficek	Four new W18x35 beams were added to support the new high-density files near column 76. WT4x20 sections were welded to the bottom of two existing W14x22 beams that supported the files. New W16x50 beams were connected below to the existing W36x135 girders that supported the beams in this area.	W99-7172 PANYNJ (Newark)

Table 3–1. Modifications made due to tenant alterations (continued).

Date	Floor(s)	Tenant	Structural Engineer	Description of Modification	Reference Work Order Number
2000	31	Salomon Smith Barney	Gilsanz Murray Steficek	Top and bottom cover plates were added to an existing W27x94 beam between columns 77 and 80 to support a new high-density filing system. The existing beam connections were also reinforced with stiffened seat connections.	W00-7122 PANYNJ (Newark)
2000	38	Salomon Smith Barney	Gilsanz Murray Steficek	Bottom cover plates were added to existing W14x22 beams between columns 76 and 77 and between columns 77 and 78 to support a new high-density filing system. Also, the following existing girders were reinforced with bottom cover plates: (1) W36x135 between columns 76 and 79, (2) W27x94 between columns 77 and 80, and (3) W27x84 between columns 78 and 81.	W00-7224 PANYNJ (Newark)
2000	39	Salomon Smith Barney	Gilsanz Murray Steficek	New W14x53 beams were added under each rail of a new high-density filing system in lieu of reinforcing existing W14x22 beams between columns 76 and 77.	W00-7202 PANYNJ (Newark)

Key: WT, wide-flange T-sections.

Chapter 4
OPENINGS MADE IN FLOOR SLABS

4.1 DESCRIPTION OF THE MODIFICATIONS

According to the Base Building modifications (Cantor 1989) for World Trade Center 7, columns 76, 78, 79, 80, and 81 were reinforced with plates that ran from the top of the 39th floor to the underside of the 40th floor due to the removal of the floor slab at the 39th floor. Similarly, column 74 was reinforced with plates that ran from the top of the 43rd floor to the underside of the 44th floor due to the removal of the floor slab at the 43rd floor. These slabs were removed to accommodate the trading floors for Salomon Brothers, Inc. Furthermore, it is stated in the *Facility Condition Survey Program* report (PANYNJ 1997), that the 41st and 43rd floor slabs were completely removed on the east side of the building to accommodate the trading floors for Salomon Brothers, Inc. Structural modifications involving openings made in the floor slabs are listed in Table 4–1. Included is a brief description of the work that was performed with respect to the modifications.

Table 4–1. Openings made in floor slabs.

Date	Floor(s)	Tenant	Structural Engineer	Description of Modification	Reference Work Order Number
1989	3, 4	Salomon Brothers, Inc.	Skidmore, Owings & Merrill	On the 3rd floor, openings were cut on the west, north, and east sides of the building. New framing was introduced around these openings. On the 4th floor, new openings and framing were introduced on the north side of the building.	W-7004 PANYNJ
1989	3	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Two 2 ft 6 in. by 3 ft 6 in. openings were cut near columns 24 and 25. New C8x11.5 framing members were added around the openings.	W-7005 PANYNJ (Newark)
1990	11	Spicer & Oppenheimer	Office of Irwin G. Cantor	A new stair opening was made between columns 77, 78, 80, and 81. New W12x16 beams were added around the opening.	W-8005 PANYNJ (Newark)
1994	43	Salomon Brothers, Inc.	Skidmore, Owings & Merrill	A new slab opening was made near column 71 in the core area. New beams were added around the opening.	W94-7746

Note: Structural calculations on the design of new structural members and on the check of the existing structural members were included for the modification made in 1989 (3rd floor) and 1990.

4.2 REFERENCES

Cantor (The Office of Irwin G. Cantor P.C.). 1989. "Salomon Brothers, Inc., Base Building Modifications – 7 World Trade Center Structural Computations." W-7004, Port Authority. Newark, January.

PANYNJ (The Port Authority of New York and New Jersey). 1997. *Port Authority Facility Condition Survey Program – 7 World Trade Center*. Engineering Quality Assurance Division, Engineering Department. April.

Chapter 5
MODIFICATIONS MADE TO BEAM WEBS AND FLANGES

Modifications made to beam webs and flanges are summarized in Table 5–1. Included is a brief description of the work that was performed with respect to the modifications.

Table 5–1. Modifications made to beam webs and flanges.

Date	Floor(s)	Tenant	Structural Engineer	Description of Modification	Reference Work Order Number
1993	28	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Two 1 in. by 36 in. openings, located 3 ft apart, were cut into the web of an existing W24x55 beam (unknown location). Plates were welded on each side of the web along the upper and lower edges of the openings.	W93-7138 PANYNJ (Newark)
1993	4–7, 16, 21, 29, 38, 45	Salomon Brothers, Inc.	Office of Irwin G. Cantor	Notches were cut in the bottom flanges of various beams on these floors to accommodate ductwork. Plates were welded to the upper side of the bottom flanges.	W93-7221
1998	1	Mayor's Office of Emergency Management	The Cantor Seinuk Group	A notch was cut into the top flange of an existing beam (unknown location). Two plates, one on each side of the web, were welded under the top flange.	W98-1734
1999	36–44	Salomon Smith Barney	The Cantor Seinuk Group	Two new openings (68 in. by 22 in. and 76 in. by 22 in.) spaced 3 ft 10 in. apart were cut into the web of the existing W24x62 beam framing into column 75. Horizontal and vertical stiffener plates were added on all sides of the openings. Also, a new WT15x74 section was welded to the bottom of the beam. The same size openings were made in an existing W27x94 beam on the 43rd floor, which was reinforced in a similar manner.	W99-7127 PANYNJ (Newark)
1999	42, 44	Salomon Smith Barney	Gensler	New web openings were cut in numerous beams along the north and east sides of the building.	W99-7127

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