Project No. 4
Analysis of Active Fire Alarm Systems in WTC 1 & 2

Robert J. Keough

Rolf Jensen & Associates

Raymond A. Grill, P.E., FSFPE

Arup Fire

NIST

Objectives

- **Document the design and installation of the fire alarm systems and compare them to applicable code and standard requirements.**
- **Document the normal operation of the fire alarm systems.**
- **Document modifications made to the fire alarm systems in WTC 1 and 2 following the 1993 bombing.**
- **Document the performance of the systems on September 11, 2001**

Summary of Scope

- **Task 1 – Document the Fire Alarm Design and Installation and compare the designs to the applicable codes and standards**
- **Task 2 – Document the normal expected operation and provisions for redundancy**
- **Task 3 – Document the modifications to the fire alarm system in WTC 1 & 2 after 1993**
- **Task 4 – Document the probable performance of the fire alarm system on September 11, 2001**

Summary of Scope

- The primary source of information was lost on 9/11 during the collapse.
- Extensive review of documentation at PA in New Jersey.
- Additional information was requested by following visits to the Port Authority facilities in NJ.
- Extensive review of documentation was performed at fire alarm manufacturer office in NJ.
- Extensive review of documentation performed at NIST.
- Interview of fire alarm project manager was performed in VA and at NIST.
- Reviewed information provided by NIST from witness interviews.

Summary of Scope

- Information used for this study originated from:
  - The Port Authority of New York and New Jersey
  - Silverstein Properties
  - City of New York
  - FEMA
  - Siemens
- Documents from the above list included the work of many other organizations.
- Documentation was reviewed and analyzed for factual information only.
- Judgment statements, opinions and findings/conclusions were omitted from our work.

Task 1 & 2 – Design, Installation, Operation, Redundancy and Code Compliance

- Provided a summary of the fire alarm system performance requirements.
- Documented the phased replacement of the pre-1993 fire alarm system.
- Documented the design criteria, equipment used, functions of the system, and installation architecture of the system.
- Documentation for WTC7 is very limited.

Fire Alarm History

- Fire alarm replaced after February 1993 bombing.
- Initial fire alarm purchase order signed on March 17, 1993.
- Fire alarm replacement separated into 4 projects:
  1. WTC1 and WTC2
  2. WTC4 and WTC5
  3. Concourse Level
  4. Sub-Grade Level

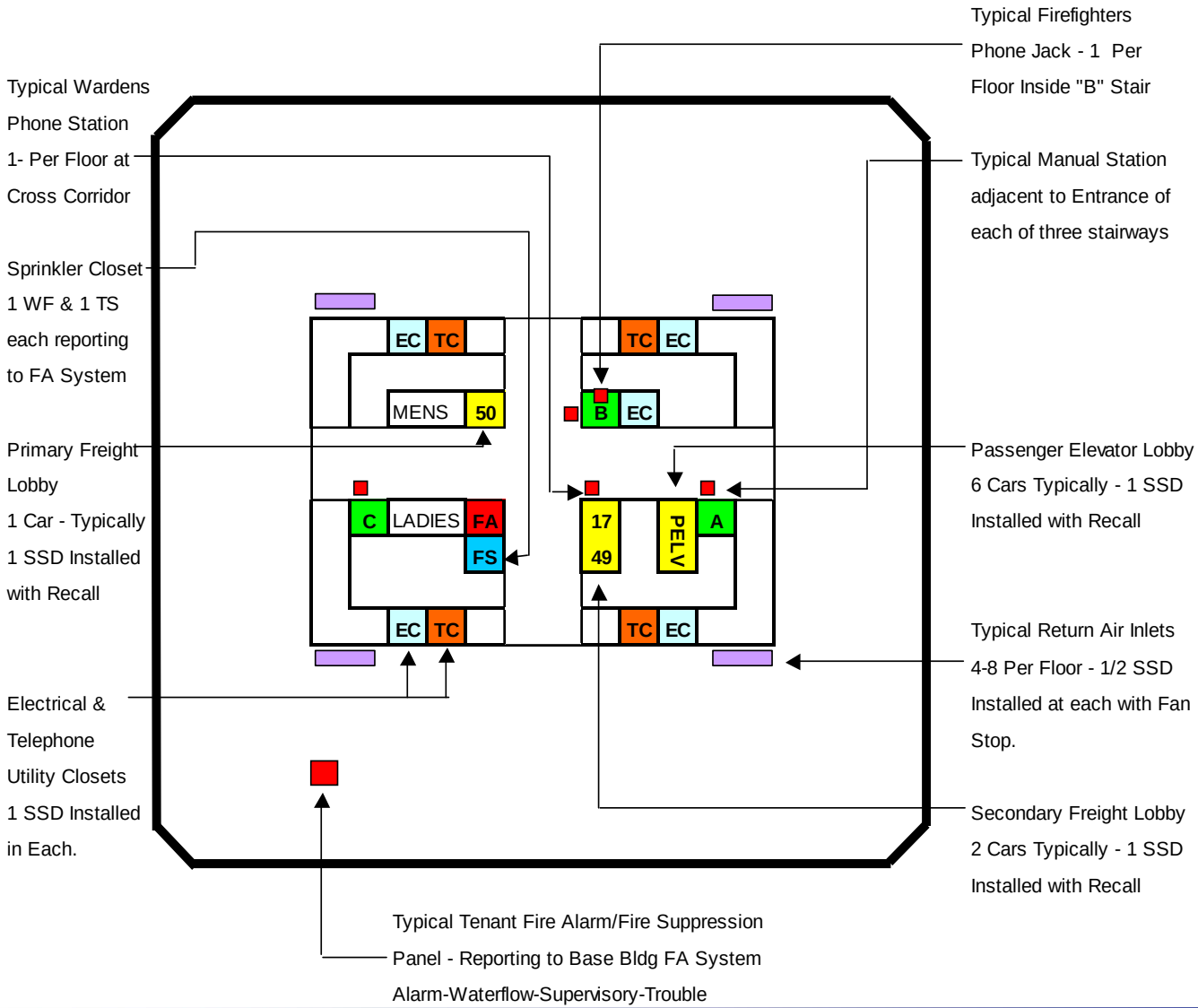
Fire Alarm History

- WTC1 and WTC2 fire alarm retrofit projects divided into 3 phases:
  I. Installed back-bone head-end panels, remote panels, and terminal cabinets.
  II. Transition detection, monitoring, and control from old to new system, which also included new warden telephones, core area speakers, and manual devices.
  III. Expanded new system into tenant spaces and mechanical equipment rooms.

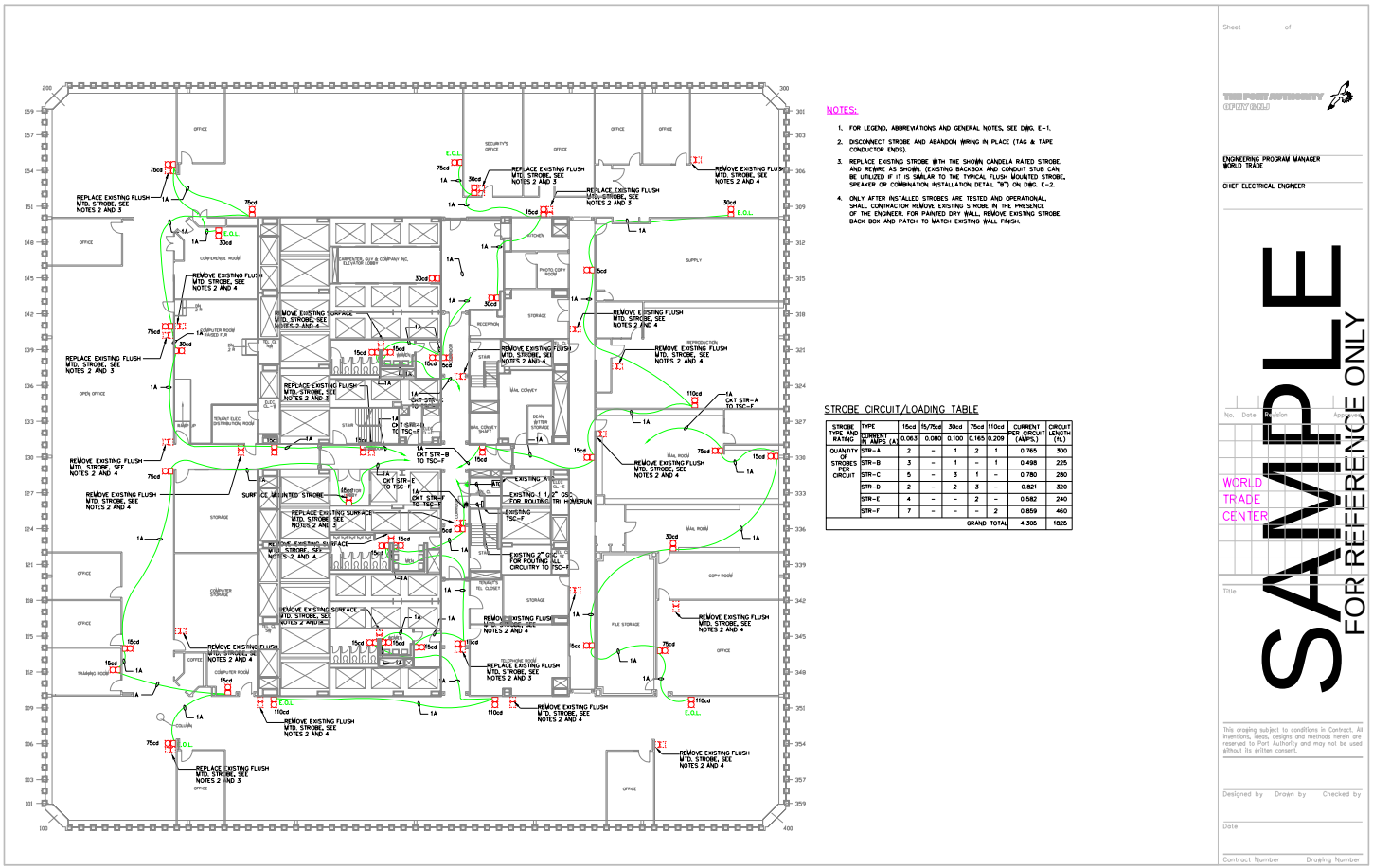
WTC1 & WTC2 Design Approach

- Port Authority provided fire alarm system backbone architecture details for contractors to implement that described the core system interface equipment and hardware.
- The PA also developed other specific design criteria as follows:
  - Fire detection and interface device design criteria for device locations, installation, and connections.
  - Audio and visual notification appliance design criteria for device locations, installation, and connections.
  - Fire alarm riser/one line diagram criteria requiring a diagrammatic format for each interface cabinet, circuit, raceway, detection device type, and notification appliance type.
  - Circuit performance criteria with forms for documenting test procedures, results, and verification.
  - Contractor tie-in and pretest checklist to document that the design and installation procedures have been followed.
  - Acceptance testing forms to document and assure the performance of the fire alarm monitoring, detection, and notification devices.
  - Project summary that reviews the deliverables required for the fire alarm installation through design, installation, acceptance, as-built documentation, and final project close out.

Design Approach



Design Approach



NOTES:

1. FOR LEGEND, ABBREVIATIONS AND GENERAL NOTES, SEE DWG. E-1.
2. DISCONNECT STROBE AND ABANDON WIRING IN PLACE (TAG & TAPE CONDUCTOR ENDS).
3. REPLACE EXISTING STROBE WITH THE SHOWN CANDELA RATED STROBE, AND REWIRE AS SHOWN. (EXISTING BACKBOX AND CONDUIT STUB CAN BE UTILIZED IF IT IS SIMILAR TO THE TYPICAL FLUSH MOUNTED STROBE, SPEAKER OR COMBINATION INSTALLATION DETAIL "B") ON DWG. E-2.
4. ONLY AFTER INSTALLED STROBES ARE TESTED AND OPERATIONAL, SHALL CONTRACTOR REMOVE EXISTING STROBE IN THE PRESENCE OF THE ENGINEER. FOR PAINTED DRY WALL, REMOVE EXISTING STROBE, BACK BOX AND PATCH TO MATCH EXISTING WALL FINISH.

STROBE CIRCUIT/LOADING TABLE

STROBE TYPE AND RATING	TYPE	15cd	15/75cd	30cd	75cd	110cd	CURRENT PER CIRCUIT (AMPS.)	CIRCUIT LENGTH (ft.)
	CURRENT IN AMPS (A)	0.063	0.080	0.100	0.165	0.209		
QUANTITY OF STROBES PER CIRCUIT	STR-A	2	–	1	2	1	0.765	300
	STR-B	3	–	1	–	1	0.498	225
	STR-C	5	–	3	1	–	0.780	280
	STR-D	2	–	2	3	–	0.821	320
	STR-E	4	–	–	2	–	0.582	240
	STR-F	7	–	–	–	2	0.859	460
						GRAND TOTAL	4.305	1825

Sheet of

THE PORT AUTHORITY OF NY & NJ

ENGINEERING PROGRAM MANAGER WORLD TRADE

CHIEF ELECTRICAL ENGINEER

No. Date Revision Appd.

WORLD TRADE CENTER

Title

SAMPLE FOR REFERENCE ONLY

Designed by Drawn by Checked by

Date

Contract Number Drawing Number

Typical Strobe Layout

Additional Quality Assurance

- Written Acceptance Test Procedures
- Contractor Tie-In & Pre-Test Checklists
- Circuit Test Forms

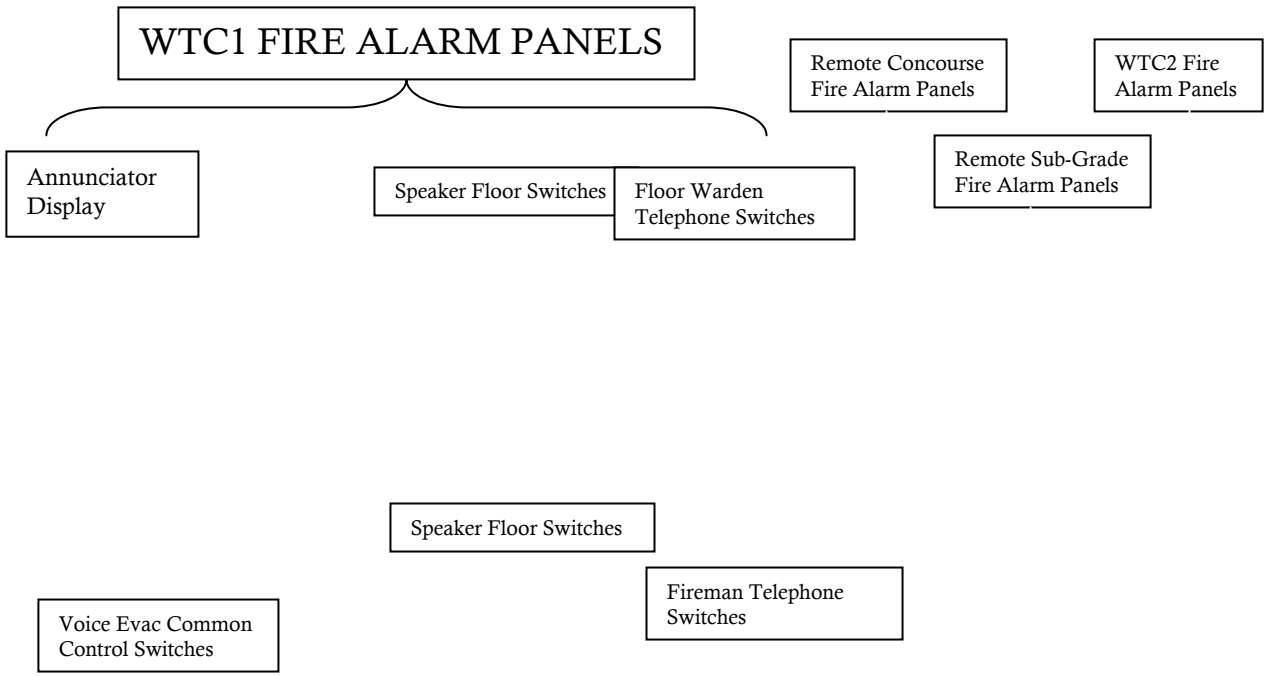
Fire Alarm Equipment & Circuits

- Fire Command Station
- Operation Control Center
- Base Building Fire Alarm Equipment & Circuits
- Detection, Monitoring, Control Devices & Circuits
- Notification Appliance Devices & Circuits
- Warden & Fireman Telephones & Circuits

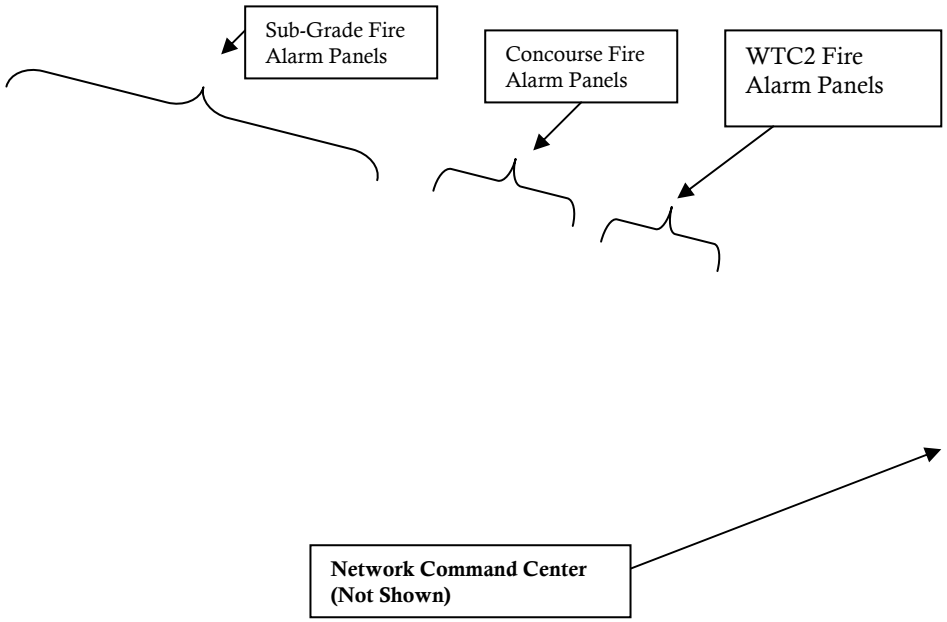
Fire Command Station
(Features required by New York City)

1. An audible alarm signal.
2. Emergency voice and alarm communication capability.
3. Means for silencing the audible alarm signals when the loud speakers are in use and for activating the audible alarm system automatically when use of the loud speakers is terminated.
4. A means to control the alarm sounding devices on all floors.
5. A manually reset the information display.
6. Manual controls and display lamps to include on/off condition of air-handling systems.
7. A Standpipe Fire Line Telephone system with the capability to make announcements over the emergency voice and alarm communication system.
8. A two-way communication system connected to a designated floor warden station on each floor, the mechanical control center, elevators, air-handling control rooms, and elevator machine rooms.
9. Means to manually transmit a fire alarm signal to the fire department via a central station of a franchised operating company.
10. Means for testing the display, alarms, and connection to the central station.

Fire Command Station

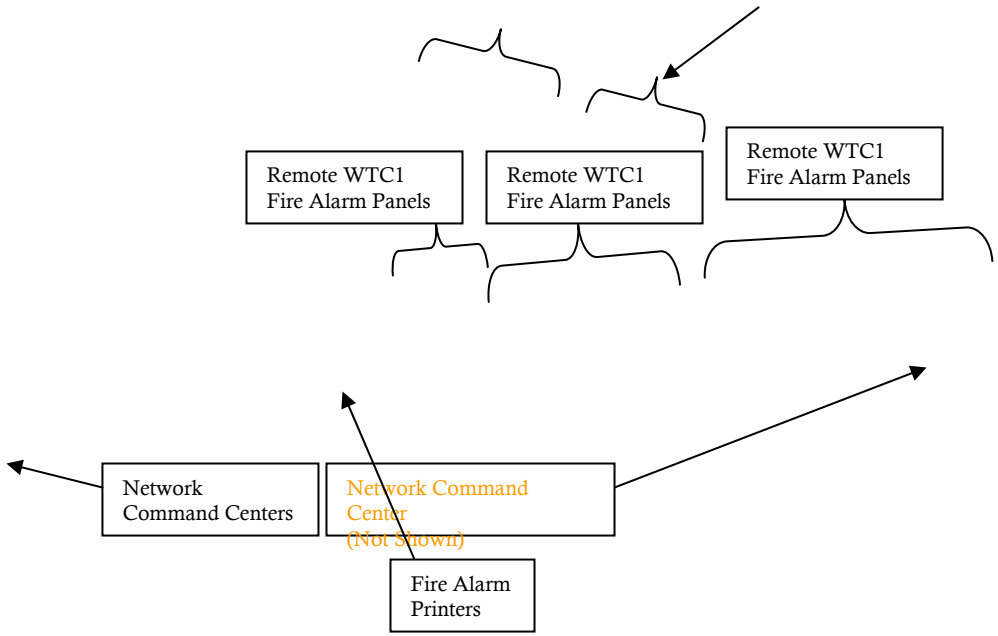


Fire Command Station



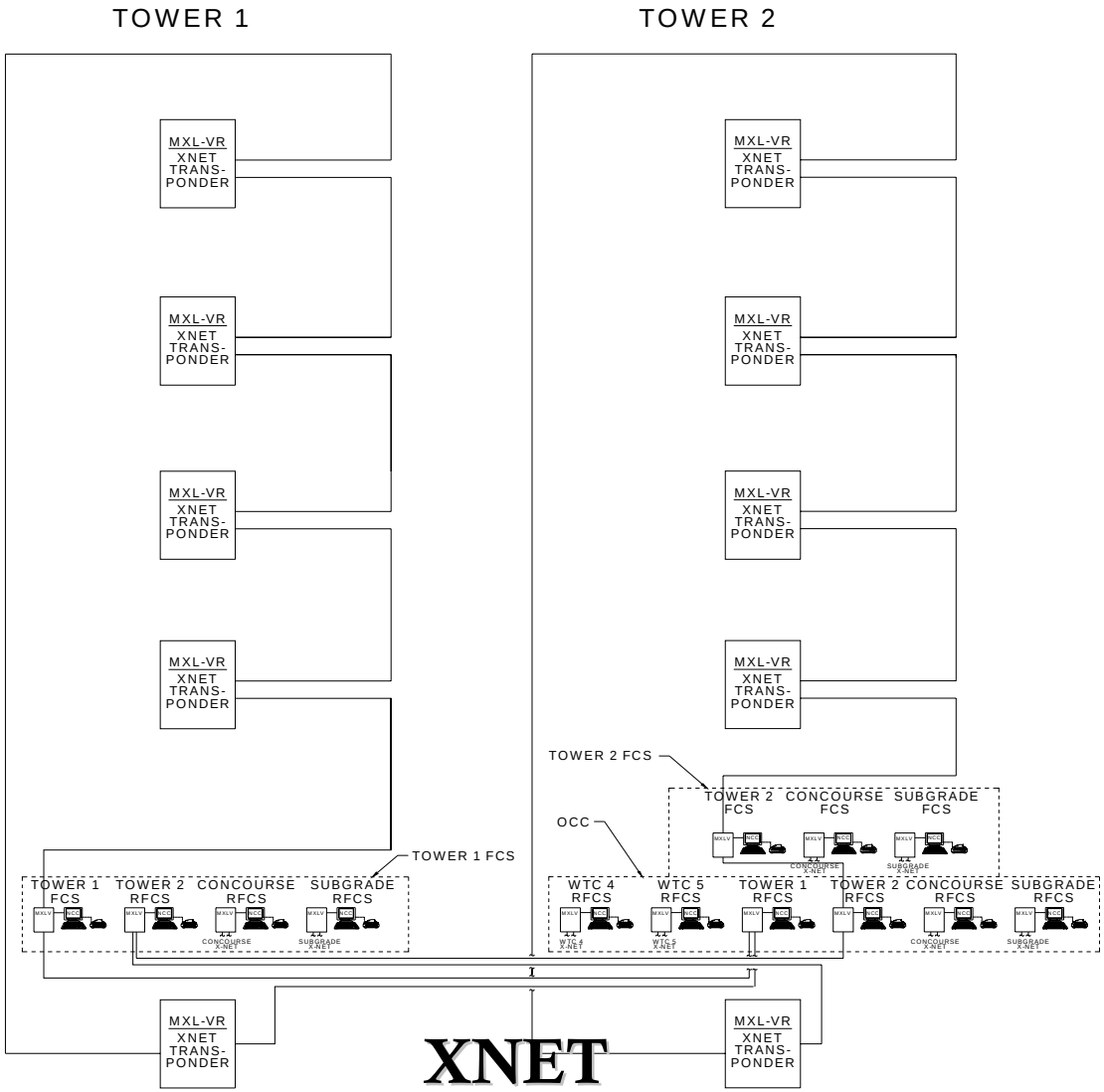
WTC2

Operation Control Center



Note: Sub-Grade, WTC5, and WTC4 fire alarm panels are located on the wall behind the photographer.

Base Building Fire Alarm Equipment & Circuits



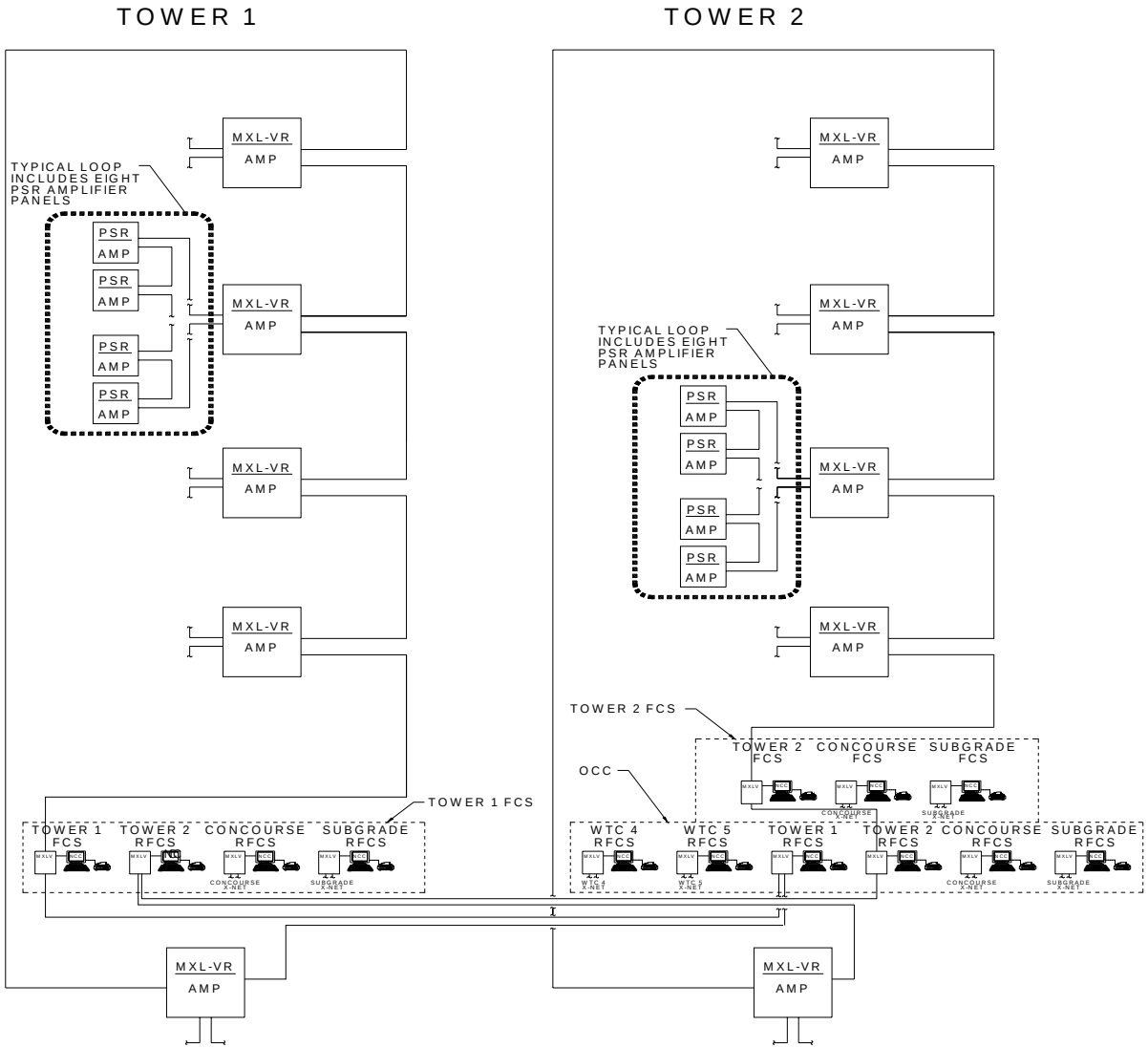
Detection, Monitoring & Control Devices

- Addressable open area ionization smoke detectors (ILI-1)
- Addressable high-air velocity open area ionization smoke detectors (ILI-1A)
- Addressable duct ionization smoke detectors – high air velocity (ILI-1B)
- Addressable open area photoelectric smoke detectors (ILP-1)
- Addressable open area photoelectric smoke detectors with fixed heat detector (ILPT-1)
- Addressable open area rate compensated heat detectors (ID-60T-135)
- Addressable single input monitor modules (TRI-60)
- Addressable dual input monitor modules (TRI-60D)
- Addressable single input with relay control output modules (TRI-60R)
- Addressable single-action pull stations (MS-MI)

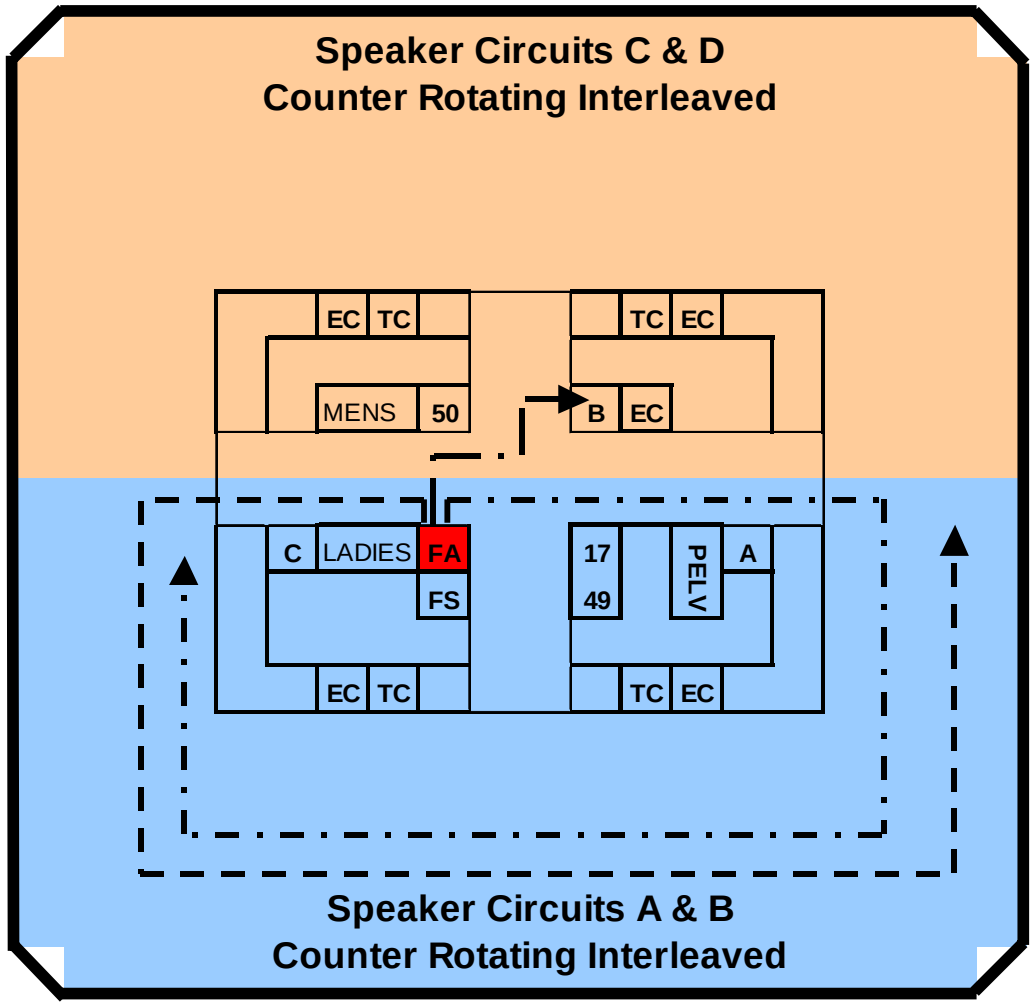
Detection, Monitoring & Control Devices

1. ELEV Branch – Elevator lobby smoke detectors, passenger and freight.
2. AREA Branch – Open area smoke detectors – phone, electric, fire alarm closets, and sprinkler monitoring.
3. HVAC Branch – Ventilation smoke detectors for plenums and ducts.
4. TEN1 Branch – Tenant 1fire alarm subsystem interface monitoring by BBFAS.
5. TEN2 Branch – Tenant 2 fire alarm subsystem interface monitoring by BBFAS.

Notification Appliance Devices & Circuits



Notification Appliance Devices & Circuits



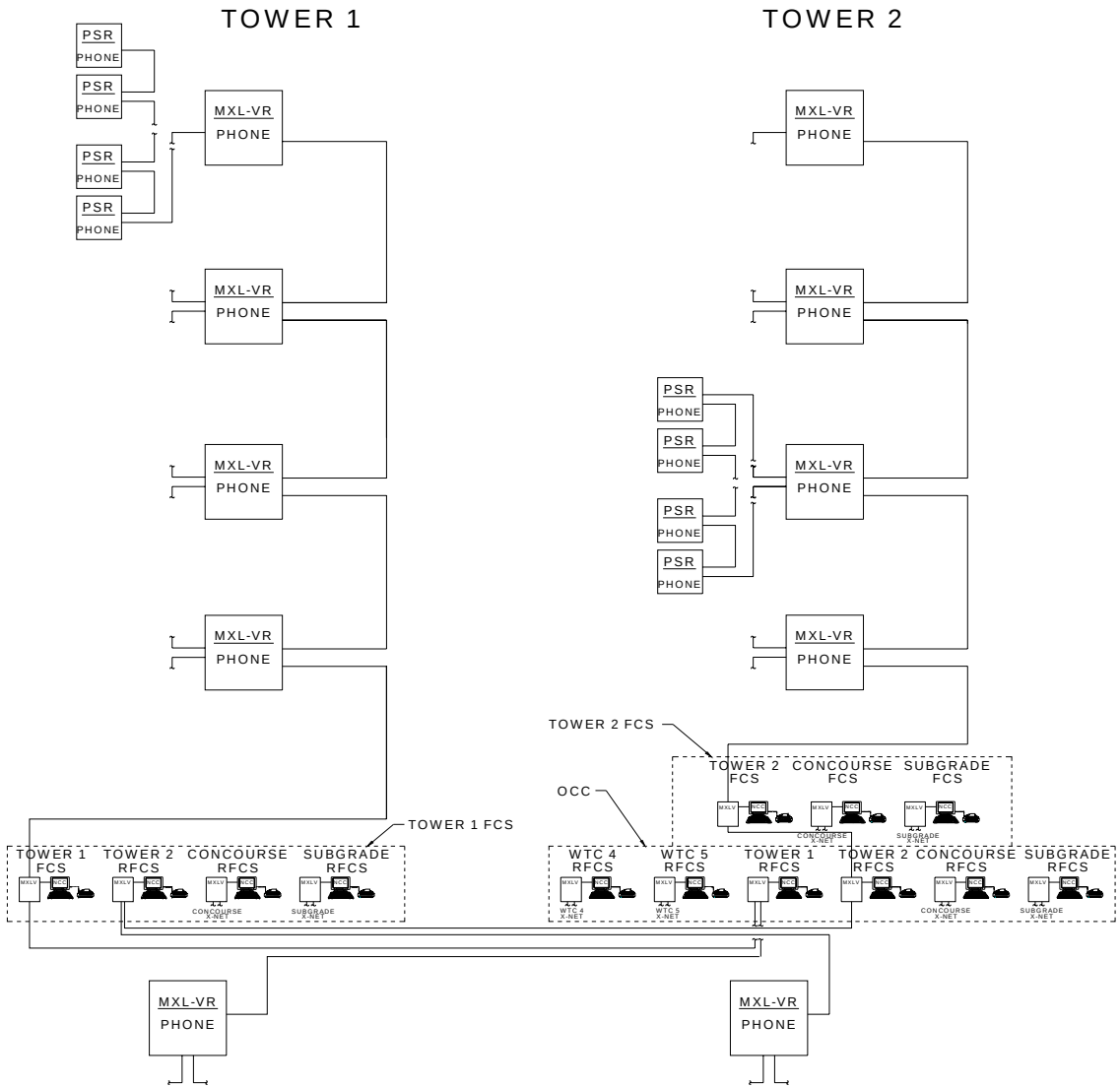
Class B- 70.7 V - 150 / 200C Teflon FPLP Free Air
4 Circuits Provided Per Floor + Additional Stairway Only Circuit typically every 4-5 Floors. Coordinated with Reentry Points.

NIST

Notification Appliance Devices & Circuits

- Ceiling mounted round speakers, 70 volt (SPK-9070)
- Wall mounted square speakers, 70 volt (SPK-7070)
- Wall mounted speakers, 25/70 volt (SPK-1070)
- Wall mounted speakers, 70 volt, with 24 volt 15/75 cd strobe (SS70-15/75)
- Wall mounted strobes, 24 volt 15/75 cd (S15/75-SGL)
- Wall mounted combination speaker, 70 volt, with 24 volt 15/75 cd strobe (SS70-15/75)

Warden & Fireman Telephones & Circuits



Warden & Fireman Telephones & Circuits

- Flush wall mounted floor warden telephone station (FB-300)
- Surface wall mounted floor warden telephone station (FB-301S)
- Remote firefighters telephone station with armored cable (FT-301CL)
- Surface box for fireman standpipe or maintenance jack (PUR17)
- Firefighters telephone jack (FJ-303)
- Portable firefighters telephone (PT-304)

Task 3 – WTC1 & 2 Fire Alarm Modifications Post 1993 Bombing

- Document pre-1993 fire alarm system.
- Provide comparison of the performance and functions between the old and post-1993 fire alarm system.

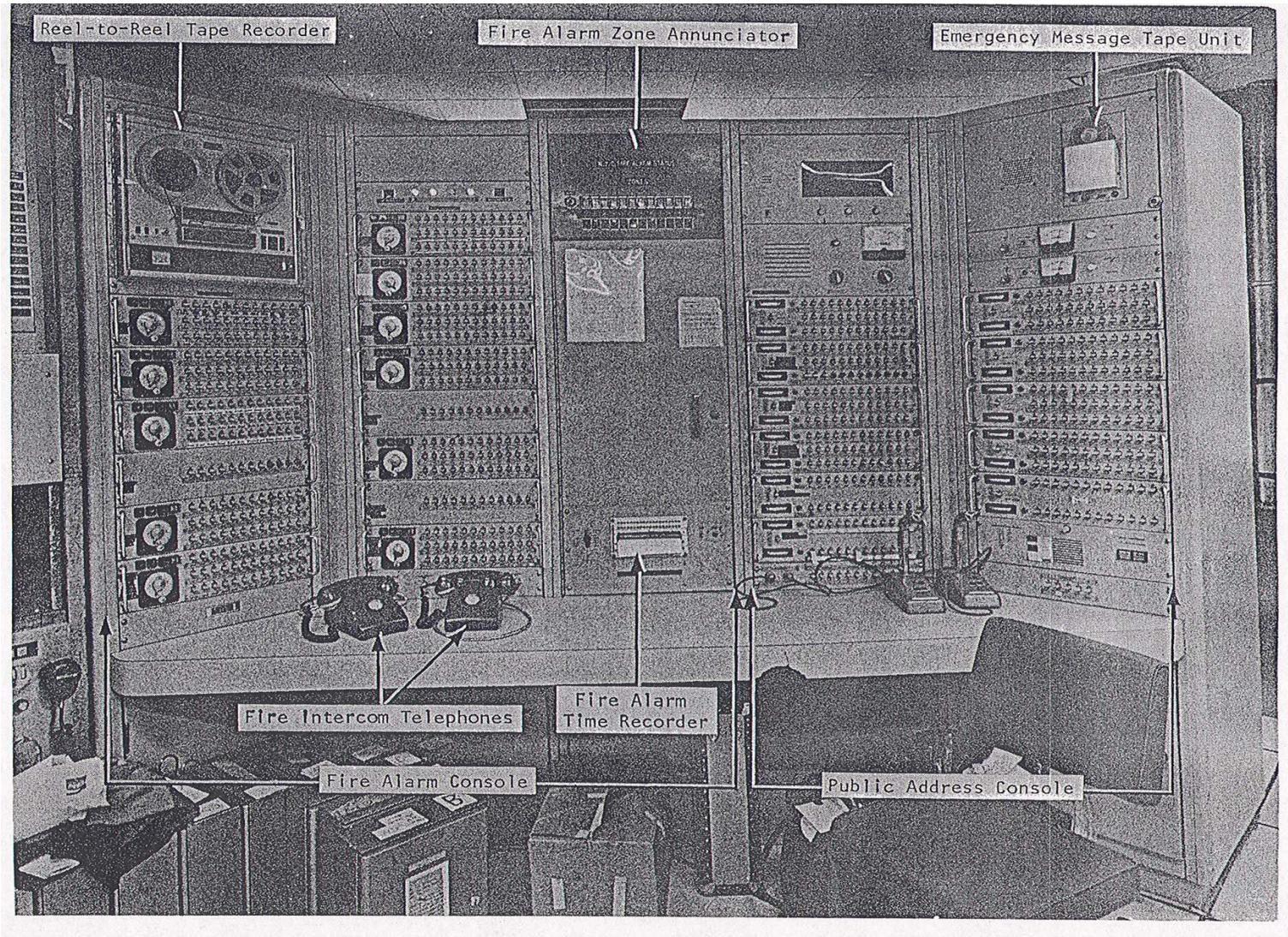
Pre-1993 Fire Alarm System

- Operations Control Center
- Base Building Fire Alarm Equipment & Circuits
- Detection, Monitoring, Control Devices & Circuits
- Notification Appliance Devices & Circuits
- Warden & Fireman Telephones & Circuits

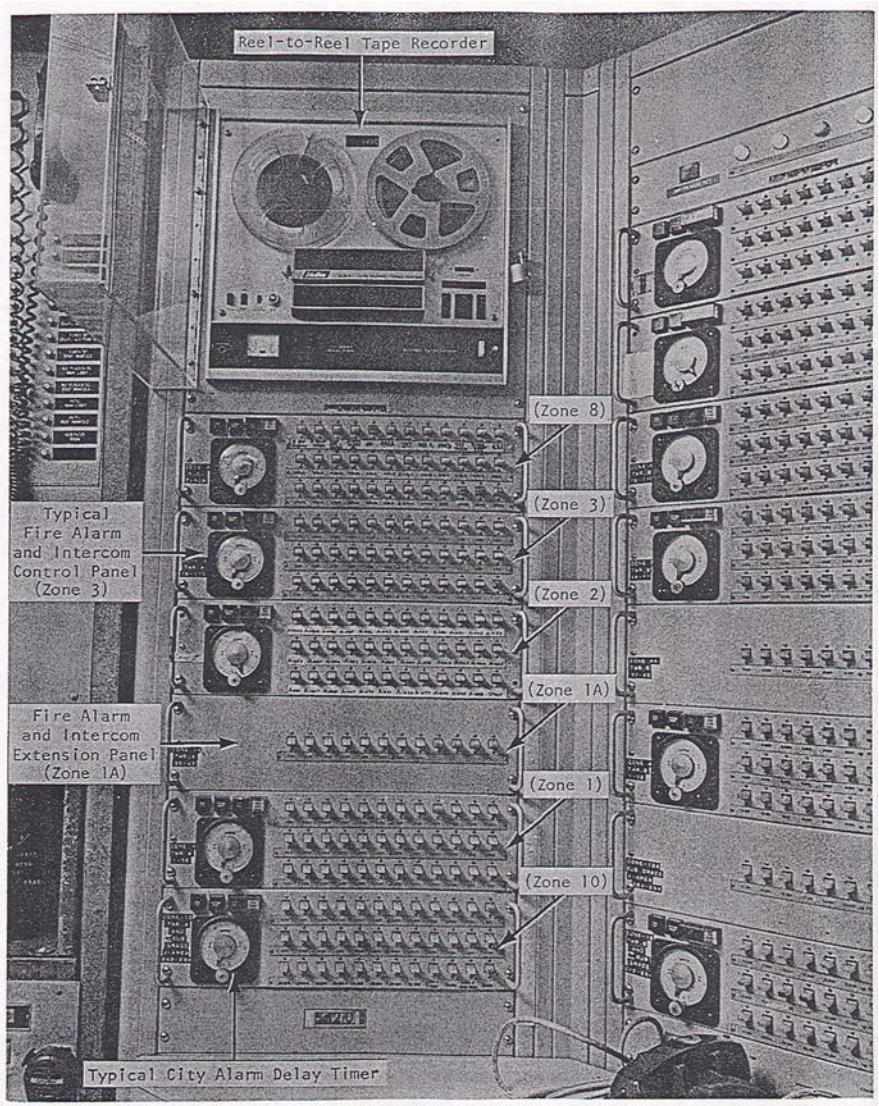
Operations Control Center

- Fire Alarm Zone Annunciator with Time Recorder
- Public Address Console
- 10 Zone Intercom & NYCFD Fire Alarm Signal Transmission Panels.
- Intercom Tape Recorder

Operations Control Center



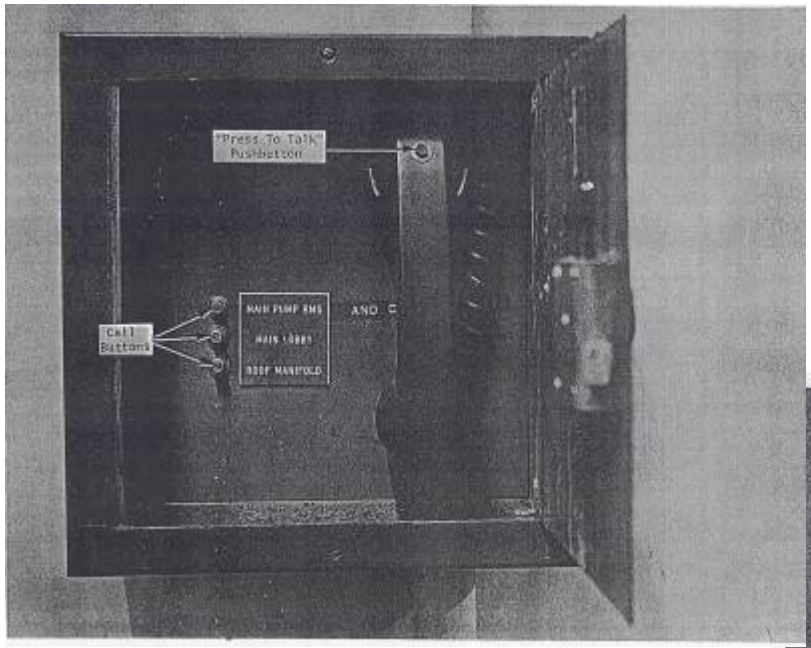
Operations Control Center

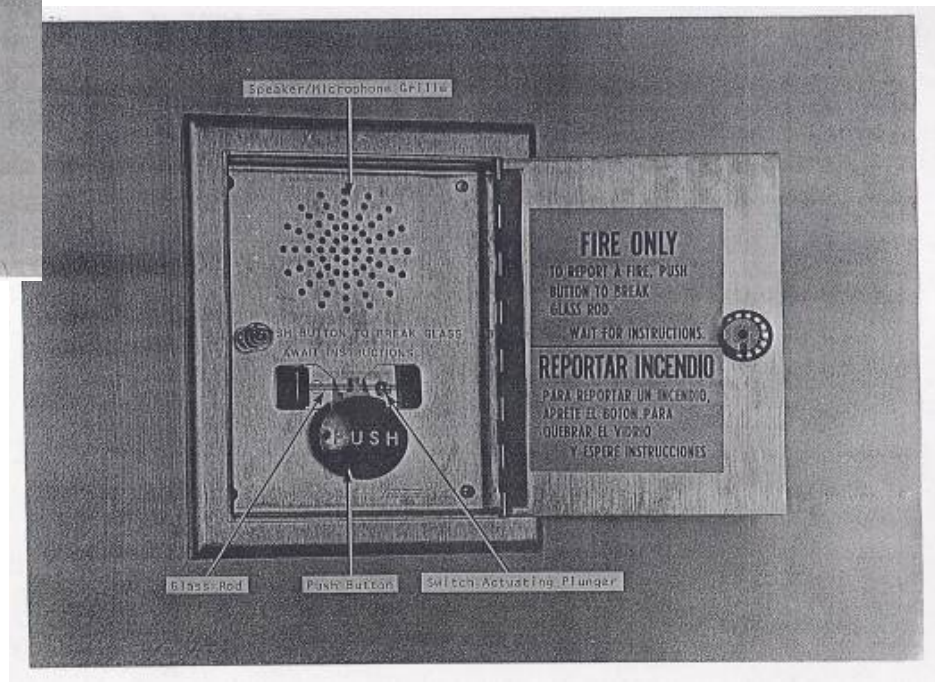


Warden & Fireman Telephones & Circuits (pre-1993)

- Break Glass Stations provided automatic fire alarm notification to NYFD & two-way intercom communication.
- PA console operator has 20 seconds to respond or fire alarm signal automatically broadcast to fire zone.
- Adjustable delay in sending alarm to NYFD.
- Fire Line Communications Systems was a separate Standpipe Fireline Communication phone system.

Warden & Fireman Telephones & Circuits





Comparison of Performance Between Pre & Post 1993 Fire Alarm Systems

- Similar Functions
  - Return air smoke detection
  - Elevator lobby smoke detection and recall
  - Mechanical room air handling unit smoke detection and shutdown
  - Sprinkler water flow and tamper monitoring
  - Tenant systems monitored
  - Voice broadcast capability for each floor
  - Occupant and fireman two-way communication for each floor
  - Notification of NYFD upon alarm

Comparison of Performance Between Pre & Post 1993 Fire Alarm Systems

- Post 1993 Enhanced Features
  - All equipment functions and circuits were made or installed to recognized performance standards (Class A).
  - System had distributed intelligence and control features.
  - Consolidated all the fire detection, monitoring, control and communication systems for the common use areas (not tenant).
  - Smoke detection was also provided in electrical, telephone, and fire alarm closets.
  - Manual stations were provided by each stairway door.
  - Floor return air detectors would shutdown associated air handling unit upon activation.
  - Mechanical Equipment Room air handling units provided shutdown & deluge sprinkler activation capability.
  - Speakers and strobes were spaced and installed based upon intelligibility, audibility, and visual performance standards.
  - Common two-way telephones provided for floor wardens and firefighters.

Task 4 – Probable Performance of Fire Alarm Systems on 9/11/01

- Fire alarm print-outs lost on 9/11.
- Analysis based on limited video and witness accounts.
- Fire alarm visual indications provide inconclusive evidence without alpha/numeric display or print-out.

Task 4 – Probable Performance of Fire Alarm Systems on 9/11/01

- Fire Command Station
  - All equipment viewed on Nudet video appear to be functioning.
  - All panels have an illuminated alarm and trouble indication.
  - WTC2, Concourse, and Sub-Grade panels have an illuminated audible silence indication at 9:58 AM, seconds before the WTC2 collapse.

Task 4 – Probable Performance of Fire Alarm Systems on 9/11/01

- WTC2 telephone zone illuminations indicate warden telephones on floors 64, 71, 73, 93, and 94 are active.
- The WTC1 Fire Safety Director initiated an audio alarm signal to floors 1 through 84 at 8:59 AM. Speaker zone lights do not illuminate above floor 84 for unknown reasons.

Task 4 – Probable Performance of Fire Alarm Systems on 9/11/01

Task 4 – Probable Performance of Fire Alarm Systems on 9/11/01

- Speaker panel and telephone panels indicate circuits on floors 76-84 malfunctioning. (Based on Druckers best recollection). Cause likely is loss of PSR circuits. Evidence is inconclusive.