High-rise Design

TS 400-1-1

Friday 9:00am-12:00pm

Frank Teebagy PE, FASPE
Plumbing Design in High-rise Buildings

ASPE Symposium, Orlando, FL
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Program Outline

• Introduction
• Heights of Interest
• Comparison of Systems
  • Sanitary and Vent
  • Water Distribution Schemes
  • Hot Water Return
• Ultra Tall Buildings
• Buildings Under Construction
• Construction Considerations
• Summary
Contributors

• Trump International Hotel and Tower (Chicago)
  – Engineer, WMA Consultants; Ken Cutler, CPD
• Waterview Tower
  – Engineer, Teng Associates; Robert Thompson, CPD
• Chicago Spire
  – Engineer, Cosentini Associates; Robert Jackson, CPD
• Dan Fagan, PE Chief Engineer, OWP/P
• Susan Dolaher – Marketing; Cosentini Associates, Inc.
Are the days of skyscraper numbered?

• No. However, in North America there are no proposals for anything that would surpass the Sears Tower, aside from One World Trade Center (Freedom Tower) in NYC.

• Mostly a matter of economics – buildings start to lose their economic viability at 80 stories or so.
• In Asia and the Middle East, there is still great interest in designing the tallest of buildings.

• Typically, specific provisions addressing high rise and high density construction are primary drivers for city specific codes or code amendments.

• Necessity is the mother of invention, and code changes.
Why High Rise?

• Today’s competitive economy Developers are finding themselves having to offer international class luxury developments (Residential or Commercial).
• Apartments are typically designed as core and shell to allow maximum flexibility for custom tenant fit out.
• Commercial and Retail Spaces are also typically shell and core design.
Ultra High Rise

• Defined as buildings over 1000 ft.
• The taller the building, the more unique problems it has and the more unique solutions are required.
• Some current “ultra tall” buildings were not anticipated by present Codes.
Types of Buildings

• So having the tallest building is all about --- prestige?
• For sure. For instance, the Petronas Towers remain only partially occupied because the economy of Malaysia cannot support those buildings as economic entities. But they are symbolic for the Malaysian economy & people.
• Is there a theoretical upper limit to tall buildings?
• From a structural point of view, there really is not; the limitations are primarily economic.
Types of Buildings

• The type of building and how it is constructed are equally important
  – High Rise construction has been primarily residential condominiums over the last few years.
  – These buildings have been overwhelmingly poured concrete, drop panel or flat slab construction, with the underside of slab used for ceilings in many areas
  – The greatest possible use of vertical risers and stacks has allowed the minimization of ceiling installation
What is a High Rise?

Defined in Model or Local Building Codes

- IBC-Occupied Floors > 75 ft above Fire Department access
- MA State Bldg 8th Edition 70 ft
- From mean grade to roof. Defined in Local Building Codes of Large Cities:
  - Chicago Building Code; Height > 80 ft
    - Additional requirements for buildings over 400 ft tall
International Codes & Regulations

• International Building Code.
• International national Mechanical Code.
• International Plumbing Code.
• British Standard.
• National Electrical Code.
• NFPA Fire Protection Regulations.
High Rise Plumbing

- How does High Rise relate to Plumbing?
- Are Story heights important?
  - Not really
- Basically, it is a switch from horizontal plumbing to vertical plumbing design
- Typically occurs from 3 stories up.

Horizontal Distribution
Vertical Plumbing Design

- High rise equals vertical plumbing design
- Primarily, the floor to floor plumbing fixture arrangement lines up.
- Multiple stacks and water risers are used.
Multiple Risers

• Minimize horizontal distribution
• Decision is to distribute water and collect waste through multiple risers and stacks
  – Rather than gathering to a centralized point
• The essence of the design remains virtually the same regardless of building height.
Riser Locations

- Ideally, a stack would be located adjacent to each fixture
- Ideal location is near water closets
- Goal is to minimize labor cost, stack installation is less labor intensive
Flows in Stack

The flow in the stack tends to cling to the wall of the pipe. There is a slight spiral motion as the water flows down the pipe.

Stack Capacity Equation is as follows:

\[ q = 27.8r^{5/3}d^{8/3} \]

Where:
- \( q \) = flow rate in gpm
- \( r \) = ratio of area of water to area of stack
- \( d \) = diameter in inches
Terminal Velocity

- Does height make a difference?
- Terminal velocity occurs after 3 stories of flow.
- The Plumbing Codes are based on terminal velocity for sizing.

Terminal Velocity Equation is as follows:

\[ V_T = 3.0 \left( \frac{q}{d} \right)^{2/5} \]

Where:
- \( q \) = flow rate in gpm
- \( V_T \) = terminal velocity in stack, fps
- \( d \) = diameter in inches
Benefit of Terminal Velocity

- Plumbing is the same from 4 to 100 stories.
- Drainage in the stack is the same for a hotel or an office building.
- Venting becomes critical for the system.
Vent Stack and Stack Vent

- The Vent Stack must connect to the base of the drainage stack.
- The connection must be at or below the lowest horizontal branch.
- Lowest floor would connect to the horizontal building drain after the hydraulic jump.
Vent Stacks

- Vent Stacks must be sized in accordance with the Plumbing Code.
- When more than 10 stories in height, a relief vent has to be the same size as the vent stack.
- A vent stack is not required by code when a Sovent System is designed.
Air Movement In Tall Stacks

- Studies have shown that the air movement is within the conventional stack.
- Pressures attempt to balance out between floors.
- There is no need for over sizing a vent pipe as previously believed.
Relief Vent

- For drainage stacks more than 10 branch intervals in height, a relief vent is required.
- The relief vent must be located every 10 branch intervals down from the top of the stack for conventional systems.
Relief Vent Sizing

- Vent must be $\frac{1}{2}$ the size of the drain.
- Sometimes easier and cheaper to be the same size.
- Must connect 42 inches above the next floor.
Vents for Drainage Offsets

- When a drainage stack offsets on lower floors, vents may be required for the offset.
- The venting of the offset is for the upper section and the lower section.
Sanitary Stack Vent

- This venting relies on the drainage stack to serve as the vent.
- The stack is oversized.
- A stack vent must be installed the same size as the drainage stack.
- Each fixture must connect independently to the stack.
- Offsets are prohibited.
- ACW = Auto Close Washer
Single Stack Venting

- A single stack venting system is a single stack drainage and vent system.
- Water closets and urinals can connect to the stack without additional venting.
- The stack is oversized.
The Single Stack Venting System, also called the Philadelphia Single Stack, is based on an oversized stack.
   – Typical loading is approximately 10 percent
The limitation on number of fixture units is less than stacks vented by other means.
The table must be followed for sizing the stack.
   – Sizing is based on height of stack
   – And fixture unit load
# Single Stack Sizing

<table>
<thead>
<tr>
<th>Stack Size (inches)</th>
<th>Maximum Connected Drainage Fixture Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stacks Less than 75’ to Less than 160’</td>
</tr>
<tr>
<td>3</td>
<td>75’ 24</td>
</tr>
<tr>
<td>4</td>
<td>225</td>
</tr>
<tr>
<td>5</td>
<td>480</td>
</tr>
<tr>
<td>6</td>
<td>1015</td>
</tr>
<tr>
<td>8</td>
<td>2320</td>
</tr>
<tr>
<td>10</td>
<td>4500</td>
</tr>
<tr>
<td>12</td>
<td>8100</td>
</tr>
<tr>
<td>15</td>
<td>13,600</td>
</tr>
</tbody>
</table>
Single Stack Limitations

- Water closet connections must be located within 4 ft of the stack
- Other traps can be 12 ft from the stack
- A vertical drop of 4 ft is permitted, provided the drain is 2” minimum
Single Stack-WC Limitation

- can be located a maximum of 8’ from the drainage stack when connecting to a sanitary tee.
- When located more than 8’ from the stack must be vented by other means (individual vent).
- Limit of three water closets are permitted on a 3 inch stack.
Single Stack Limitations

- The lowest two floors cannot have horizontal branch connections.
- The pressure in this area can be disruptive.
- Any fixtures must be vented by other means.
Sovent

- Sovent is another single stack venting system.
- Sovent uses special fittings called aerator and deaerator fittings.
- The fittings slow the flow of drainage down the stack.
- ASSE 1043 regulates Sovent installations.
Sovent Installation

- An aerator fitting is shown for the connection on the floor.
- The water closets connect to the side openings.
- The other fixtures connect directly
Sovent Base of Stack

- A dearator fitting is required at the base of the stack.
- The dearator neutralizes the pressure at the base.
- Each floor has an aerator fitting.
Sovent Limitations

WC

12’ max.

Aerator

3"

Sovent Stack

Remainder

12 ft. max.

Sovent Stack

3"

4"

WC

15 ft. max.

3"

WC

2"

LAV
Sovent Limitations

2” Waste, Max. 15’-0”
3” Waste, Max 15’-0”

2” Waste, Max. 15’-0”
on 4” Stack

3” Soil, Max. 12’-0”
4” Soil, Max 27’-0”

Aerator

4” Sovent Stack

WC
Water and Pressure Concerns

- Water Systems
  - Model plumbing codes limit the pressure supplied to a fixture to 80 psi
  - The minimum pressure required at a fixture is also specified in the code.
  - The most demanding fixtures are:
    - WC Flush Valves at 25 psi
    - Showers at 20 psi
Water and Pressure Concerns

- Allowing for friction loss and a safety factor, this means there is at most 45 psi that can be utilized as elevation head pressure.
- This equates to 104 ft, or approximately 8 - 10 stories.
Water Pressure & Height

- Water Systems
  - Any building over 100 ft tall will require more than one water distribution zone
    - $104 \times 0.433 = 45 \text{ psi}$
    - $45 + 25 = 70 \text{ psi}$
    - 10% safety factor and friction.

Max 80 psi/start new zone

25 psi to fixture

104 ft/45 psi differential

Max 80 psi/start new zone
Creating a Zone

- Buildings over 10 stories in height require multiple water piping zones.
- There are various design options for creating zones.
- Multiple means of supplying water.
Storage Tank Down Feed

- Very popular on the East Coast (NYC) is the use of storage tanks.
- The tanks must be sufficiently elevated for adequate pressure.
- One of the distribution methods is a down feed.
A downfeed/upfeed system utilizes a large downfeed line.

The upfeed lines are distributed throughout the building.

Some engineers believe there is better control.
Top of Riser

• Good engineering practice is to provide a means to relieve the air in the piping system.

• At the top of the riser and at the end of runs, an automatic air release valve should be considered.
Options for Zones

Multiple booster pumps could be utilized, with one for each zone
Zones with Floor PRVs

PRVs could be installed at each floor where the pressure exceeds code maximum.

Zoned Cold Water Distribution with Floor by Floor PRV's
Creating Zones for Floors

Through the use of pressure regulating valves, inserted off of a common high pressure express main.
Difference with Multiple Zones

Once we have reached the point of creating zones for water distribution, additional height just means additional zones.
When Does Building height Start to make a Difference?

Next reasons for change are

- Limitations of components and materials
- Constraints imposed on other building systems that make us reconsider the plumbing distribution
- Building characteristics that impose constraints on the plumbing
When Does Building Height Start to Make a Difference?

Limitations of components and materials

- Piping – Commonly good up to 500-600 psi

- Valves – Formerly expensive in high pressure, now 600 psi valves available at Home Depot

- Pumps – High pressure/large horsepower constant speed pumps exhibited issues with control, **variable speed pumping makes this much easier**

- Water Heaters – P/T relief valves limited to 150 psi, heaters cannot serve more than 2 pressure zones

- HW recirculation problematic when there are multiple CW zones
Keeping Hot Water Hot

• There are two means of keeping hot water at an acceptable temperature in a high rise building.
  – Recirculation
  – Heat tracing

• Another alternative is the use of multiple water heaters throughout the building.
Multi-Zone Hot Water Recirculation with Multiple Heaters
Multi-Zone Hot Water Recirculation with Multiple Pumps
Zone Specific Hot Water Recirculation with Single Main Pump
Zone Specific Hot Water Recirculation with Single Main Pump
High Rise Office Building – Domestic Hot Water System
Direct Plumbing Supply
Up Feed and Down Feed Zones

• When combining an upfeed with a downfeed, the pressures must be balanced.

• This requires creativity in the design of PRV stations.
Balancing Pressures

By-Pass

PRV

PRV Pilot Operated

Circuit Setter
Heat Loss in Piping

The typical heat loss in insulated piping can be found in the following table:

<table>
<thead>
<tr>
<th>Pipe Size (in)</th>
<th>Insulation Thickness</th>
<th>Heat Loss (Btu/hr/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>¾</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>1-1/4</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>2 or less</td>
<td>½</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2-1/2</td>
<td>1-1/2</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>1-1/2</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>1-1/2</td>
<td>19</td>
</tr>
</tbody>
</table>
Sizing Recirculation Piping

The equation for determining the flow rate in a Recirculation line is:

\[ Q = \frac{q}{S_h \Delta T} \]

Where:
- \( Q \) = flow rate (pounds of water/hour)
- \( q \) = heat loss (Btu/hr)
- \( S_h \) = specific heat of water = 1
- \( \Delta T \) = temperature drop in circulating lines (°F)
Simplified Recirculation Equation

Changing the Pounds of water/hr to gpm, divide by 8.33 pounds/gallon of water and divide by 60 min per hour resulting in:

\[ Q = \frac{q}{8.33 \times 60 \times 1 \times \Delta T} = \frac{q}{500 \Delta T} \]
Height Making a Difference

- Constraints imposed on other building systems that make us reconsider the plumbing distribution
  - Fire Protection Systems
    - System pressure formerly limited to 175 psi (now 250 psi where components are so rated)
    - Limitation of pump discharge pressure to 350 psi at flange (NFPA 20)
    - Limitations of Fire Department pumping capacity (pumper trucks)
    - Requirements for stored water - reliability
**Height Difference**

- Building characteristics that impose constraints on the plumbing
  - Offsets, setbacks or transitional floors
  - Changes in layout or location of fixtures
  - Unheated areas such as garages
# US Cities With Most High Rises

<table>
<thead>
<tr>
<th>#</th>
<th>City</th>
<th>Population</th>
<th>Completed Buildings</th>
<th>Buildings Under Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>New York City</td>
<td>8,104,079</td>
<td>5,469</td>
<td>102</td>
</tr>
<tr>
<td>2.</td>
<td>Chicago</td>
<td>2,862,244</td>
<td>1,045</td>
<td>31</td>
</tr>
<tr>
<td>3.</td>
<td>Los Angeles</td>
<td>3,845,541</td>
<td>457</td>
<td>7</td>
</tr>
<tr>
<td>5.</td>
<td>San Francisco</td>
<td>744,230</td>
<td>370</td>
<td>11</td>
</tr>
<tr>
<td>6.</td>
<td>Philadelphia</td>
<td>1,470,151</td>
<td>336</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>Houston</td>
<td>2,012,626</td>
<td>331</td>
<td>6</td>
</tr>
<tr>
<td>8.</td>
<td>Washington</td>
<td>553,523</td>
<td>272</td>
<td>13</td>
</tr>
<tr>
<td>9.</td>
<td>Boston</td>
<td>569,165</td>
<td>245</td>
<td>12</td>
</tr>
<tr>
<td>10.</td>
<td>Dallas</td>
<td>1,208,318</td>
<td>241</td>
<td>7</td>
</tr>
<tr>
<td>11.</td>
<td>Miami</td>
<td>379,724</td>
<td>198</td>
<td>50</td>
</tr>
<tr>
<td>12.</td>
<td>Minneapolis</td>
<td>373,943</td>
<td>194</td>
<td>3</td>
</tr>
<tr>
<td>13.</td>
<td>Atlanta</td>
<td>419,122</td>
<td>193</td>
<td>13</td>
</tr>
<tr>
<td>14.</td>
<td>Seattle</td>
<td>571,480</td>
<td>180</td>
<td>9</td>
</tr>
<tr>
<td>15.</td>
<td>Denver</td>
<td>556,835</td>
<td>180</td>
<td>4</td>
</tr>
<tr>
<td>16.</td>
<td>Detroit</td>
<td>900,198</td>
<td>177</td>
<td>1</td>
</tr>
<tr>
<td>17.</td>
<td>Arlington</td>
<td>186,117</td>
<td>173</td>
<td>18</td>
</tr>
<tr>
<td>18.</td>
<td>Baltimore</td>
<td>636,251</td>
<td>154</td>
<td>4</td>
</tr>
<tr>
<td>19.</td>
<td>St. Louis</td>
<td>343,279</td>
<td>147</td>
<td>4</td>
</tr>
<tr>
<td>20.</td>
<td>Pittsburgh</td>
<td>322,450</td>
<td>144</td>
<td>3</td>
</tr>
</tbody>
</table>

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## How Many/How Tall

<table>
<thead>
<tr>
<th>Height in ft</th>
<th>NY (Completed Buildings)</th>
<th>Chicago (Completed Buildings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300-399</td>
<td>278</td>
<td>106</td>
</tr>
<tr>
<td>400-499</td>
<td>150</td>
<td>67</td>
</tr>
<tr>
<td>500-599</td>
<td>106</td>
<td>51</td>
</tr>
<tr>
<td>600-699</td>
<td>43</td>
<td>20</td>
</tr>
<tr>
<td>700-799</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>800-899</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>900+</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Rank</td>
<td>Tallest Building</td>
<td>City</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>Sears Tower</td>
<td>Chicago</td>
</tr>
<tr>
<td>2</td>
<td>Empire State Building</td>
<td>NYC</td>
</tr>
<tr>
<td>3</td>
<td>Bank of America Tower</td>
<td>NYC</td>
</tr>
<tr>
<td>4</td>
<td>Aon Center</td>
<td>Chicago</td>
</tr>
<tr>
<td>5</td>
<td>John Hancock Center</td>
<td>Chicago</td>
</tr>
<tr>
<td>6</td>
<td>Chrysler Building</td>
<td>NYC</td>
</tr>
<tr>
<td>7</td>
<td>New York Times Tower</td>
<td>NYC</td>
</tr>
<tr>
<td>8</td>
<td>Bank of America Plaza</td>
<td>Atlanta</td>
</tr>
<tr>
<td>9</td>
<td>US Bank Tower</td>
<td>Los Angeles</td>
</tr>
<tr>
<td>10</td>
<td>AT &amp; T Corporate Center</td>
<td>Chicago</td>
</tr>
<tr>
<td>11</td>
<td>JPMorgan Chase Tower</td>
<td>Houston</td>
</tr>
<tr>
<td>12</td>
<td>Two Prudential Plaza</td>
<td>Chicago</td>
</tr>
<tr>
<td>13</td>
<td>Wells Fargo Plaza</td>
<td>San Francisco</td>
</tr>
</tbody>
</table>
Typical Tall v. Ultra-Tall Bldg’s

• Water storage requirements for fire protection after 400 ft or 300-350 psi

• Once storing water for fire protection, it seems only natural to take advantage of this for domestic cold water

• Some system components rated at or above 300 psi are still difficult to find
Typical Tall v. Ultra-Tall Bldg’s

• Designing to the ultimate limit of a piece of equipment or component is against our conservative nature.

• Commonly recognized point of separation between tall and really tall is 500-600 ft (or correspondingly about 250-300 psi).

• Buildings close to or more than 1,000 ft are rare and respected.
Why Build so Tall?

• The first building that reached the 1000 ft level was the Empire State Building in New York, c. 1931
• Another building from that era, the Chrysler building, was nearly as tall
• These buildings were built to make a statement and prove a point, but also because they were designed during an era of economic prosperity

<table>
<thead>
<tr>
<th>Rank</th>
<th>Tallest Building</th>
<th>City</th>
<th>Height (FT)</th>
<th>Floors</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Empire State Building</td>
<td>NYC</td>
<td>1249</td>
<td>102</td>
<td>1931</td>
</tr>
<tr>
<td>6</td>
<td>Chrysler Building</td>
<td>NYC</td>
<td>1046</td>
<td>77</td>
<td>1930</td>
</tr>
</tbody>
</table>
1970’s Building Boom

- A similar circumstance occurred in the late 1960’s/early 1970’s, when 4 buildings of this magnitude were under construction simultaneously:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Tallest Building</th>
<th>City</th>
<th>Height (FT)</th>
<th>Floors</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sears Tower</td>
<td>Chicago</td>
<td>1454</td>
<td>108</td>
<td>1974</td>
</tr>
<tr>
<td>4</td>
<td>Aon Center</td>
<td>Chicago</td>
<td>1136</td>
<td>83</td>
<td>1973</td>
</tr>
<tr>
<td>5</td>
<td>John Hancock Center</td>
<td>Chicgo</td>
<td>1132</td>
<td>100</td>
<td>1969</td>
</tr>
<tr>
<td></td>
<td>One World Trade Center</td>
<td>NYC</td>
<td>1443</td>
<td>110</td>
<td>1973</td>
</tr>
</tbody>
</table>
John Hancock

- Completed in 1970
- 100-story mixed use complex of retail, offices and condos
- 49 floors of condos (top floors)
- Highest multi-functional high rise in the world
- Tallest building in Chicago from 1970-1973
- 1,132 ft (344 m) tall
Aon Building
(formerly Amoco and Standard Oil Building)

• Completed in 1973
• 82-story mixed use complex of retail and offices
• Originally the tallest marble clad structure in the world
• Tallest building in Chicago from 1973-1974
• 1,136 ft (345.3 m) tall
Sears Tower

- Completed in 1974
- 110-story mixed use complex of retail and offices
- Tallest building in the world from 1974-1997
- 1,454 ft (443m) tall
- 4.5 million square ft
- Original cost $150 million
Today’s Height Boom

• Many countries are looking to make a statement by building higher than they have before, even vying for the tallest building in the world
Waterview Tower

- Groundbreaking 2006
- Completion 2009
- 89-story mixed use complex of retail, hotel and condo
- 1,047 ft (319m) tall
- Parking floors 2-11
- Hotel Floors 12-27
- Condos floors 30-88
Waterview Tower

- Domestic water storage reservoirs on floors 27 and 88
- Tanks made from stainless steel
- Separate fire water reservoirs
- 8” CW express riser from LL2-27
- 6” CW express riser from 27-88
- 7 CW zones 27-88
- 4 CW zones LL-27
- Water heaters on floors 27 and 88
- 12” incoming CW
- 15” building sewer
Trump International Hotel and Tower

- Groundbreaking 2005
- Completion 2008
- 96-story mixed use complex of retail, hotel and condo
- 1,170 ft (356.9m) tall
- Parking floors 3-12
- Hotel Floors 17-27
- Condos floors 29-95
Trump International Hotel and Tower

- Domestic water storage reservoirs on floors LL and 50
- Tanks made from stainless steel
- Separate fire water reservoirs
- 12” CW express riser from LL-50
- 8” CW express riser from 50-90
- 8 CW zones LL-50
- 6 CW zones 50-90
- Water heaters on floors 28, 50 and 90
Chicago Spire

- Domestic water storage reservoirs on floors 39, 73 and 110
- Tanks made from stainless steel
- Combined domestic/fire water reservoirs (currently)
- CW distributed by gravity as well as pumped
- 24 CW zones
- Water heaters on floors 39, 73, 110 and 143
Trump International Hotel and Tower

Domestic water riser diagram showing expansion joints for hw and calculations for compression (GLPH)
Domestic water riser diagram showing upper zone reservoirs and pumps and lower zone water heaters.
Chicago Spire

- Groundbreaking 2007
- Completion 2011
- 149-story mixed use complex of retail, hotel and condo
- 2,000 ft (609.75m) tall
- Parking floors LL2-LL6
- Amenities/Mech 1-11
- Condos floors 12-141
Construction Considerations for Ultra-Tall Buildings

- Pipe expansion/Building Compression
  - Piping lengths of hundreds of ft will have significant expansion that must be accommodated
    - Expansion loops on HW and even CW express risers are needed
    - Some CW express risers handled by multiple cut groove fittings
Construction Considerations for Ultra-Tall Buildings

• Building will also compress as floors are added on top
  – Trump has an average compression of ¾” per floor

• Chicago uses hub and spigot cast iron with cork insert gaskets for lead and oakum joints.

• No-hub provides a means for expansion and contraction.

• Double gaskets and multiple short lengths are sometimes employed
Construction Considerations for Ultra-Tall Buildings

• Speed to market
  – The buildings under construction normally have a construction duration of 3 years or more
  – Sears tower was constructed on a round the clock schedule
  – Current plans for most buildings call for partial occupancy of lower floors before top floors are finished
Construction Considerations

- Code is not enough
  - Building codes do not address the needs of these type of buildings
  - Best practices must over rule developer mentality to assure success
  - Some practices such as embedding drainage pipe within slab questionable for buildings that likely have no limit to life expectancy
  - All high rise ultra-tall buildings provide significantly more than code minimum pressure at all floors (35-45 psi minimum, based on luxury fixture use)
Competition from Asia

• From the 1990s, the USA has had some stiff competition from Asia and in 1996 the title of world’s tallest building passed to the 88-story, 1483 ft Petronas Twin Towers in Kuala Lumpur, Malaysia.

• The completion of the 1667 ft Taipei 101 in Taipei, Taiwan, in 2004 means that the title remains in Asia now, but several new buildings, including One World Trade Center (Freedom Tower) in Lower Manhattan and the Burj Tower Dubai in the United Arab Emirates—whose final height will not be made public until it is completed—means that the crown is likely to change hands several times in the near future.
Tallest Freestanding Structure

• But no building standing today is as tall as the world’s tallest structure on land - the CN Tower in Toronto, Ontario, Canada.

• This communications tower is entirely freestanding and has no residential or office space. ‘Topped Out’ in April 1975, it measures a staggering 1815 ft 5 in.
The Future

• Skyscraper buffs will continue to argue which of the world’s architectural gems is the world’s tallest building.

• There are plans being drawn up all over the world for new ultra-tall buildings.
Closing Thoughts

- Significant changes in design of buildings have been driven by technology and equipment advances, this is equally true for plumbing.
- Every now and then a great or simple idea comes along that seems better than what was previously done.
- The boom in high rise building construction including ultra-high rise buildings may be nearing an end, and may not return for some time based on historical data.
- Code is not a design guide, as engineers we must protect the long term interests of the building.
- **Expand your horizons, Nothing is impossible.**
What are the biggest challenges facing anyone planning to build the tallest building in the world?

- One of the biggest challenges is moving people around. The amount of space the elevators consume as a ratio of the floor that’s remaining to be leased. As you go taller and taller, you need more and more elevators to get people up and down, and at some point—roughly around 80 stories— the floor area consumed by the elevators is so great that the area remaining to lease is too small to make the building economically viable. So one of the technical challenges is advances in elevator technology.
Who makes the decision on the tallest building for CTBUH? (CTBUH = Council on Tall Buildings & Urban Habitat)

- There is a committee of about a dozen people and is made up of architects and engineers from around the world.
Amman High Rise Buildings Conference
Mechanical / Electrical Systems Overview

Presented by
Shef L. Emam, P.E.
Vice President/Managing Director
DESIGN BRIEF

• In Today’s Competitive Economy, Developers are Finding Themselves Having to Offer International Class Luxury Developments to Their Customers (Residential and/or Commercial).

• The Apartments are Typically Designed as Core and Shell Only to Permit Maximum Flexibility for Custom Tenant Fit-Out.

• Commercial and Retail Spaces are Also Typically Designed as Core and Shell.
Use of Plastic Pipe

- Some believe that plastic pipe should never be used in high rise construction.
- Many projects have used plastic successfully.
- Must follow the requirements for the material.
The Advent of Skyscrapers

• During the early 20th century, the USA dominated the race to be the home of the world’s tallest building.

• New York is still the most famous home of the ‘skyscraper,’ as these giants became known. New York’s tallest ever buildings were the Twin Towers of World, dedicated in 1973 but destroyed in the terrorist atrocity of September 11, 2001. The north tower was the taller of the two and stood an amazing 1368 ft high.

• The World Trade Center was the tallest building for a relatively short time, as in 1974, Chicago’s Sears Tower was completed and took the title. Sears held on to that record for over 20 years.
Foundations

• Built as a tomb for a god-king, Egypt’s Great Pyramid at Giza was probably the world’s tallest building (220 ft) for 3500 years, from 2500 BC until the construction of the great European cathedrals in the Middle Ages.

• The modern era of tall buildings was heralded by the completion in 1889 of the 1023 ft height Eiffel Tower in Paris. And from La Tour Eiffel onward, it has been big business rather than religion, that has driven the construction of ever taller buildings.

• There is an enormous prestige attached to being the home of the world’s tallest structure.
Pyramid of Djoser

- (c. 2700- c. 2600 BCE)
- Located in Egypt’s Saqqara Necropolis and built for the eponymous pharaoh in the 27th century BCE, this pyramid reached 203 ft in height or about the same as that of the sculpted heads of the four US presidents immortalized on Mount Rushmore. In around 2600 BCE, it was superseded by the Red Pyramid of Sneferu.
Red Pyramid of Sneferu

• (c. 2600-2560 BCE)
• So called because of the pinkish limestone from which it is constructed, this 341 ft pyramid is one of three at the Dahshur Necropolis in Egypt. Built by the fourth dynasty pharaoh Sneferu, who ruled c. 2613-2589 BCE, it remained the world’s tallest man-made structure until overtaken by the Great Pyramid of Giza.
Great Pyramid of Giza

- (c. 2560 BCE 1311)
- Egypt’s largest pyramid once rose to 479 ft, though erosion now reduced its height. Also known as the Pyramid of Cheops it is one of three pyramids at the Giza Necropolis near Cairo Egypt. Completed c. 2560 BCE it was the world’s tallest structure for more than 3800 years until the erection of the Lincoln Cathedral.
St. Olaf’s Church

- (1549-1625)
- Dating from the 12th century and located in Tallinn, Estonia, St. Olaf’s Church was the tallest building in the world from 1549 to 1625 when St. Mary’s Church in Stralsund claimed the throne. It was originally 522 ft tall; after repeated lightening strikes and reconstructions, today it reaches only 404 ft.
How does the CTBUH define the height of a building?

• Height of a building is measured from the elevation of the main entrance of the building to the top of the architecture.
• Must interpret what the ‘top of the architecture’ is. For the Sears Tower, it’s the elevation of the main flat roof.