Title: **Supertall Buildings Infrastructure: Designing Vertical Cities**

Author: Mehdi Jalayerian, Executive Vice President, Environmental Systems Design, Inc.

Subjects: Fire & Safety
MEP

Keywords: MEP
Stack Effect
Supertall
Sustainability
Zoning

Publication Date: 2014

Original Publication: CTBUH 2014 Shanghai Conference Proceedings

Paper Type:
1. Book chapter/Part chapter
2. Journal paper
3. **Conference proceeding**
4. Unpublished conference paper
5. Magazine article
6. Unpublished

Supertall Buildings Infrastructure: Designing Vertical Cities
超高层建筑基础系统设施: 垂直城市设计


Mehdi Jalayerian

Mehdi Jalayerian

ESD (Environmental Systems Design, Inc.)
175 West Jackson Blvd. Suite 1400
Chicago, Illinois
60604 USA

tel (电话): +1 312.456.2268
fax (传真): +1 312.372.1222
email (电子邮箱): mjalayerian@esdglobal.com
www.esdglobal.com

Mehdi Jalayerian is Executive Vice President and Global Projects/High Performance Buildings Practice Leader for ESD (Environmental Systems Design), providing worldwide consulting services for supertall and high-rise buildings, assembly, convention/hotel, mission critical, healthcare, and education/government projects. He is a Registered Professional Engineer with over eight ASHRAE Excellence in Engineering and Technology Awards, an Illinois Council Award, and a Chicago Building Congress Award. Mehdi has over 30 years of experience in the sustainable design practice and is a member of the Advisory Group for the Council of Tall Buildings and Urban Habitat.

Mehdi Jalayerian 在美国环境系统设计公司 (Environmental Systems Design) 担任执行副总裁兼全球项目/高效能建筑系统工程设计指导。Mehdi 职责包括提供全球项目的咨询服务，其领域涵盖超高层和高层建筑、综合楼宇、会展中心/酒店、大型数据库中心等关键业务系统、医疗保健和教育/政府等项目。Mehdi是专业注册工程师，荣获由美国采暖、制冷与空调工程师学会 (ASHRAE) 颁布的八个国家级卓越工程技术奖，芝加哥地区委员会奖，以及芝加哥建筑委员会奖。Mehdi在可持续设计领域内拥有超过30年的行业经验，他亦是美国高层建筑及城市用地委员会咨询顾问中的一员。

Abstract

This paper explores the methodology behind designing a supertall building where it concerns system configurations that support sustainable construction; the ways in which the design interacts with the environment; coordinating within the limits of the manufactured products available for MEP infrastructure; and responding to regional climatic and building code requirements. It will provide discourse on some of the top concerns within supertall building design including system pressures and an electrical design capable of efficiently and economically distributing power to all parts of the building while exploring why the architectural space planning, building riser shafts, and MEP design must take into account these unique challenges. Efficiency comes from the development itself – the environment, the structural components, the configuration, the organization of building systems, and how they are envisioned to work with each other. The paper concludes that an integrated design process is the foundation of an effective, economical, and sustainable supertall building development.

Keywords: Supertall, Engineering, Stack Effect, MEP/FP Systems, Zoning, Sustainability

摘要

本文旨在探讨对于潜舍在超高层建筑中可持续性建筑的基础系统设施配置的设计方法，涵盖设计与建筑地区环境互动性能方法、机电系统设施与当地可利用的制造产品之间的协调搭配，以及当地气候和相关建筑规范要求及解决方法。本文涉及部分超高层建筑设计的热门话题，其中包括系统压力和电力设计如何能够有效地和经济地将电力运送到建筑内的各个部位。文章还探讨了机械在建筑空间规划期间、布置工程系统竖井时，以及在机电水暖设计时一定要考虑到上述这些特殊环节的重要原因。工程系统的高效率来源于系统发展本身 – 其中包括环境、结构组件、建筑布局、工程系统规划，以及如何协调这些因素。文章最终结论是: 一个整体综合的设计过程是高效、经济、可持续型性高层建筑工程设计的基础。

关键词: 超高层，建筑系统工程，烟囱效应，暖通、电气、给排水/消防系统，建筑分区，可持续性

MEP Infrastructure Of Supertalls

It's a common misconception that supertall buildings are not sustainable. Consumed with the thought of how much energy it must take to support such a large structure, people overlook the embedded opportunities of building vertically. The tendency for tall buildings to adapt to mixed-use occupancies and act as catalysts for further community development concentrates urban planning into a high-density environment that by its nature is sustainable. Not only do they conserve land resources, they also present opportunities for efficiency through load shifts that take place between day and night operational spaces – corporate or retail spaces versus residential units, for example. A mixed-use tall building development that provides and encourages a combined work-live environment reduces transportation and infrastructure utilities cost and energy consumption. Instead of presenting a barrier, supertall building design, when accomplished

超高层建筑的机电水暖基础设施工程系统

对于超高层建筑总有一种误解，普遍认为超高层建筑是不可持续的。人们误认为超高层建筑会消耗大量能源才能支持其硕大的建筑结构体，但是却忽略了在垂直建筑中的内在机遇。高层建筑的设计理念初衷是适应混合型居住使用功能，并作为社区发展中将城市规划为高密度生活环境的催化剂，而这一设计初衷本身即是可持续性的。高层建筑不仅保留了土地资源，楼宇由于日夜机电负载交替运行使得机电系统在运作方面充分体现了高效运营的效果，例如企业公司区或者零售商埠区以及生活居住区相替运营。一个综合使用的高层建筑可以提供一种工作与生活相结合的环境，以减少由于交通和市政基础设施产生的成本及能源消耗。通过工程、规划和建筑功能一体化后，超高层建筑设计可以成为可持续发展的林荫大道，而不是阻碍。

现在全球对于高层建筑的结构技术和设计趋势已有广泛的发展研究，但同时也局限在建筑多高会被认为过高而影响内部系统的设计。超高层建筑的暖通、电力、给排

through the integration of engineering, planning and architecture can be an avenue for sustainability.

There have been many developments worldwide concerning the structural technologies and design trends of tall buildings, but the limitations to how tall is too tall extend to the systems within the building as well. The mechanical, electrical, plumbing, and fire protection (MEP/FP) systems of supertall buildings present challenges for designers as they consider maximum system loads, system capabilities, system operating pressures, and the overall feasibility of constructing and efficiently maintaining taller structures.

More than just an addition of height, every supertall building takes the previously advanced systems of its predecessors to the next level. The designers work with the manufacturing and construction groups to advance the capabilities of the system components to make sure the project remains feasible. One of the greatest challenges of designing supertall buildings is controlling water system pressure, specifically in the piping design, due to the increased weight of water column caused by the extreme vertical heights. Take Jeddah's Kingdom Tower, which will stand at over 1,000 meters tall when completed and will contain more than 400kms of building services piping. As the vertical piping extends higher and higher, dangerous levels of pressure can be exerted on the vertical piping and associated equipment and fittings by the weight of the water column and pumping forces – the Kingdom Tower height represents water column pressures in excess of 100 bars or 1,450 psi.

MEP systems designers can only work within the limits of the infrastructure components available in the market. The current MEP systems design approach for supertall buildings must consider smaller vertical zones to manage the imposed system pressures and efficiently adapt to occupancy requirements. Vertical zoning enables designers to design according to the limitations of the available equipment. By creating smaller vertical zones in buildings such as Kingdom Tower, the pressure can be distributed and isolated.

Zoning supports another sustainable practice for supertall construction: the standardization of building systems and their components and a repetitive design to facilitate a lean construction process. The benefits of standardization correlate to those of economies of scale, for when units can be produced on a large scale, production costs are more likely to decrease and less excess material is wasted. This sustainability practice is also exercised in the extension of the medium-voltage primary distribution to as close as possible to the load center. On the other hand, choosing to use variations of air handler units, heat exchangers, pumps, pipes, switchboards, electrical panels, and horizontal system distribution on each floor, for example, not only increases the production and installation costs, it increases the risk of creating future troubleshooting confusion for the building engineers.

Supertall structures lend themselves to standardization and zoning through their natural mixed-use organizations. The different occupancies of these structures – office, retail, and hotel and residences – work with isolated systems and naturally designate zones within the building's structure. In terms of MEP infrastructure, it works well to think of a supertall as a vertical city, or a collection of 20- to 40-story buildings stacked on top of one another (Figure 2). Due to this zoned approach of accommodating various occupancy levels supplied through a centralized primary source of cooling, the overall primary cooling capacity and total energy demand can be reduced by as much as 25%.

Figure 1. Kingdom Tower (Source: AS+GG)
图1. 王国塔 (出自: AS+GG)

水和消防系统 (MEP/FP) 的设计为工程师们带来许多挑战，工程师需要考虑系统最大负荷、暖通系统设备容量、水系统运行压力，以及超高层建筑的建造及有效运营的单体可行性。

不仅仅是高度的增加，每一个超高层建筑都将它前辈的先进系统推向另一个高度。工程师与制造厂商以及建筑师团队合作，来提高系统设备功能，以确保项目的可行性。超高层建筑设计的最大挑战之一是控制水系统的压力，而这一挑战特别体现在在管道设计的环节中超高垂直高度所引起的静水压力的增加。例如吉达的王国塔，当王国塔建成后，该塔将高出地面1000米，并拥有超过40万米长的建筑管道系统。由于主要管道的垂直高度，静水压力水泵动压会对垂直管道以设备，配件产生各种压力危险，例如王国塔的整体高度意味着超过100巴 (bar) 或1450 磅/平方英寸 (psi) 的水力静压。

机电水暖系统的工程师根据现有市场上的设备产品，在现有的设备允许的运行负荷范围内采取相应系统设计。目前超高层建筑的机电水暖系统设计方法必须进行系统的垂直分区来减小系统压力的工作，同时又有效地满足用户端使用需求。垂直分区可以使工程师根据现有设备的承压等级进行设计。例如王国塔，通过在塔上创建更小规模的垂直区域，压力就可以被分散和隔离开。

分区设计在超高层建筑上的另一个可持续设计的实践做法: 各区建筑工程系统及其设备的标准化，及这些标准化系统的可重复性设计施工可以建造流畅精准的经济模具。当系统可被大批量

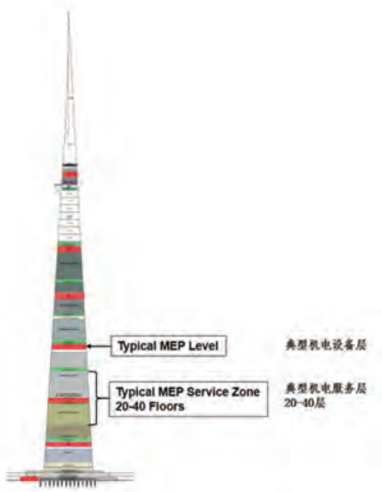

Figure 2. Vertical Zones (Source: ESD)
图2. 机电系统垂直分布 (出自: ESD)

At some future date, new technologies will need to be developed to support the construction of the next supertall because the water pressures will be too great. This is particularly relevant for products designed for residential units which are not designed to withstand significant amounts of water column pressure.

Configuration and Organization

Aesthetic design is generally a primary requirement for a successful supertall building. These structures are highly visible and statements to be admired in their city skylines. The rising perception on these tall buildings, however, is that the best aesthetic designs work alongside elements of nature – the sun and wind, for example – to produce sustainable solutions. Integrating sustainable design solutions into an aesthetically appealing development can be challenging and requires early project integration of all team members, including the MEP/FP design consultant. MEP system integration and building configuration are necessary during the planning and design stages of a project as the development, configuration, and organization of the building each influence the building loads and the overall efficiency of the building.

The shape of the building has a lot to do with reducing its environmental impact. Super high-rises, due to their high surface to volume ratio, interact significantly with the outside environment, in particular solar energy and temperature. Orientation and configuration should be decided together – for neither can be truly optimized without the other – and early on in the design process, taking into consideration the geographical environment of the building and the existing infrastructure of the building area. In the Middle East, for example, designers avoid large east and west facing façades because of the low and harsh morning and afternoon sunlight. Kingdom Tower is oriented so the façades align instead from the northeast and northwest, reducing the overall solar load. The orientation was also influenced by the culture of the building's environment as one of the tower's wings points toward Mecca. Close collaboration between the architects and MEP designers can also enhance high-performance aspects of the building façade, from wall design to glass performance to wind and airflow effects around the building.

At higher altitudes the outdoor environment temperature is cooler and less humid when compared to sea level. Due to moisture content of outdoor air, the variation of outdoor temperature due to altitude is slightly different for arctic versus desert or tropical zones. Supertall developments offer energy reduction opportunities for HVAC systems associated with air conditioning zones located in higher elevations (Figure 4). For Kingdom Tower, the fresh air cooling energy requirement is 40% lower for the topmost air conditioning zone than the zone at grade level. Similarly, the heat gain from outdoor environment temperature is 30% lower for the topmost spaces as compared to spaces at lowest portion of tower.

Stack Effect

The quantity of uncontrolled ventilation in a building is influenced by indoor-outdoor temperature difference, wind velocity, wind direction, height of the building, and building design. A major contributor is the phenomenon known as stack effect. Stack effect is driven by thermal buoyancy, when the less dense air inside buildings rises to escape from the upper portion of the building. In warmer climates, the process is

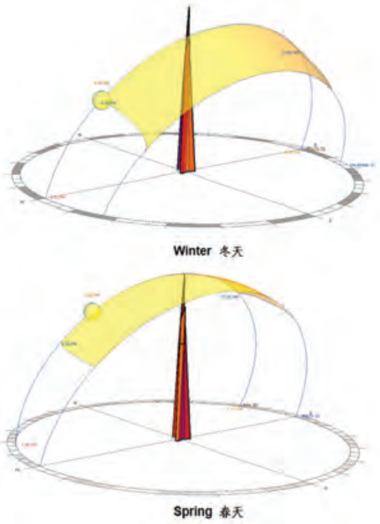

Figure 3. Solar Orientation (Source: ESD)
图3. 日光角度和辐射热 (出自: ESD)

重复施工时，标准化有助于规模经济生产，这意味着建材成本的降低，以及施工建材更为经济化地使用。这种可持续设计也实施在电力设备中，其可将中压电输送到尽可能接近负载中心的使用区。相反，如果选择使用不同种类的空调机组、热交换器、泵、管道系统、开关柜、配电盘，及每层采用横向输配系统，不仅将增加生产和安装成本，还会给未来楼宇维护技师增添故障排除的不确定性。

超高层建筑通过其自身混合功用的建筑特性来实现标准化和分区设计的理念。利用超高建筑的使用功能分区来设计相应的机电系统，例如办公区、商户区、酒店区和住宅区均有其它对应的独立机电水暖消防系统。就机电系统的设施而言，可以将超高层建筑很好的理解为一个垂直的城市，或者是多个20层到40层普通高层建筑所叠加而成的更高层建筑 (图2) 。为了满足不同用户的需求，分区设计的理念可采用不同功能区共享中央冷源的方式，总体冷负荷和总的能源消耗可减少25%。

对于相关超高静水压问题，将有待未来高科技产品的研发制造才能得以解决。尤其对那些为住宅所设计的产品，这些产品不能承受更高的水压。

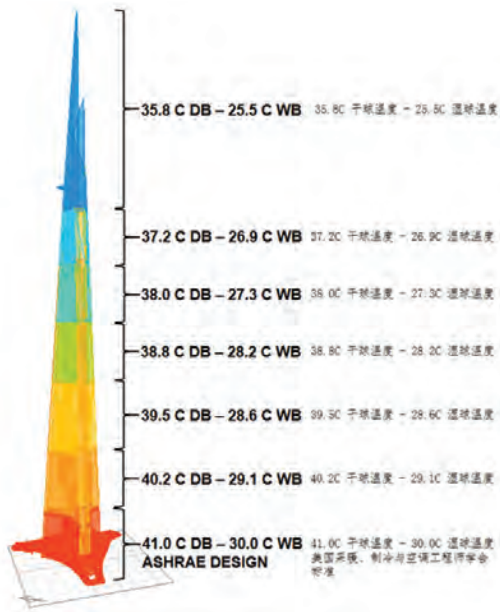

Figure 4. Vertical Design Temperature (Source: ESD)
图4. 垂直温度梯度分布 (出自: ESD)

reversed. Uncontrolled ventilation air flow in high-rise buildings has the potential to significantly increase building energy use and adversely impact the mechanical system operations. Therefore, the configuration, orientation, and space planning of the building must take all of this into account to optimize its effect.

For Kingdom Tower, vertical zoning of the air systems and building risers, introduction of air locks at the main lobbies and sky lobbies, as well as maintaining a minimum of two air separation barriers between the building shafts and the exterior on typical floors provided a design approach with the highest degree of air infiltration control.

Vertical zoning and effective infiltration control also helps mitigate the properties of stack effect by reducing the pressure differential and controlling the movement of air throughout the building. It is common for tall buildings to use the unoccupied, structural cross-bracing or reinforcing floors to house the main MEP systems servicing the vertical zones of the building. This is another example of the need for early integration of MEP, structural, and architectural design. The mechanical rooms of the top mechanical zones in Kingdom Tower will align plenum intakes to take full advantage of wind speeds, thus reducing the energy consumption of the mechanical equipment. Similarly, exhausted air will be focused downstream to assist in the removal of unwanted air.

Kingdom Tower's distinctive spire, while unoccupied, needs to be maintained and ventilated as well. It is designed to utilize its microenvironment – consisting of increased wind speeds, lower outside air temperatures, and reduced air density – to passively cool itself and maintain structurally required rate of temperature rise. The air is brought in at the base of the spire just above the sky raft (at approximately +680m elevation) and ventilated out the top portion of the spire at approximately +980m elevation. The system includes air control dampers to limit daily temperature variation (range) to below 10 C (18oF). Taking advantage of solar heat gain and day-time/night-time temperature variation, the slopped vertical walls of the spire facilitate and expedite vertical air buoyancy movement on the building surface, and therefore improve the cooling effect on the exterior wall and ultimately the interior spire volume (Figure 5).

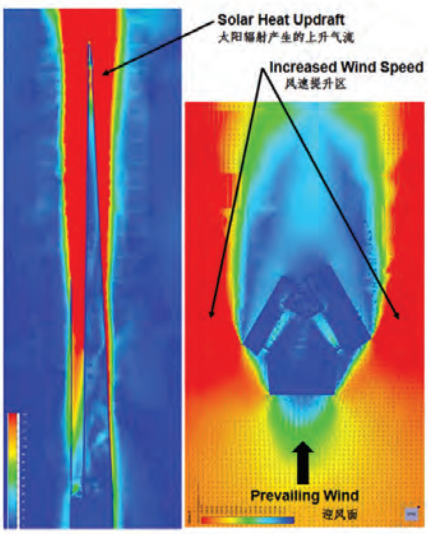

Figure 5. Spire Solar Heat Flux and Wind Flow (Source: ESD)
图5. 螺旋顶阳光热辐射通量和风速分布区 (出自: ESD)

结构和组织

美学设计对于成功的超高层建筑而言通常是首要要求。这些标志性建筑在其城市的天际线上遥望可见。而另一个最重要的建筑美学构想是，这些日益瞩目的高层建筑应是最好的建筑美学设计与阳光和风等自然元素一起结合所产生的可持续设计结果。将可持续设计方法与美观设计相结合是具有挑战的，同时这也要求建筑和工程等所有团队成员在早期设计环节中的整体配合，其中机电水暖/消防设计的参与是必不可少的。在项目规划和设计的阶段，有必要使机电水暖系统与建筑布局规划整体合一，这会对于整体建筑的开发、布局、使用区组成规划产生重要影响，甚至可能会直接影响到建筑总机电系统的负荷和今后运营维护的效率。

建筑体的形状对于减少建筑对环境的影响有很大的作用。由于建筑表面积相对体积的高比例，特别是在日光辐射和温度上，超高层建筑对外界环境有显著影响。由于建筑朝向和结构要相互依赖才能进行最优化设计，所以在早期设计环节时，这两方面应该同时考虑，其他考虑因素也包括建筑的地理环境和建造地区的现有市政管网电气等基础设施。例如在中东地区，由于早晨和下午期间日光辐射强度的剧烈变化，工程师们要避免建筑物幕墙大面积的朝东和朝西朝向。王国塔主体幕墙是设计为东北和东西朝向的，从而减少整体的太阳辐射。建筑物的朝向同时也受当地环境文化影响，因此王国塔的其中一个主翼指向麦加。建筑师和机电工程师之间的紧密合作也确保了建筑幕墙的高性能，这包括从建筑墙体设计到建筑幕墙玻璃性能设计，以及风速和气流对整体建筑的影响。

与位于海平面地区相比，高海拔地区室外空气气温会更低更干燥。对沙漠和热带地区而言，由于饱和蒸汽压不同而造成的室外空气温度差异与由海拔差异造成的气温变化是有差别的。超高层建筑为采暖空调系统带来了节能减排的机会，而坐落在相对更高海拔地区的空调服务区地处于不同的室外气温环境中 (图4) 。例如王国塔，在顶层空调区，新风冷量负荷要比底层区域减少40%。同样，塔楼顶层空间来自室外环境的得热比底层空间减少30%。

烟囱效应

造成烟囱效应的主要原因是，受室内室外的温差、风速、风向、建筑物的高度和建筑结构设计等因素所影响，建筑内部产生了部分难以控制的通风量。烟囱效应是由在建筑内密度较小的空气上升到建筑上部后由空气热浮力效应所产生的空气加强对流现象。在温暖气候带，烟囱效应气流方向与上述过程全然相反。高层建筑内不可控制的大量气流会造成大量建筑能源耗损，并同时对空调系统运行造成不利影响。因此，需把建筑的造型、建筑朝向和空间设计全部且综合的进行综合考虑，才能达到优化效果。

对于王国塔而言，竖向空调分区和垂直立管，主入口和空中大堂引用气闸 (门斗) ，以及在竖井和建筑外围护结构之间至少设2道空气隔绝措施这些设计措施有效地防止了空气外墙渗透现象。

竖向分区和有效的防渗透设计 (建筑气密性设计) 也有助于通过减小压差，控制建筑内气流运动等方式减小烟囱效应。在高层建筑里，常常会利用闲置空间、结构斜撑架、或者结构加强层，作为服务竖向分区的主要机电系统管道井及输送系统。这也是另一个需要在早期设计中将机电系统、结构和建筑功能融为一体的例子。王国塔内高层机电层的空调机组新风摄入区将充分利用高层迎风面风速，从而减少风机设备的能源耗损。同样地，将排风安排在下风向处以排除废气，也有助于提高设备运行效率。

不管是入住与否，独特的王国塔螺旋顶也需要维护和保持通风。工程师们充分使用高层外部的高速风速、室外空气的相对低温，

A Closer Look at Kingdom Tower

Along with the optimized and controlled stack effect, Kingdom Tower's air-side economizer system will cool the building using outside air, producing an effective and free cooling opportunity during cool climatic conditions. The energy recovery fresh air systems will recover the coolness from the used air and reuse it to cool the new air being ventilated through the space. The air conditioning condensate recovery system will remove and collect up to 65,000 liters of water from the air's natural humidity for irrigation and other purposes within the building.

One of the most common mistakes in supertall building design is the assumption that all life-safety loads need to be running simultaneously on the emergency / standby generator plant instead of just considering what's necessary for the worst-case scenario. The electrical system sizing for mixed-use occupancies can include diversities that provide for most economical installation tailored specially to the needs of the building operation.

The same mistakes can be made concerning the water system. Kingdom Tower will utilize a gravity distributed domestic water and fire protection system, made possible due to the residential component's non-constant use of water. This system increases efficiencies by using gravitational forces rather than constantly running pumps to distribute the water from storage tanks in the higher levels of the building. Water storage tanks located strategically in upper level mechanical spaces reduce pumping system energy requirements for both normal occupancy as well as emergency fire-fighting operations.

Kingdom Tower incorporated enhancements in the design of its fire protection system compared to previous supertall buildings. Beyond the manually operated gravity feed, the systems include redundant sprinkler supply via a looped floor system fed from two risers and provisions for combined standby fire pumps.

Generally, fire and life-safety codes do not cover all provisions for the construction of a supertall. Stretching buildings to new heights previously unimagined means there are no codes anywhere in the world that describe exact applications for these buildings. For this reason, one responsibility of the design team is to work with local authorities – building authorities, utility companies, and fire brigades – to create a better understanding of how the building systems need to work and how the latest international code models can be taken to the next level and made applicable to new projects. The resulting designs incorporate best international codes and standards practices and anticipate subsequent local code changes.

Kingdom Tower will also incorporate the latest technology of vertical transportation which uses both single-deck and double-deck elevators to shuttle occupants and visitors to the designated sky lobbies for efficient transportation throughout the building's many floors. These sky lobbies will contain separate elevator banks to distribute transportation, again localizing the building systems and aligning with the vertical city concept. The express elevator shuttles between the main lobby and the sky lobbies and local zoned elevators can be compared to public transportation efficiencies in major city hubs and local neighborhoods. Shuttle elevators are also utilized as life boats for rapid evacuation of occupants in an emergency event.

以及相对低密度的空气等微观环境来对王国塔螺旋顶进行被动散热处理，并同时使其保持结构构件上所需要的温升速率。新风从厚承台 (筏板) 上部 (680米高) 与螺旋顶底部之间区域进入，在大约980米高的螺旋塔顶部排出。该通风系统包括空气控制阀门，用以控制顶部每日温差在10摄氏度 (18华氏度) 之间。充分利用了阳光热辐射以及昼夜的温差，倾斜的塔尖和立墙更促进了建筑物表面的垂直空气流动，从而提高了对外墙的冷却效应，最终达到冷却螺旋顶内部的效果 (图5) 。

王国塔近观

随着优化和可掌控的烟囱效应，王国塔的空气节能器系统在过渡季气候凉爽气温时通过外部空气来冷却建筑内部，从而充分使用非机械制冷系统达到冷却效果且节约能源。新风系统能源回收可通过排风与新风间的焓盘式热交换器进行回收，从而减少新风冷负荷荷载。空调系统中凝结水回收系统通过冷冻水处理空气来回收高达65,000公升的水，用以灌溉及满足其他建筑内用水。

在超高层建筑设计中的一个常见错误是假设认为各个消防运行负载必须要由紧急/备用发电机同时供给运行，而不是考虑仅在最紧急情况下最恶劣状况中所需要的相关装备负荷。混合用途的建筑的电力系统负荷可以针对建筑多元化运行的特定需要，来选择最为经济的设备运行负载系统。

同样的错误也会发生在水系统上。王国塔在生活给水和消防供水中采用了重力输配系统，非机械送水这一设计理念是在考虑到住宅部分非连续性用水的现实。此系统通过使用重力，而非机械运行的给水泵，高效地将水从位于高层的储水箱分配到下层用水区。储水箱独具匠心的被放置在双层设备层的上层，从而减少正常情况和消防时由于泵运行所需要的能源。

与以往超高层建筑相比，王国塔特别增强了其在消防系统上的设计。除了非机械重力供水外，该系统还包括了备用喷洒系统，该喷洒系统与非机械给水系统并联并且共享一个公用备用立管而组成由给水消防泵和非机械给水共组的可信赖消防给水及备用系统。

一般情况下，消防规范并不涵盖所有相关的超高层建筑条款。将建筑提高到从没有想像过的实际高度意味着世界上没有任何规范条款可以准确的规定相关系统在建筑中是应该如何被设计并运行的。因此，设计团队的一项任务是与当地部门合作，其中包括建筑主管部门、市政部门、消防部门，从而更好地理解建筑系统和运行的特点，并在遵守当地规范的同时又探索如何将最新的国际规范应用到新项目中，以使新项目可以在设计上迈进更新的领域。上述措施可结合最好的国际规范和标准，并可有望给当地规范带来改变。

王国塔将会引进最新的垂直交通技术: 即采用了单轿厢和双轿厢电梯将用户和游客直接运送到相应的多个空中大堂。这些空中大堂将拥有相对独立的电梯组分配交通，而这也再一次体现了集中建筑系统和建造垂直城市的设计概念。连接主体大堂和各空中大堂的高速区间电梯及各分区电梯均可以与当地主要城市和各社区的相应公共交通的效率相媲美。区间电梯同时也可用作紧急情况下的用户撤离救生艇。

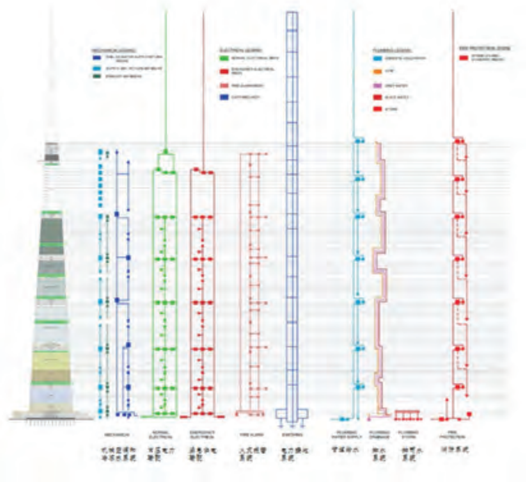

Figure 6. Building Systems Configuration (Source: ESD)
图6. 机电给排水消防系统结构 (出自: ESD)

Figure 7. Typical Mechanical Level (Source: ESD)
图7. 典型设备层 (出自: ESD)

Conclusion

The successful development of a supertall starts with the early coordination and collaboration of all disciplines in the design phase. There are a multitude of considerations that can contribute to the building's sustainability and efficiency, and the ability of the structure's shape, orientation, and configuration to work with its MEP systems can optimize the effects of influencers such as stack effect. Standardization of MEP system components allows for cost effective procurement and efficient and consistent quality construction. Variation of outdoor environmental design conditions due to altitude provides a significant opportunity for energy efficiency and operational cost savings. Zoning the building with dedicated systems for each occupancy allows for this optimization and calls for the integrating of disciplines throughout design. The systems need to work together to support load centers and provide reliability as well as be integrated with the architecture and space plan to support occupancy and life safety concerns. Sustainable design cannot occur in a vacuum. It is an integrated process through and through.

结论

一个超高层建筑的成功开始于设计早期阶段所有设计部门的合作协调。多种因素有助于建筑的可持续性和高效性设计，而建筑外形、朝向、高度和体型与机电水暖系统消防系统结构的结合设计可优化建筑设计，诸如烟囱效应的控制。机电水暖消防系统结构的标准化有助于成本效益高的建材采购以及高质量且可持续的施工。由于建筑本身造成的海拔原因，室外环境的变化给机电系统的设计提供了高效能源利用和运行成本节约的机会。根据建筑的功能分区进行机电系统的分区也为设计优化提供了可能，但同时在整个设计中也需要所有设计部门的协调。整个机电水暖消防系统需要共同合作才能支持各个建筑分区的负载，保证系统运行可靠性，只有将建筑设计和空间规划相结合才能确保用户的生命安全。可持续性设计不会凭空发生，它是一个整体综合的设计过程。