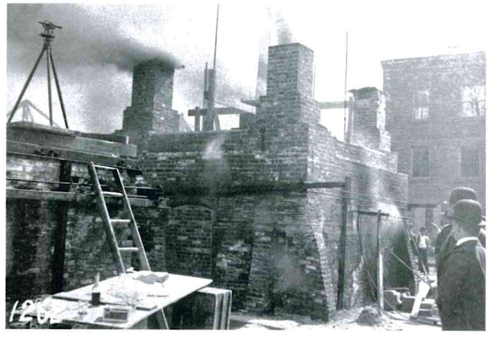

Fig. 5.9
Top of 11' x 14' Guastavino vault prior to a fire test, New York City, 1897

Fig. 5.10
Completed tile vault with Guastavino Sr. (second from left) prior to the fire test

Fig. 5.11
During the fire test, a temperature of 2,000 degrees was maintained for four hours

Fig. 5.12
After the fire test, the tile vault was safely loaded with 600 pounds per square foot

In 1897, the Guastavino Company carried out a particularly important fire test for the New York City Department of Buildings, which was published in the trade journal *The Brickbuilder* the same year.[11] [**Figs. 5.9–5.12**] Such tests established the strength and fire resistance of Guastavino vaulting, and they served as the primary confirmation of the safety of the building method. As yet, no calculations were required to prove the integrity of such a system. When, one hundred years later in 1997, a fire in the Oyster Bar of Grand Central Terminal (1912), New York City, caused hundreds of tiles to delaminate from the ceiling, engineers cited the 1897 test as proof that the fire-damaged vaults still had significant load capacity.[12] It was common in the nineteenth century for construction practice to proceed in advance of structural theory, and this was certainly the case for many of the daring structures built by the Guastavino Company.[13]

In the 1920s, the Guastavino Company, lacking suitable calculation methods, had to create complicated testing procedures to satisfy engineers that its domes could carry heavy wind and snow loads.[14] At this point, detailed building codes had been developed and implemented across the United States, which often called for calculations that could only be performed on steel- and concrete-framed structures. Guastavino's vaults were covered by a clause in the new building regulations that stated that "The use of any material already fabricated or of any construction already erected... shall be permitted"; but certainly these codes, and the rise of the structural engineering profession, also threatened future opportunities for the Guastavino Company.[15]

Innovations in Tile Vaulting

To compete economically and to anticipate the needs of architects, it was essential for the company to make technical innovations. The company adapted to the architectural demands of the period, such as fireproofing, soundproofing, sanitation, and decorative effects for varying architectural styles. The patenting of their innovations allowed the Guastavino Company to transform the traditional Spanish vaulting system into a signature product: the Guastavino System. By the early twentieth century, they had developed their vaulting systems substantially beyond the traditional Spanish tile vault in order to adapt to the realities of the American construction market.

The father and son earned a total of twenty-four U.S. patents detailing new developments and protecting the company system from competition. At its height, the Guastavino Company controlled the entire tile-vaulting construction process, from manufacturing tiles to installing vaults in the building. For this reason, it had a financial interest in optimizing the entire process, and constantly sought improvements in construction. Many of its patents focused on construction details, which improved the economics, durability, and speed of construction. The patents not only provide direct insight into the evolution of the Guastavino system, but also proved essential in securing the confidence of potential clients.

How original were their patents? The "fireproof" vaulted stair in Guastavino Sr.'s second patent would have been very familiar to builders in Spain in the 1880s. However, his stair differs from a traditional Spanish vaulted stair in two important ways. Firstly, Guastavino specified a piece of angle iron in two locations as a secondary means of reinforcing the stair. Secondly, Guastavino specified the use of Portland cement, which, in combination with the careful attention paid to "breaking" the joints, was thought to create greater "cohesion" or tensile capacity in the material. Though some builders may have been using such a system in Spain at the time, Guastavino appears to have been the first to treat it as a modern, standardized system, using new materials and rigorously detailing the construction methods. Guastavino father and son extended the traditional tile vault further than any previous builder in terms of material, structure, and construction. They each made substantial contributions to the development of the traditional tile vault as an engineered structural system.

The use of metallic reinforcing as an integral part of the construction system constituted a structural innovation for the traditional vaulting system. The father introduced metallic reinforcing to tile vaulting in the 1880s and possibly earlier. In 1910, the son received a patent for reinforced masonry in which he illustrated the use of metallic reinforcing between layers of brick for arches, walls, and vaults. Such a system predated thin reinforced concrete shells, such as those of the engineers Franz Dischinger (1887–1953), Eduardo Torroja (1899–1961), Eladio Dieste (1917–2000), and other engineers working later in the twentieth century. One particular advantage of the reinforced tile vault is that, unlike reinforced concrete shells, it can be built without formwork.[16]

The father and son also devoted significant time to the manufacturing of tiles, which was an initial barrier to their work in the United States. The father's patent of 1895 detailed a technique for manufacturing six tiles in one block, which lowered costs for tile manufacturing. This block could be broken apart on-site with "a slight blow of a hammer."[17]