ON MODELS AND MODELING

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The requirement of having a model of the invention filed together with the drawings and description of that invention was peculiar to the American patent system.

There may be some commonsense reasons why it was so. For one, if you are designing a machine or any mechanical contraption and have trouble calculating what the forces, sizes, or materials ought to be for a given purpose, the only thing to do is to "try," by building your proposed structure on a small scale first—it's cheaper and safer—and then scale up step by step if it proves successful. That, essentially, is the essence of modeling. Now, there is no doubt that the determination of the forces at play, the stress and strain in the machines the patent models represented, were well beyond the capacities of even the better-trained engineers of the time. This was, in fact, the period when the sciences of strength of materials, of elasticity and of thermodynamics, which form the basis of such calculations, were being established, when the very concepts of stress and strain were being worked out. The only way to figure out what to do was, therefore, to build a model.

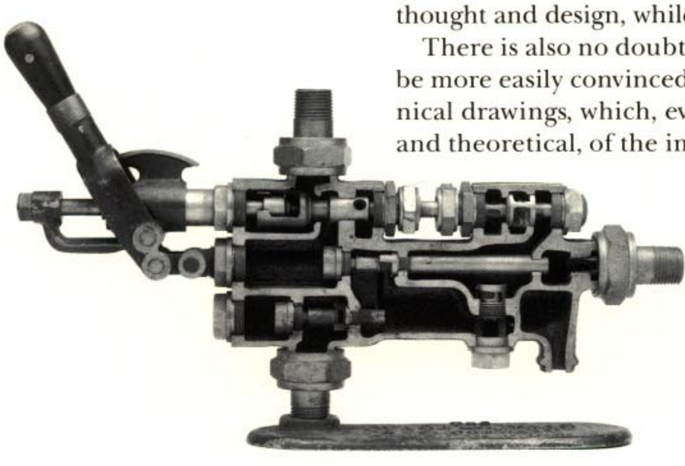
Another reason for the model requirement is that relatively few of the inventors probably knew much about technical drawing and reading drawings. Though drawings have been made from time immemorial, (c.f. Altamira and Lascaux), it was only around 1800 that Gaspard Monge invented descriptive geometry and laid the foundations of modern technical drawing. There is no doubt that the inventors and tinkerers, "practical men" and "men of progress," most of them untutored or self-taught in the arts and sciences, felt more comfortable with working models than with abstract representations and descriptions of their devices. It was assuredly easier for them to communicate directly with the model maker, if they used the services of one, than through graphical means with a distant patent examiner.

The use of models in technical design has a long history. There is some evidence that the ancients built models of their proposed constructions. Medieval master masons and engineers certainly did, as can be seen from account rolls in some cathedrals.[1] Judging from the costs mentioned in these accounts, the models must have been large and elaborate. The tombstone of Hugues Libergier (d. 1263) in Rheims Cathedral, the architect of the now defunct church of St. Nicaise, represents him holding in his left hand his measuring rod and in his right hand a model of his church. Vasari tells us in his life of Brunelleschi that in 1417 "the wardens of works of Santa Maria del Fiore in company with the consuls of the Wood Guild called a congress of local architects and engineers to discuss how to raise the cupola... Following this, models were designed and executed."[2]

We are furthermore informed by Prager and Scaglia that Brunelleschi "worked extensively by means of models and full-scale constructions and not in general by writing or drawings."[3] Interestingly, these authors remarked that Brunelleschi "had pupils and admirers who witnessed his performance. Some of them, in turn, left a secondary record of his teachings... for example, the engines in Taccola's treatises... [which] reappear in many textbooks and treatises of the late Quattrocento."

Judging from the notebooks of Villard de Honnecourt (ca, 1250) and Leonardo da Vinci (c. 1500) this practice of working from models and using drawings for the record, must have been common practice and must have extended to the nineteenth-century world of our inventors. It is only with the rise of the engineering schools and the teaching of descriptive geometry since the end of the nineteenth-century, that the practice reversed itself: drawings being used for thinking and design and the model, if used at all, for the purpose of record or public presentation. Interestingly enough, with recent development in Computer Aided Drafting and Design (CADD), we find ourselves in the old situation again, where "physical" modeling takes precedence in helping thought and design, while drawing finds itself relegated to record and documentation.

There is also no doubt that in case of litigation, judges, attorneys, and juries would be more easily convinced by "working models" they could see and touch than by technical drawings, which, even in their patent versions, retained an aura of the abstract and theoretical, of the impractical.



Patent No. 537,279
T. M. Eynon and J. W. Gamble, Inventors 1895
In this model of an injector, the skin has been cut away to to reveal its internal anatomy. An injector acts as a pump to introduce water into a boiler under pressure. It has no moving parts, and is thus robust and free of trouble. Using steam from the boiler as a propellant, it also acts as a water heater.
Cliff Petersen Collection
Photography, Joanne Savio.

The model requirement, therefore, must have been perceived as a vindication of the common man, of the mechanic, in line with the Constitution, which confers upon Congress the power of "securing to inventors the exclusive *right* to their discoveries," as against the claims of the school-trained gentlemen, men of paper and of drawing, and against the English law whereby the Crown *may grant* or confer upon the inventor the royal privilege of a patent, subject to conditions and limitations from the same Crown.

Modeling, however, is a difficult art and a subtle science—more difficult and more subtle than was realized at the time. It is ironical that the patent model requirement was being phased out as the science of modeling was being established. Characteristically, it also occurred during the same period that electrical engineering, aeronautical/naval engineering, and chemical engineering came into their own.

Electrical phenomena are not as readily apprehended by the senses as movements of levers and connecting rods, but on the other hand, they lend themselves more readily to mathematization, and the inventions they brought forth could be more easily evaluated on paper than on three-dimensional physical models. As for aeronautical/naval and chemical engineering, which deal with complex phenomena that defy any simple mathematization and modeling, these required a whole new approach to the modeling art based on sound scientific principles. Everything, therefore, in the development of technology and engineering conspired to bring to an end the glorious and naive faith in patent models. It is among the ironies of history that one of the founders of dimensional analysis, the basis of modeling theory, which was to play a central role in the development of aeronautics, was William Thomson, First Baron Kelvin, who ponderously announced that "Heavier-than-air flying machines are impossible."

Patent No. 137,121
W. H. Alcorn, Inventor 1873
Here is a stately thing, an oscillating carriage to teach a child self-reliance: "My invention... shall be constructed that a child sitting upon its seat and pulling upon a lever can give the seat an oscillating movement." The child-activated swing with a set of levers and connecting rods is a popular theme in the nineteenth century. Dozens and dozens of swings were patented.

Be that as it may, it is of interest to note that, for the most part, patent models could not have been more than of qualitative value in judging the performance of the proposed inventions. As Galileo pointed out with his "square-cube" law, scaling up has its problems. Suppose, for instance, you are designing a steam engine. For a given pressure, the power is proportional to the piston area and to the stoke, and, therefore, to the cylinder volume. If you double the linear size of your machine, the volume goes up by a factor of $2^3 = 8$, while the surface will go up by a factor of $2^2 = 4$. The power yield is, therefore 8 times greater, and so would be the weights and forces involved in the moving parts, while the stresses and temperatures which result from the ratios of forces to surface and power to surface, respectively, would, therefore increase as the lengths. So double the size, double the stress, double the temperature, double your trouble!

Of course, if stress is no problem and temperature is not involved, as in masonry buildings, where only static stability is of concern, then scaling up will work well. That explains Brunelleschi's success with his models, as well as that of innumerable others. It may also explain some of the disastrous boiler explosions and industrial catastrophes that monotonously punctuate the nineteenth century. Patent models were adequate to give an idea of how "the thing" would look, what its kinematics would be (i.e., how it would move, whether this part would clear this one and by how much in slow motion), but not what its dynamics would be (i.e., the forces, the stresses, and strain that would develop under full scale working conditions). One need only look at the double-pendulum type swings proposed by some of our inventors to realize that either they knew not what they were doing or they were animated by a rare degree of gleeful insanity.

Notes

1. John James, *Chartres, The Masons Who Built a Legend* (Boston: Routledge and Kegan Paul, 1982) 71.
2. Georgio, Vasari, *Lives of the Artists*, Vol. I (Baltimore: Penguin Books) 141.
3. Frank D. Prager and Gustine Scaglia, "Brunelleschi as Structural Engineer," in *Modern Perspectives of Brunelleschi* (Cambridge, 1970).