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The LEGO Group: Publish or Protect?

The absolute worst case would be if we come up with an innovation and then our competitors use it, or even worse, they prevented us from using it!

— Per Høvsgaard, Director, Concept Center

Per Høvsgaard, the director of the Concept Center at the LEGO Group, the iconic Danish toy maker, was meeting with Kathrine Petersen and Tina Poulsen. Petersen was his senior director in charge of the LEGO Group's "concept factory" of the future, and Poulsen was a project director responsible for a strategic cross-functional project defining the future molding platform of the LEGO Group. They planned to discuss the upcoming presentation to the LEGO Group's board of directors. Concept Center engineers had come up with significant innovations that improved both the speed and precision of their manufacturing processes, but the three were uncertain on whether or how to protect these new inventions.

The LEGO Group was the third-largest toy manufacturer in the world. Its core product, introduced in its present form in 1958, was a building system that employed interlocking plastic bricks using a stud-and-tube coupling system. (See **Exhibit 1** for a drawing from the original LEGO® patent filed by Godtfred Kirk Christiansen, son of LEGO's founder, Ole Kirk Christensen.) A regular pattern of studs on top of the bricks fit into spaces alongside tubes on the underside of the bricks, allowing a rigid and precise interlock. With the dimensions of the interface standardized, LEGO® bricks became modular building blocks for constructing a wide range of objects. Over the 50-plus-year life of this defining product, the company had manufactured over 600 billion of the eponymous bricks and other elements in thousands of variations. The tight mechanical tolerances required for the bricks to have a good mechanical "clutch power" as well as the highly polished surface finishes meant great precision was required in the plastic injection molding process. Thus high-volume precision molding was a core competence, and a critical advantage that the company was intent on maintaining.

Patenting the recent inventions did not automatically convey protection. The very act of patenting meant the company would have to disclose details of the invention in its filings. With Asian competitors operating in property rights regimes that could best be described as mixed, Petersen questioned how much protection patenting would realistically afford. "We could always just publish it," she observed. Publishing the invention would establish it in the public domain and at least prevent others from patenting something similar, thus insuring the LEGO Group's freedom to operate. Alternatively the company could elect to maintain the technology as a trade secret.

Professor Willy Shih and HBS Doctoral Candidate Sen Chai prepared this case. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

With the board meeting looming, Høvsgaard, Petersen, and Poulsen had gotten together to review recommendations from outside counsel and started to sketch the outlines of the board presentation. "I wonder what students of intellectual property rights would say about our circumstances," Poulsen quipped as they gathered around a blank whiteboard.

The LEGO Group and Its "Building System"

The LEGO Group was established by Ole Kirk Christiansen, a carpenter, in the Danish village of Billund in 1932. Like many other craftsmen, Christiansen used leftover wood to make toys. The name LEGO® was a contraction of the Danish words *leg godt*, which meant "play well." By coincidence, it also means "I put together" in Latin. LEGO® toys were made of wood for several decades, and the company first moved into plastic materials around 1949. But it was not until 1963 that it began using acrylonitrile butadiene styrene (ABS), a plastic that has excellent impact resistance and toughness. It was at this point that LEGO® bricks took on their modern form (see **Exhibit 2** for a timeline of the LEGO Group's history).

The LEGO® "System of Play" came out of the new coupling system. The modular bricks (see **Exhibit 3**) could be put together in a vast number of combinations: six eight-stud bricks of the same color could be combined in 915,103,765 different ways, and the good mechanical strength of the couplings meant that children could build large objects such as houses, cars, or airplanes. The initial play system offered 28 sets and eight vehicles, along with supplementary elements to add touches of detail.[1] All bricks possessed the standard interface and therefore were interchangeable, so children could combine sets and design and construct their own creations.

As the LEGO Group grew its molding capabilities, it expanded the variety of components to include objects like gears, universal joints, motors, flowers, people, flags, and a vast assortment of other building blocks for making more complicated structures. At its peak in 2004, the company produced 12,400 different pieces, all of which adhered to the interface design rules and could be connected. In 2011, the company produced 300 million toy tires, making it one of the world's largest tire manufacturers, and in 2012 it produced 340 million minifigures, which standing next to each other would form a line from Billund, Denmark, to Dallas, Texas. Kits were packaged with detailed graphic instructions that were devoid of words; they used pictures only and could be shipped anywhere in the world thanks to their universality. (**Exhibit 4** shows excerpts from the instruction manual for the Model 8043 Motorized Hydraulic Excavator.)

Construction play was the core play activity for children, although the company went through a shift toward more narrative and role-playing activities in the mid-1990s. A financial crisis in 2004 caused the company to focus back on its core construction-play roots, as it recognized that the building of something, whether a train or a car or a house, was the product. In the words of Danish design professor Per Mollerup, "The journey, not the destination is the purpose."[2]

This reemphasis on the company's traditional brick building product meant that it was crucial to maintain competitive advantage not only through clever modular designs and product introductions, such as the highly successful LEGO® Friends line, but also through manufacturing innovation that would bring down costs and improve cycle times while upholding the LEGO Group's high quality standards.

Making LEGO® Bricks

ABS is a thermoplastic, meaning it can be formed when heated above its glass transition temperature and that, upon cooling, it returns to a rigid solid state. It is normally shaped into products by injection molding. Plastic beads (see **Exhibit 5**) are fed into a heated feed barrel, mixed, and then forced into the cavity of a mold at temperatures between 230°C and 310°C and pressures from 25–150 tons (see **Exhibit 5**), depending on which element is being produced. Once in the mold, it cools and hardens to the shape of the cavity.

The vast quantities of bricks necessitated a highly productive manufacturing system. ABS granules were stored in large silos that held 33 tons each, and were fed by pipe to manufacturing halls with long lines of machines (see **Exhibit 6**). As soon as the pieces cooled, the three-piece mold separated the finished bricks from waste and dropped them onto a conveyor, which took them to bins next to an aisle. Automated guided vehicles picked up the bar-coded bins and transported them to a high-bay warehouse.

The LEGO Group's volume growth and the vast assortment of elements that it produced posed unique manufacturing challenges and, in keeping with the modular mind-set of the company, had been organized into a unique system. The highest volumes were concentrated on a small percentage of elements in a portfolio of around 7,000 products. The company's manufacturing footprint reflected a careful balance of staying close to its major markets while using low-factor-cost production facilities for labor-intensive operations like painting minifigures. It served the U.S. from a factory in Mexico, and the EU from Hungary and its home plant in Billund. Asian manufacturing was targeted for future manufacturing expansion, and the company foresaw a large growth opportunity there. Complex packaging—such as for its Technic line of technically complex kits, which featured parts like gears and motors, as well as construction techniques that used beams and pins—was done exclusively in Billund.

The present high-volume molding setup dated back 25 years and featured a modular system of molds with standard-sized cavity inserts. Over the years the company had constantly refined its processes and made incremental improvements like adding color at the point of use and reducing plastic scrap or improving its reuse. The LEGO Group used standard injection molding machines supplied by companies like Engel Austria GmbH; Arburg of Lossberg, Germany; and Wittman/Battenfeld GmbH—three European companies with long traditions in manufacturing hydraulic injection molding machines.

The Next-Generation Molding Platform

We have to be in the driver's seat. We need to use the time now to define the next-generation production setup.

— Per Høvsgaard

Per Høvsgaard and his team saw numerous challenges when they launched their "Future Molding Platform" project. Foremost among these was that they faced the continuing demands of strong volume growth. In the 2012 holiday season, the company had struggled to keep up with demand for its LEGO® Friends line when stock outages before Christmas led to too many disappointed children and parents. The team had gotten their arms around some of the complexity issues by getting the variation down to about 7,000 different elements with a "Top Elements" list that Kathrine Petersen proudly displayed on a board in one of the conference rooms.

The Future Molding Platform had several broad goals: increasing the overall volume as well as throughput per square meter of factory floor space, while improving sustainability through lower power consumption, less waste, and a better work environment. Petersen saw an important path to this through higher standardization and modularization of molding. With seven standard mold sizes that used multiple inserts, the most straightforward way to increase productivity was to increase the number of inserts per mold. Yet the larger molds also placed more demands on mold design to ensure uniform molding temperatures and cooling across the increased number of cavities. Even so, Petersen was gratified by early results that demonstrated a fourfold increase in output per 10-second cycle.

Good molding shops also maintained their tools carefully, as this extended the lifetime of the molds. The Society of the Plastics Industry (SPI) had an injection mold classification system that served as a guideline for projecting service life of molds. A Class 101 mold had a projected life beyond 1 million cycles, and mandated hard molding surfaces (hardness grade of 48 on the Rockwell C scale), guided ejection, wear plates for sliding parts, and corrosion resistance treatment for the cooling channels. Petersen's team worked carefully to extend the life of tools far, far beyond the Class 101 standard, and she felt this was a huge advantage reflected in reduced amortized tooling costs. LEGO engineers also worked hard to design in ease of maintenance, which mostly entailed cleaning and polishing the molds, along with removing contamination or corrosion. Petersen also saw an important focus on moving more from quality control to quality assurance, which meant a greater emphasis on process control.

Process control had always been important in injection molding, but several technological changes foreshadowed both opportunities and challenges:

- Asian injection molded plastics producers had largely shifted to electric drive from hydraulic drive machines. The LEGO Group's traditional suppliers, who were predominantly German and Austrian, had stayed with hydraulic drives and had continued to innovate extensively in complementary equipment like materials handling systems and robotics. While the LEGO Group had brought in some electric drive machines, the primary benefit they saw was in reduced power consumption, which definitely furthered the goal of sustainability. Petersen and Poulsen had begun an analysis to see if electric drive had implications for better process control of the molding process. (See **Exhibits 8** and **9** for a discussion of electric drives in injection molding.)

- Additive manufacturing promised a revolution in the toolmaking process—producing the mold tools. Traditional tool manufacturing entailed the carving out of mold patterns through subtractive methods, using methods such as electric discharge machining (EDM), grinding, or high-speed milling. These extreme methods were necessary because the tool steel of which molds were made was extremely difficult to cut—it was the same material cutting tools were made of, after all. This limited the design of molds to ones in which physical grinding paths were accessible. Because of their high labor intensity, the manufacture of a lot of injection molding tools had migrated to China, where after the grinding and milling, small armies of workers would sit and polish tools by hand. Among the new additive methods was a process called selective laser sintering, in which a high-powered laser was used to fuse finely ground martensitic[a] thermo-setting tool steel into the desired three-dimensional shapes. Finished pieces had to be heat-treated in a furnace and polished, but the additive process not only meant faster cycle times for tool production but also meant that molds could incorporate

[a] "Martensitic" refers to the crystalline structure of the steel.

> radically new designs that were not physically possible to build in the past. This was particularly important in the design of conformal cooling channels and in the manufacture of small parts. The improved cooling could lead to faster cycle times as well as better quality. The Future Molding Platform team was also evaluating a number of other new technologies that would speed cycle time and improve productivity or quality.

Petersen thought about the dynamic state of the industry. For something that was supposed to be as mature as plastic injection molding, change seemed to be coming at a rapid pace. The pace of internal innovations had picked up as well. She commented to Poulsen and Høvsgaard,

> Over the last five years, we have experienced 15% to 20% volume growth every year. Our Future Molding Platform is targeted to help us increase both our output and our productivity. As we work on this, we also are generating some of our own innovations which we think can dramatically improve the results. Now the question is whether we should share those inventions!

Publish or Patent?

We are great at protecting our products and novelties with patents; the question is, should we protect our production technologies as well?

— Tina Poulsen

The two broad technological thrusts in the industry presented distinctive challenges. Petersen and Poulsen knew that, compared with hydraulic drive, electric drive meant better sustainability, but they were unsure of the implications for other performance attributes of the molding. Literature reports suggested that electric drive afforded a much simpler way to get into the control loop of molding machines, but indications were that most Asian users of electric drive were primarily interested in the lower costs the platforms provided. Independently, LEGO engineers had perfected some inventions that afforded the possibility of dramatically better tool life and performance. The inventions involved controlling behavior of the tool while in use. The inventions were independent of whether the company used hydraulic or electric drive, though hydraulic drive stood to benefit more because of the difficulty of getting in the control loop.

The circumstances in the field of additive manufacturing were quite different. Three-dimensional manufacturing (3D) had attracted so much interest that it was shaping up to become a patent minefield. So many companies and organizations, like research universities and institutes, recognized its importance that there had been very active patenting. The LEGO Group had selected a particular tool supplier because it appeared to have the leading and most formidable patent position on the 3D methods. Since toolmakers nominally indemnified their customers from patent risks, Høvsgaard felt this choice held out the prospect for the greatest freedom to practice. Since LEGO often pushed against the limits on tool design in the use of advanced tooling systems, it also came up with numerous innovations during the course of its development activities. So here the question was how much to share with its tool supplier. Through the normal course of collaboration, Høvsgaard had witnessed a substantive spillover of ideas flowing mostly in the direction of the toolmaker. Høvsgaard observed, "While our culture is open and not about trading in this area, it would be very frustrating if ultimately some competitor could prevent us from using our own inventions!"

Despite different circumstances around these two streams of technological change that the LEGO Group was investing in, the need to protect these inventions was becoming urgent. John Hansen, senior vice president of engineering and quality, commented: "I want protection where our competitors can't copy and repeat what we are doing. And we don't want to teach our competitors to do what we do in places where we consistently drive down costs."

The question was complex. Høvsgaard asked, "How should we drive our molding platform and protect it?" There were several alternatives, but the choice was far from obvious. The company could expand its practice of patenting novel brick-building blocks to the patenting of inventions coming out of its manufacturing processes. It could also attempt to keep these inventions as trade secrets, or at the other extreme it might simply publish them. As they weighed the pros and cons of each alternative, the LEGO Group team realized that it was crucial to first understand why these inventions needed protection and whom they should be protecting themselves from. On the one hand, Poulsen noted, "Our key question is to figure out where are our control points." On the other hand, they needed freedom to practice in the field. What if other parties ended up with patents that prevented the LEGO Group from using a critical new manufacturing technology? Poulsen reflected on the natural instinct of company engineers: "If we build something fantastic, we would like to own it."

One of the most common methods companies employed to protect their intellectual property (IP) was patenting. Patents, which are granted by governments, convey the right to exclude others from making, using, selling, offering to sell, or importing a protected invention. The belief was that, absent a reward, most inventors would keep inventions secret. Patent grants gave inventors an exclusive period of benefit (20 years in the U.S.) in exchange for disclosure of the invention. U.S. patent applications, for example, were published 18 months after the earliest priority date of the filing, so they became public knowledge at that time. The idea was that others could build on the knowledge embodied in the patent, either with proper compensation (in the form of licensing) or after the expiration of the patent exclusivity period.

By filing lots of patents, the LEGO Group could also get some assurance of freedom to practice by having IP to trade with other patent holders (in the form of a cross-license) in case it needed access in the future to cutting-edge technologies developed by others. This was what economists called a real option. However, there were some drawbacks to this approach. In addition to the cost of filing and maintaining a patent (countries charged annual patent maintenance fees), public disclosure of the invention could encourage competitors to copy or imitate by making minor changes or small incremental inventions. Defending patents through litigation was an expensive process with uncertain outcomes. It was also sometimes difficult to prove infringement of manufacturing process-based inventions because their use was hard or impossible to detect. The culture in the LEGO Group's manufacturing division did not favor this direction. "Our core is the minifigurines and bricks. Our culture is not about trading," commented Høvsgaard.

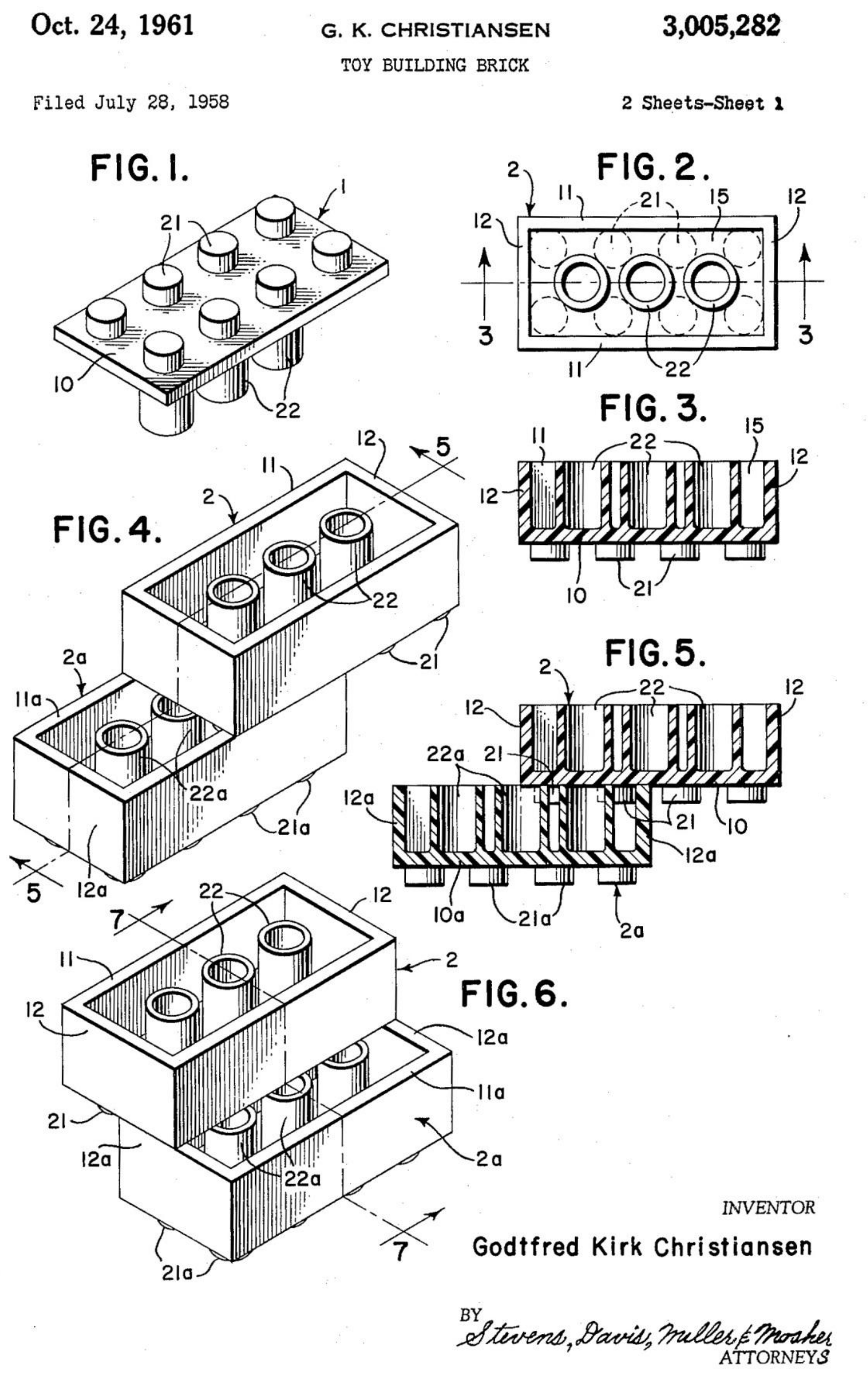
One way to avoid public disclosure of inventions as well as associated expenses was by maintaining the inventions as trade secrets. As long as the inventions stayed contained within the walls of the company, patenting might not be necessary, though this was a risky strategy. Employees who left a company carried knowledge in their heads with them, so they posed a spillover risk, especially in emerging markets or regions where loyalty to a firm was low and multiple companies set up manufacturing plants within a small geographical radius. Job swapping in these environments was a significant problem, as employees in search of better compensation and benefits carried tacit knowledge out the company's door and into the competitor's.

In the tooling area, incentives were not aligned between the LEGO Group and its tool suppliers. The LEGO Group wanted to keep its tool inventions and innovations private, but it was a lead user to its suppliers, who much preferred to make newly developed innovations available to all their respective customers as quickly as possible. In a worst-case scenario it ran the risk of losing its freedom to operate if imitative competitors succeeded in appropriating and patenting the company's inventions.

A third possible route was simply publishing inventions. A cheaper alternative to patenting, publishing inventions established them in the public domain as prior art, which meant nobody else could patent them. This provided some measure of freedom to operate, though if a competitor should develop a patent portfolio that the LEGO Group needed access to, it would not have as much in its portfolio to trade. The LEGO Group would also essentially be giving away the fruits of its R&D, without recovering any potential license income to offset the costs.

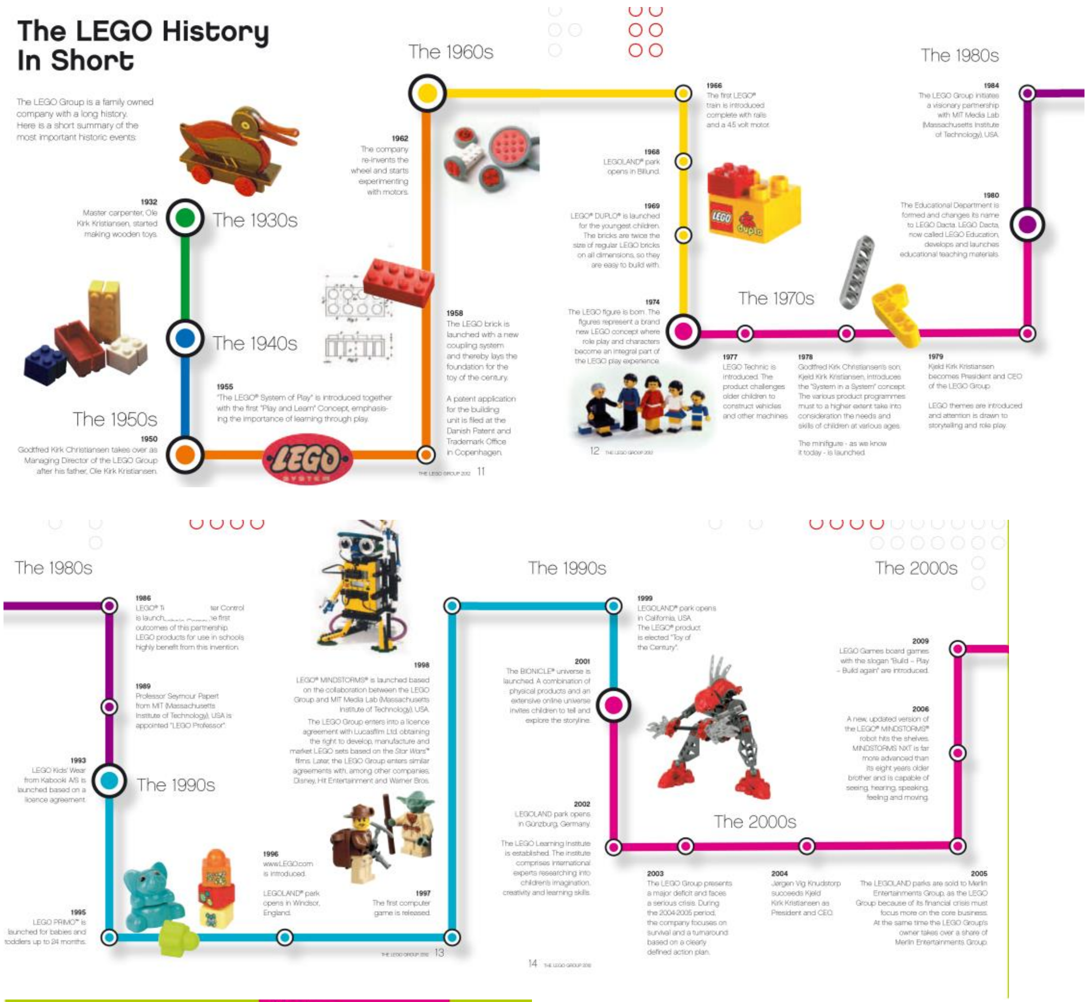
As Petersen, Høvsgaard, and Poulsen continued outlining points on the board, their feelings of being unsettled seemed to be getting worse.

Exhibit 1 LEGO® Stud-and-Tube Interlocking System from U.S. Patent 3,005,282



Source: U.S. Patent 3,005,282.

Exhibit 2 The LEGO Group Historical Timeline



Source: Adapted from company website.

The LEGO Group was founded in 1932 by Ole Kirk Kristiansen and started from a small carpenter's workshop. The company has been passed from father to son and is now owned by Kjeld Kirk Kristiansen, a grandchild of the founder. It is now an enterprise with a global footprint with sales attaining as the world's third-largest manufacturer of toys. In 2013, still headquartered in Billund, Denmark, the LEGO Group employed approximately 10.000 people, with manufacturing and assembly in Denmark, Hungary, Czech Republic, Mexico and China, serving markets in more than 130 countries.

The LEGO® brick in its present form was launched in 1958 and is the company's most important and fundamental product, and was twice named "Toy of the Century". The interlocking principle with its tubes makes it unique, standardized and modular, and offers unlimited building possibilities. These core building brick designs were at the basis of the LEGO Group's 35 product lines in 2013, targeted

Exhibit 3 Standard Four- and Eight-Stud LEGO® Bricks

Source: Company photo.

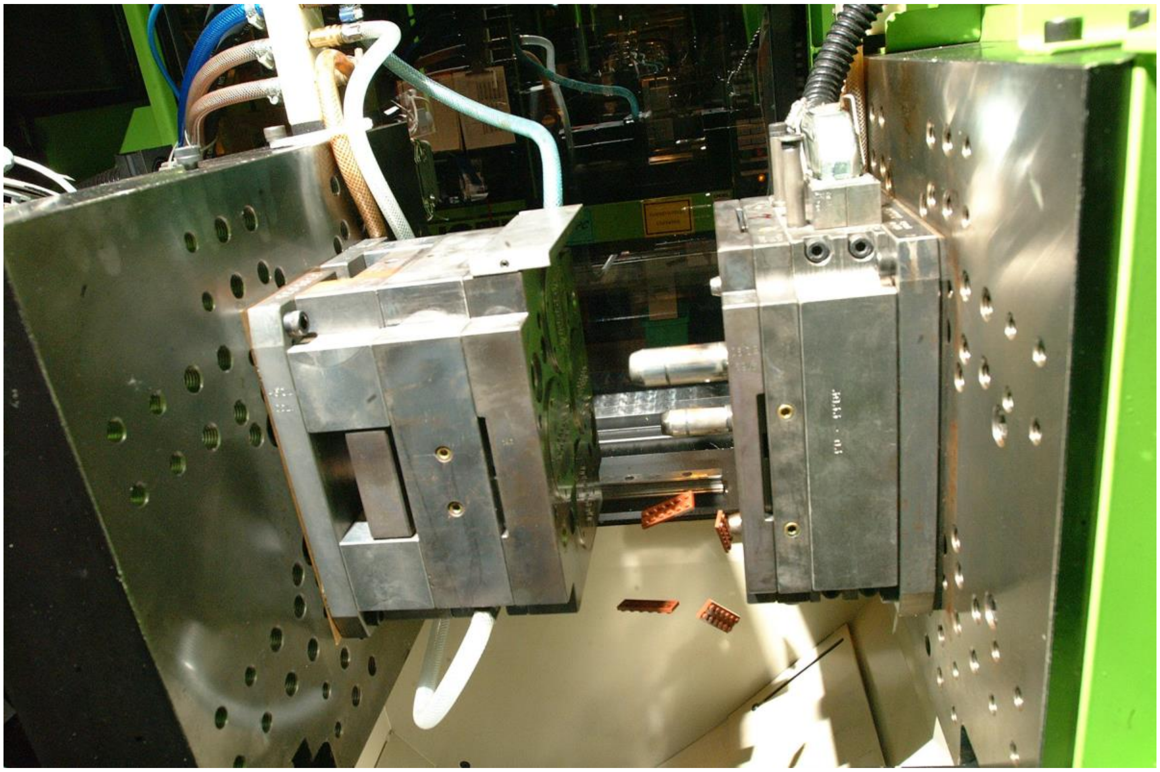
Exhibit 4 Selected Pages from LEGO® Instruction Manual for Model 8043 Motorized Hydraulic Excavator

Source: Instruction manual published by company.

Exhibit 5 ABS Feedstock

Source: Company photo.

Exhibit 6 Injection Molding Tool



Source: Company photos.

Exhibit 7 Processing Hall

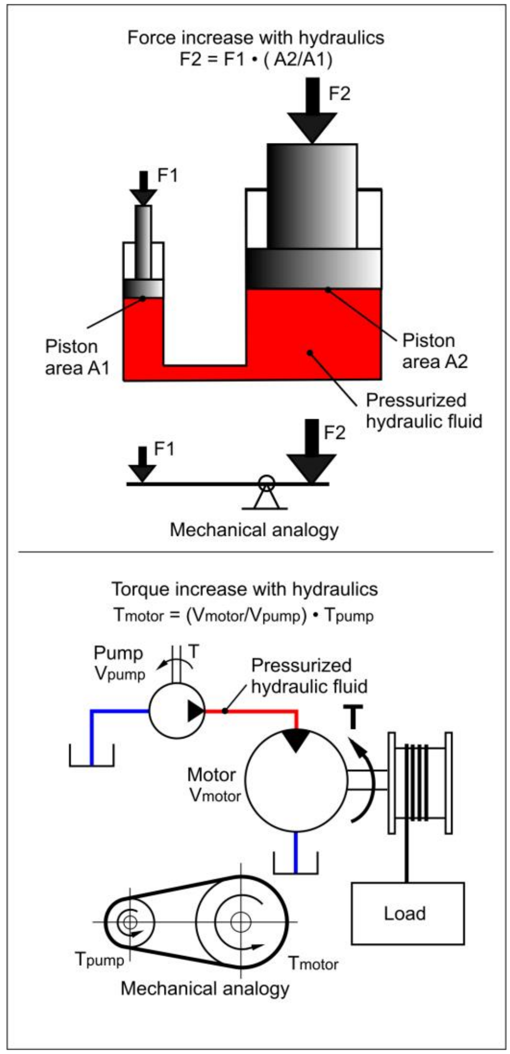
Source: Company photo.

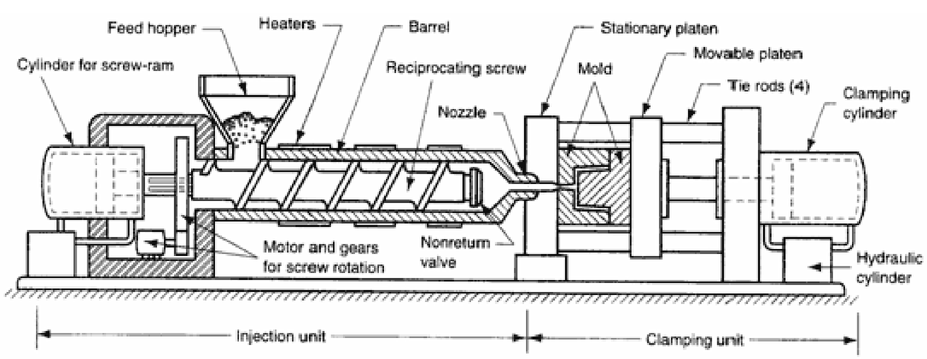
Exhibit 8 Hydraulic Drive Systems in Injection Molding

Plastic injection molding machines traditionally have used hydraulic drives. Hydraulic drives use a pressurized working fluid, typically hydraulic oil, to produce large mechanical forces. Pascal's Law states that the pressure anywhere in a confined incompressible fluid is transmitted equally in all directions, so because the force on a piston is proportional to the (Pressure) × (Area), a small force on the small piston can be converted to a large force on the bigger piston.

In a plastic injection molding machine, a pump is substituted for the small piston, and the pump can be mechanically throttled to control the movement of the piston that drives molten plastic into the mold.

One hydraulic cylinder typically drives a ram that forces molten plastic into the mold from one side, and a separate clamping cylinder drives a moveable platen from the opposite direction (see below).





Source: Top: Lidingo, "Hydraulic Force Torque 275px.png," CC-BY-SA-3.0, http://commons.wikimedia.org/wiki/File: Hydraulic_Force_Torque_275px.png; Bottom: Sumitomo SHI Demag Plastics Machinery, http://shipmi.co.in/wp-content/uploads/2011/06/Direct-Drive12.jpg.

Exhibit 9 Electric Drive Systems in Injection Molding

Electric injector system of Milacron Plastics Technologies Roboshot S2000i-B All-Electric Injection Molding Machine

Electric drive systems replace the hydraulics with electric servomotors to control the drive pressure. They are more efficient, and they offer several other advantages:

- The electric drive systems show less process variability over time because there are no hydraulic hoses to expand, and no hydraulic fluid to expand and heat up.
- Electric drive systems are digitally controlled, so the processes can be more predictable and repeatable. Electric drive injection molding machine makers claim better accuracy, repeatability, and consistency.
- Faster injection speeds, and faster overall cycle times.
- Electric drive systems are also much more efficient, using 30%–70% less energy.

Source: Milacron website, http://www.milacron.com/products/injectionmolding/electric/roboshot/overview.html# accessed February 9, 2013. Reproduced with permission of Milacron.

Endnotes

[1] Maaike Lauwaert, "Playing outside the box—on LEGO toys and the changing world of construction play," *History and Technology* 24, no. 3 (September 2008): 221–237.

[2] Per Mollerup, *Collapsible: The Genius of Space-Saving Design* (San Francisco: Chronicle Books, 2001), cited in Lauwaert, "Playing outside the box."