Power Sources for the Granite Industry

the availability of power for the efficient quarrying, finishing and transport since granite is heavy (170 lbs. per cubic foot) and very difficult to work. Roughly, from the mid 19th century to the mid 20th century, the granite industry progressed through manual power, draft animal, water wheel, water turbine, steam engine, steam turbine, compressed air engine, electric motor, and internal combustion engine. It is nothing less than an historical parade of this nation's principal sources of power.

The basic problem is the conversion of energy from various sources (draft animals, falling water, burning wood or coal, etc.) into motive power and then transmitting that power to the granite working and moving machinery. The cost of power is typically only a small part of the total cost of a granite operation but it is a critical part – any power interruption can shut down the entire manufacturing process. Granite companies need continuous power for continuous operation and power reserve to meet peak demands. Granite became a major nation-wide industry only after the introduction of highly efficient tools and machines and the availability of reliable power to run them. In the end, the choice of a power source depended on the scale of the granite operation, the number and size of local water power sites, the local availability and cost of fuel, and the possibility of sharing power sources with other local industries.

Figure 1. *Horse Sweep-Powered Derrick Hoist, Barre, VT.*

Figure 2. *Riverside Granite Polishing Mill Powered by Water Turbine, Hardwick Granite Co., Hardwick, VT.*

Initially, the quarrying, lifting, moving, and finishing of granite were manual operations. Granite was quarried with hand tools such as the hand drill, drilling hammer, and wedge and shims. Granite was lifted and moved by lever, hand-operated derrick, sledge and rollers. Granite was finished with hand tools such as the hand hammer and chisel. Manual granite quarrying and finishing was a slow and costly process and only relatively small granite pieces could be lifted and moved. Except for coastal quarries where boat transport was available, granite markets were limited to areas within a few miles of the quarry. The granite products were relatively simple – mostly stones for foundations, hearths, steps, sills, lintels and posts. Next, draft animals (horses and oxen) were employed under human guidance to lift, move and transport granite. A horse could provide a continuous one-half horsepower whereas a man could produce only about one-eighth continuous horsepower. The upkeep cost of a horse was about the same as the salary of a skilled worker. Quarry overburden was removed by ox shovel and wagon. Lifting of quarry blocks

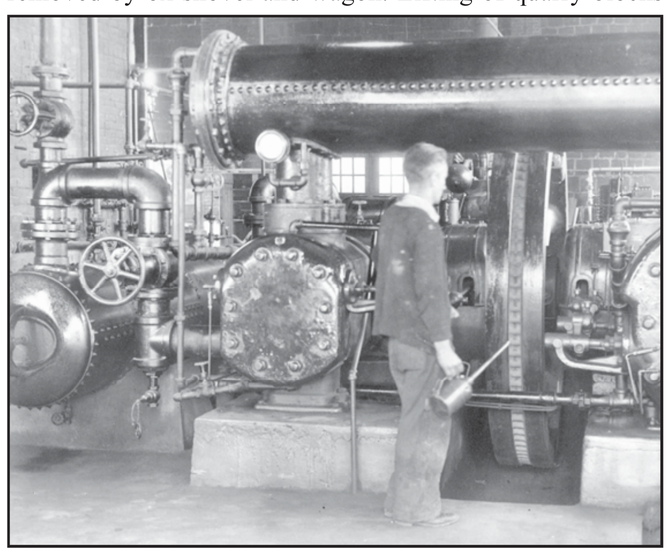

Figure 3. *Steam Turbine-Driven Two-Stage Air Compressor, Jones Bros., Barre, VT.*

Figure 4. *Shay Geared Locomotive No. 2, Hardwick & Woodbury RR, Hardwick, VT.*

was done by horse sweep-powered derrick hoists (Fig. 1) and transport was accomplished by horse and ox-drawn wagon or, during winter, by sled – sometimes aided by block and tackle for very steep or muddy roads. Now, granite blocks of many tons could be lifted and transported.

The granite industry followed the factory system pioneered by the textile industry in the early 1800s in Waltham and Lowell, MA. This included the use of water and later steam power, the integration of all manufacturing steps in one building, automated production by complex machinery, and distribution of power to machines located throughout the building via millworks. Granite finishing sheds were at first (prior to the use of steam engines) located at waterpower sites at a rapids or water falls on streams and rivers for which the granite company had purchased the water rights or mill privilege. A millrace (or headrace) was used to channel water from a dam to a water wheel (overshot, breast or undershot) which was connected via a millwork (shafts, pulleys and belts; cranks and rods; cams and lifters; or gears) to the various granite-working machines such as gang saws, polishing machines and lathes. For low water flow and heads of ten feet or more usually the overshot wheel was used. The breast wheel could be operated for a range of lower heads but required a larger water flow. The undershot wheel could be operated with a small head by utilizing the force of the stream flow itself but required a large water flow. A water wheel has the virtue of simplicity – it has only a single moving part, can be made almost entirely of wood, and can be constructed by traditional craftsmen such as millwrights, carpenters and blacksmiths. No precision parts, enclosure or flywheel are needed. Water wheels rotate slowly – the larger the wheel the slower the rotation. They mostly range in diameter from eight to thirty feet with rotation speeds of twenty to five RPM. As a result, one of the tasks of the millwork was to increase the rotational speed (by belts, pulleys and gears) to that needed by the granite-working machines.

Later, by about the 1850s, water wheels were increasingly replaced by water turbines which ran at higher speed and produced more power (Fig. 2). In addition, turbines were compact, durable, efficient and low cost. Whereas water wheels were made primarily of wood, turbines because of their design complexity and the required strength and close tolerances were made of iron and were manufactured at distantly-located factories. The turbine operated with water under pressure conveyed from a dam via a wooden or iron penstock. Since turbines were oriented horizontally with vertical shafts, bevel gearing was used to transfer power from the turbine shaft to the horizontal main shaft of the millworks. Although water power was relatively inexpensive in operation (once the costly dam and canal system had been constructed), it had two major drawbacks: (1) granite finishing sheds had to be located next to a waterpower site where there might not be an available workforce or worker housing and which exposed the shed to potential flood damage, and (2) during periods of low rainfall, there might not be enough water to operate the granite-working machinery.

Millworks typically consisted of a main shaft driven by the power source and one or more back (or counter) shafts driven from the main shaft and located over the machines to be powered. A millworks had three primary functions: (1) distribution and division of power from the prime mover to multiple distributed machines, (2) changing rotational speed from that of the prime mover to that required by each machine, and (3) changing direction from that of the prime mover (e.g., vertical to horizontal, rotational to reciprocating) to that required by each machine. Shafting was normally hung from the ceiling so that the moving shafts and belts would be out of the way of the workers. Power was most often transmitted between power source, shafting and machines by wooden or metal pulleys and flat leather belts. By altering the ratio of pulley diameters on each end of a belt, the rotational speed of the driven shaft could be increased or decreased. Power could be applied (or not) to a machine by shifting its belt from an idler (loose) pulley to a keyed (fixed) pulley (or vice versa), or by engaging (or disengaging) a belt tightener. For machines that needed to operate at multiple speeds such as granite cutting lathes (a slower speed was used for the initial rough turning), a system of speed reducing gears or a pair of cone (stepped) pulleys was employed.

By the time inland granite companies began to expand (1880s and 1890s), steam engines were readily available but their additional cost of purchase, operation and maintenance induced many companies to delay their introduction and continued to depend on water power. With the use of the steam engine, the drawbacks of water power could be avoided. The steam engine could be located almost anywhere, could be designed with a range of output capacities, and was not dependent on stream flow. However, compared to the water wheel, the steam engine cost more, had to be shipped at added cost from a distant manufacturer, had to be continuously attended and maintained, and was more costly to repair. In addition, there was increased insurance cost due to the risk of boiler explosions and fire. These negatives, added to the fact that small steam engines were not fuel-efficient, meant that steam engines were mostly installed by large granite firms. In 1909, Jones Brothers, one of the largest granite firms in Barre,VT, was powered by both water power and by a 150 HP Corliss steam engine. By 1913, Jones Bros. had a total capacity of 300 HP of mechanical power from both water and steam. Later, the Jones Bros. wheelhouse contained two cast iron horizontal wheel water turbines – each with a ten-foot vertical shaft connected by bevel gears to an electric generator. There was a clutch for each turbine that connected the turbine to the generator. Either one or both turbines could be connected, depending on the power requirements and available water. By the 1930s, the machinery at Jones Bros. was powered by electricity from the local electric utility (Green Mountain Power Co.). Two coal-burning Babcock & Wilcox steam boilers were used for heating only.

Often, the steam engine was just substituted for the water wheel or water turbine, retaining some or all of the overhead shafting and pulleys, belts, and gears. Or, the water wheel or turbine might be retained to provide low-cost power and the steam engine used as backup or to meet peak loads. Initially, wood-burning steam boilers were used, supplied with fuel from local woodlots. As coal became available and as local wood became scarce and more expensive (ca. 1880s), boilers were converted to burn coal. Also, coal allowed the use of mechanical stokers to replace the hand shoveling of coal into the boilers. For large installations, a coal trestle might be constructed for efficient railroad delivery of coal. An important byproduct of the boiler was the use of steam to heat the sheds during winter operations. Often, the exhaust steam from a steam engine or steam turbine was run through pipes in a heat exchanger. A fan blew air over the hot pipes and into large diameter ducts for distribution of hot air throughout the granite shed.

Just as water wheels were replaced by water turbines, reciprocating piston steam engines were replaced by steam turbines where greater power and rotational speed were needed such as for air compressors and electric generators (Fig. 3). Turbines are best used for applications requiring high rotational speed and continuous operation. Compared to the steam engine, the steam turbine is simpler, having only one moving part. In addition, the steam turbine has lower size and lower weight per horse power, higher efficiency (for large sizes), and can run for months unattended.

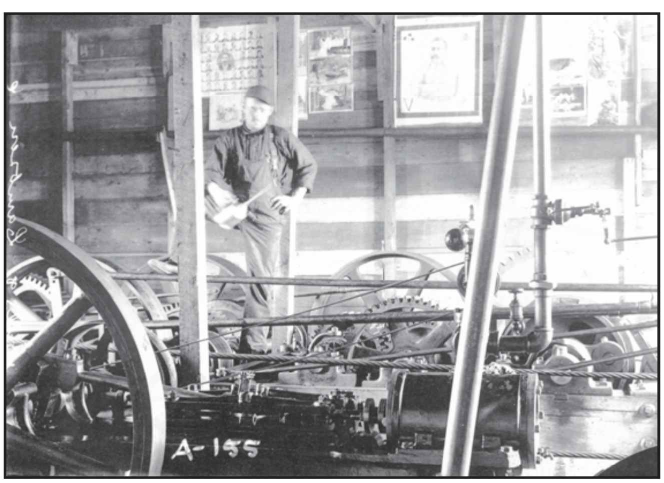

Figure 5. *Steam Piston-Powered Derrick Hoist, Barre, VT.*

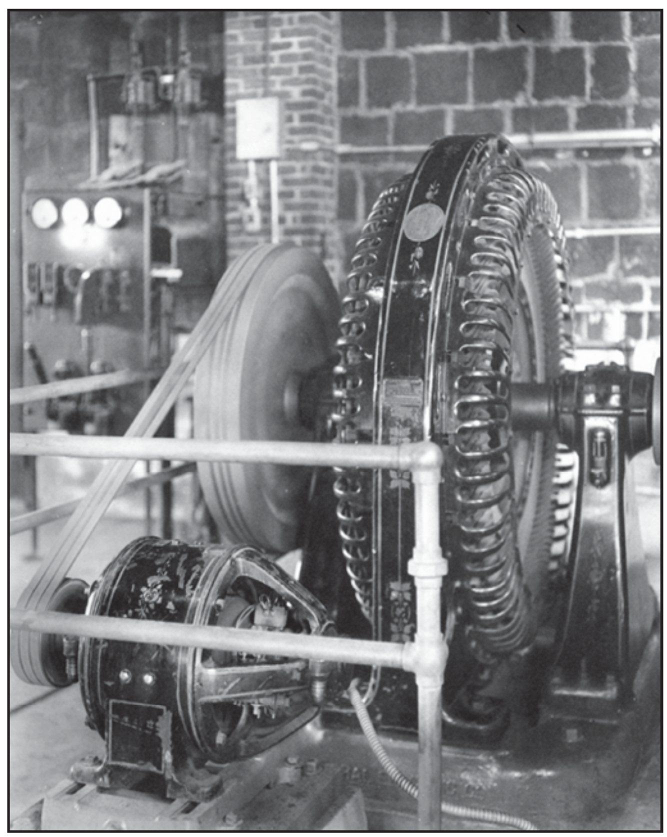

Figure 6. *Electric Motor Drive for Air Compressor. (The small motor is a starter motor.) Jones Bros., Barre, VT.*

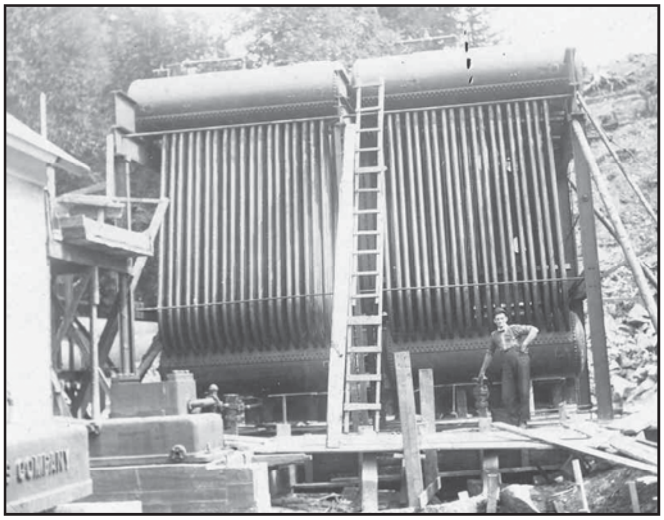

Figure 7. *Babcock & Wilcox 1000 HP Vertical Steam Boiler, Woodbury Granite Co., Hardwick, VT.*

The mobility of the steam engine made possible the low-cost transport of granite via railroad and opened up the interior granite quarries for exploitation. Before this time only the coastal quarries, serviced by sloops and schooners, could be profitably operated. Overland transport by horses and oxen was both slow and expensive. Really heavy loads (50 tons) might require a team of two or three dozen oxen and horses and might proceed at the snail-like pace of one or two miles per week! In addition, the heavy granite loads caused deep ruts in the dirt roads and crushed the culverts running under them, much to the anger of local residents. Initially, locomotives were wood fired but by the 1880s were being rapidly converted to coal. Coal weighed half or less and had a volume several times less than seasoned hardwood of the same heating value. By carrying their own fuel, wood or coal in tenders, locomotives were not tethered to a stationary power source. Although by the 1870s interior New England was well serviced by rail, it was not until quarry railroads, with their steep grades and sharp curves, were built in the 1880s and 1890s to haul granite from the quarries to the finishing sheds that the interior New England granite companies really began to prosper. Strong-traction saddletank locomotives were often used on quarry railroads and, for extreme grades, geared locomotives on which all the wheels were driven were used to provide outstanding tractive power for grades of 10% and more (Fig. 4).

Quarries posed special problems with respect to power. Quarries were often located at higher elevations with no rivers or streams for water power. By the 1870s and 1880s, coal was often transported to the quarry by wagon to fire boilers which provided steam for drills and derrick hoists (Fig. 5). Later, if the quarry was serviced by a railroad, coal might be brought in very economically. Sometimes water was so scarce that it was a challenge even to find enough to replace the steam engine's escaped steam and for wet drilling (the use of water to remove granite cuttings from the drill hole and to keep down the dust). Although the high and exposed location of many quarries suggests the possibility of using wind power, the author is not aware of this source having been used in the granite industry. The only significant New England use of wind power appears to have been on waterpower-poor Cape Cod for the salt industry and for grist milling. In any case, even the largest windmills of that time produced only three to five horsepower, far less than the power needed for the typical granite operation.

As mentioned above, steam was initially (ca. 1870s and 1880s) used to power quarry drills and derrick hoists. Steam was difficult to handle and always dangerous. After the 1880s, compressed air gradually replaced steam. Pneumatic rock drilling was pioneered in the U.S. in 1866 at the Hoosac Tunnel in western MA, powered by air compressors directly connected to water turbines. When compressed air began to be used in the granite industry in the late 1800s, first steam turbines and then electric motors were used to drive air compressors. Compressed air has many advantages: there is an inexhaustible supply of air and air exhaust is no problem, pipe leaks are not as dangerous, compressed air can be transmitted several miles without significant loss, it can be easily subdivided for use by many tools and machines, and can be used expansively in unmodified steam engines or in a variety of specialized air motors. The one major drawback was air compressor inefficiency (only 40-55% in the 1890s) due to heat loss during compression. However, the convenience of compressed air more than compensated for this inefficiency. Air compressors require relatively high torque and rotational speed which could be delivered by steam turbines. Electric motors did an even better job of driving air compressors (Fig. 6). The use of compressed air deep hole quarry drills, plug drills, jackhammers, and derrick hoists as well as surfacing machines (to produce flat granite surfaces) and hand-held pneumatic carving tools in the finishing sheds did not really become widespread until the advent of the electric motor-driven air compressor in the 1890s.

The next major step in power technology was the introduction of electrical power in the 1890s. Initially granite sheds produced their own electric power by water or steam turbine-powered generators. In 1909, The Woodbury Granite Co. of Hardwick,VT, the largest building (construction) granite company in the U.S., had their own proprietary electric power plant with two hydrogenerators producing a total of 500 KW (373 HP). By 1913, the Woodbury Granite Co. power plant could generate 1000 HP of hydro power and 2000 HP of backup steam power. The Woodbury Granite Co. fired the steam boilers with sawdust and waste slabs from it's sawmill whenever possible and only burned the more expensive coal when the scrap wood was not available (Fig. 7). Later, in the early 20th century, public electric power utilities increasingly supplied power to the sheds. At first, a single large electric motor would be used to replace the steam engine or turbine, using existing millworks. As smaller, lower-cost motors became available, multiple motors were used, each powering a group of similar co-located granite-working

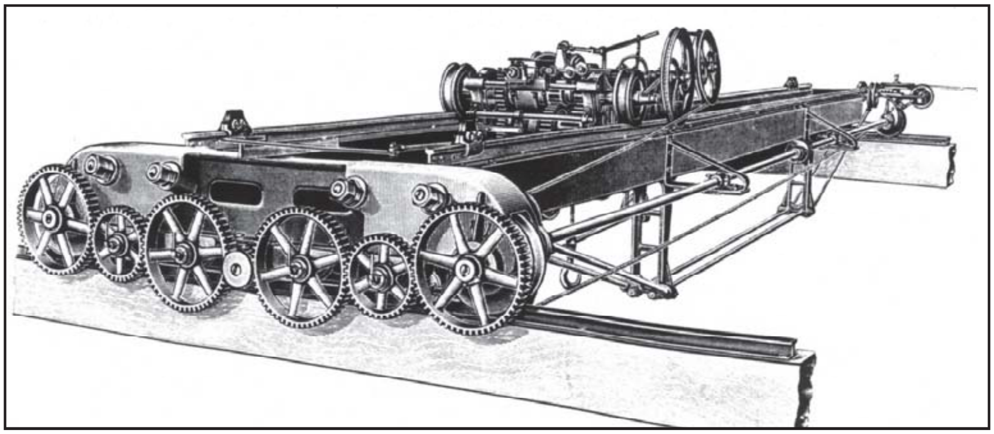

Figure 8. *Rope-Driven Overhead Traveling Bridge Crane, Manufactured by Lane Mfg. Co., Montpelier, VT*

machines. Finally, each machine was manufactured with its own integral electric motor. The use of one motor per machine greatly simplified power transmission from motor to machine (usually a geared or direct connection) and meant that the motor needed to be running only when the machine was in operation. Also, a machine with an integral motor could be more easily moved. Finally, and perhaps most important, the mechanical millworks which consumed from 20% to 50% of the power generated were replaced by electrical connections that consumed 5% or less of the power generated. As electric motors continued to decrease in size, the power per motor volume and weight increased and hand-held tools were developed with integral motors powered via an electric cord. (An early pre-electric example of a machine with a "built-in" motor was the tub wheel grist mill in which a horizontal water wheel with vertical shaft was directly connected to the upper mill stone.)

An important byproduct of the electric generator was the ability to use electric lighting. Centrally-generated electricity was originally introduced as power for the electric light with power for the electric motor as a byproduct. Much granite working required good light, for example for fine carving and sculpting, and electric light bulbs were able to provide improved lighting during late winter afternoons and cloudy days. A typical installation was a row of 500 watt light bulbs with porcelain reflectors hung below the shed roof ridgeline at intervals of twelve feet or so.

Since the cost per horsepower decreases as the prime mover size and capacity increases, economy of scale drove the granite industry to build boiler houses with multiple large steam boilers (usually, due to fire hazard, a masonry building separate from the main shed), to build compressor rooms with multiple large air compressors, and finally to purchase electric power from public utilities. This both reduced the cost of power and improved reliability by the backup power generation capability of multiple prime movers. Often an entrepreneur would install a large air compressor and sell compressed air to surrounding small to medium-sized granite sheds that couldn't afford to buy a compressor. Or, an entrepreneur might build a granite shed with compressed air, electricity, heat and lighting and rent space to small granite firms. Sometimes, a small firm purchased surplus compressed air or electric power from a large neighboring firm.

At high voltages, electrical power can be transmitted over long distances without significant energy loss which makes region-wide electric utilities possible and allows the tapping of previously unexploited remote water-power sites by hydroelectric power. Steam and compressed air is more difficult to transport over long distances due to frictional and heat losses and therefore led to the use of localized boiler houses and compressor rooms. Transport of power mechanically, for example by hemp or manila rope, or by steel cable or rods, is even more limited, typically a mile or less. Steam and compressed air was transported to work sites or stations by large diameter (four inches) rigid threaded iron pipes. At each work site or station, a smaller diameter (one half to one and a half inches) flexible rubber hose tapped off the iron pipe (through a turn-off valve) to power a tool or machine. For compressed air systems, a small diameter (three-quarter inch) steam pipe was often run inside the larger diameter iron pipe to heat the air and decrease the relative humidity. If not heated, the temperature of the exhaust air from the tool would be so low that the tool's valves and ports would freeze up, especially during winter, disabling the tool.

Mention has been made above of moving and lifting granite in the quarry. Material handling in the finishing shed was an even more challenging problem – granite had to be moved expeditiously from one workstation to the next for the various finishing steps. The solution to this problem was the overhead traveling bridge crane which could reach any part of a rectangular-shaped building, called a "straight shed". A typical shed of a medium to large-size company was several hundred feet long and had one or two overhead cranes that were in constant motion supplying the needs of one to two hundred granite workers. The key difficulty was how to power a machine that was moving over an area forty feet wide and several hundred feet long. The first solution was the "flying rope" overhead crane which was powered by an endless loop of rope, driven by a steam engine or electric motor, which ran the length of the shed on pulleys (Fig. 8). The rope loop ran onto the crane which moved on tracks over the length of the shed. The rope powered the movement of the bridge over the length of the shed, the movement of the trolley over the length of the bridge, and the movement of the hoist drum that was located on the trolley. There were two difficulties with this design: (1) the mechanism to translate the power of the moving rope to the motion of the bridge, trolley and hoist was complex and required frequent costly repairs and (2) the long loop of 1 to 1_-inch diameter rope moving at high speeds was dangerous – inone case having come off its pulleys and decapitated a worker. (Another example of a rope-powered machine for moving granite, in this case using wire rope, was the cableway or Blondin used in the quarries to move waste granite and small granite blocks.) The best solution to powering the overhead traveling crane came with the availability of the smaller lower-cost electric motor. Three motors were used, one on the bridge to power bridge movement and two on the trolley to power trolley and hoist movement. Electric power was conveyed to the motors via conducting wheels that ran on bare copper wires strung the length of the shed and the length of the crane bridge.

Later in the 20th century, the internal combustion engine (diesel) began to power both electric generators and air compressors, especially at the quarry where, due to its remoteness, central electric service was often not readily available. In modern quarries, the diesel engine also powers large forklift trucks and long-haul flatbed trucks. The Fletcher Quarry in Woodbury, Vermont's highest producing quarry, consumes 40,000 gallons of diesel fuel per year. Although a small gas engine with gas tank can be designed integral with a tool (like a chain saw or lawn string trimmer), the author is not aware of any such tools for the granite industry – probably since gas engine-powered electric generators or air compressors can readily provide electricity or compressed air for electric or pneumatic tools at the working site. Since most granite-working tools require lots of power, a self-contained fuel supply is not really a good option and the tools must therefore be tethered to their power source to insure an adequate flow of power to the tool.

For the purposes of this article, a **tool** is defined as a hand-held and hand-guided unit designed to carry out a particular granite-working task. A tool may be human-powered or may be powered by steam, compressed air, or electricity via a steam hose, compressed air hose, or electric cable with, respectively, an integral steam engine (usually a small piston steam engine), compressed air engine (usually a small piston air engine) or electric motor. Although power can be supplied to hand-held tools via flexible shafting or belt arrangements, steam, compressed air and electric power connections are more flexible and allow the operator to more easily hold, move and guide the tool to perform its intended work. In fact, one of the key problems of tool design for granite working is the application of non-human power under the fine motor control of a human operator. Electrical connections are probably the most desirable, being flexible and lightweight, having low power transmission loss, and being simple to connect, for example by a plug. Steam and air hoses must be heavy and strong enough to withstand high pressure, heat, and moisture.

A **machine** is defined as a non-hand-held unit designed to carry out a particular granite-working task. A machine may be human powered but is normally powered through mechanical power transmission from an animal, water wheel/turbine or steam engine, or (as with a tool) by an integral engine/motor powered by steam, compressed air or electricity. A machine may be fixed (for example, bolted down), moveable (for example, on tracks), or portable (for example, on wheels). A stone may either be brought to the machine (for example, a gang saw, a very large twelve-foot by forty-foot machine which is bolted down) or the machine may be brought to the stone (for example, a pneumatic surfacer, a much smaller machine typically mounted on wheels). For most granite-working machines, the stone remains static while the machine's working head moves. One exception is the lathe where both the stone and the working head (cutting disc) move. A machine may require continuous human guidance (for example, a polisher in which the polishing wheel is continuously moved by hand over the granite surface), may be semi-automatic requiring periodic adjustments (for example, a quarry drill for which ever longer drill bits have to be employed as the drill hole deepens), or may be fully-automatic where instructions are issued via mechanical adjustments or settings, buttons, switches or keyboard after which the machine can complete a job unattended (for example, a gang saw for which the stone is positioned, the number and spacing of the saw blades set, and then the saw left to run with an abrasive slurry continuously delivered by a pump until the saw block is sawn through).

Since granite-working tools and machines work on granite mechanically (drill, split, break, saw, trim, hammer, carve, polish, grind, turn, sand blast, and crush), power has to be eventually translated into mechanical motion – driving steel or abrasives against the granite. (An exception is the flame channeler in which a high-temperature oil-oxygen flame spalls off chips by causing rapid temperature changes in the granite. The flame channeler is a complex machine, requiring inputs of oil, oxygen, water, electricity, and compressed air.) A water wheel or a water or steam turbine drives a shaft in a rotary motion which can be converted, if necessary, to a linear motion (for example, for a gang saw) by placing a crank on the shaft which drives the machine via a pitman rod. A steam, compressed air or gasoline-driven piston moves in a linear trajectory which can be converted, if necessary, to a rotary motion (for example, for a derrick hoist drum) by causing the piston rod to drive the machine via a shaft with a crank. If power is transmitted by compressed air or electricity, two additional steps are required between the prime mover and the final mechanical motion for granite working – power converter and secondary mover. For compressed air transmission, mechanical power needs to be converted to compressed air power by an air compressor and then converted back to mechanical power by an air motor. For electrical transmission, mechanical power needs to be converted to electrical power by an electric generator and then converted back to mechanical power by an electric motor.

Table 1 summarizes the power sources, prime movers, power converters, power transmission, and secondary movers for tools and machinery used in the granite industry. The power sources are shown in rough time order (from top to bottom) of utilization. The transmission of power is in four forms: mechanical (M), steam (S), compressed air (A), and electricity (E). Certain forms of power such a windmill prime movers, power transmission by hydraulic pressure, and tools with integral internal combustion engines have not been included since they were not commonly used in the granite industry.

Table 1 lists examples of tools and machines of the granite industry and shows how they fit into Table 1. Power Source 1 is man. Power Source 2 is draft animals. Power Source 3 is water wheel/turbine, steam engine/turbine or electric motor external to and mechanically coupled to the tool or machine. Power Source 4 is steam, compressed air or electricity used to power a steam engine/turbine, compressed air engine/turbine or electric motor integral with the tool or machine. Those tools or machines with Power Sources 3 or 4 but not Power Source 1 are automatic or semi-automatic – that is, do not require the continuous guidance and control of a human operator. The very important derrick hoist, used for heavy lifting both at the quarry and in the shed yard, is unusual among machines used in the granite industry since over time, it has been powered manually, by draft animals, by steam, by compressed air, and finally by electricity. Channeling, the cutting of a deep groove or channel around a block to be removed from the quarry, is a process that also has evolved through a number of technologies: steam quarry drill with broaching bit, channeling machine with an array of steam-powered chisels, pneumatic quarry drill with broaching bit, wire saw, pneumatic core drill, high-temperature flame channeler, and high-pressure water channeler.

One machine that is not represented by Table 1 is the early steam-driven, track-mounted channeling machine with an integral steam boiler that powered an array of chisels. This large and cumbersome machine was rapidly supplanted by a machine with an external boiler and a steam hose connection. I am not aware of any granite-working tools or machines with integral water turbine and pressure water hose connection or with an integral gas engine and integral gas tank or gas hose connection. There may have been experimental or small production examples of these but if so they never gained popularity in the granite industry. The high pressure water channeler and Hydrosplitter have integral electric motor driven water and oil pumps, respectively. In the former, the stream of high pressure water acts as an abrasive to wear away the granite. In the latter, hydraulic cylinders drive a knife at high pressure against a granite block, splitting the block along the knife edge.

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Table 1. Power Sources for Selected Tools and Machines

Tool (T) or Machine (M)	Power Source 1	2	3	4
Drilling Hammer (T)	X			
Hand Drill (T)	X			
Wedge & Shims (T)	X			
Striking Hammer (T)	X			
Bull Set (T)	X			
Hand Hammer (T)	X			
Hand Chisel (T)	X			
Stone Jack (M)	X			
Polishing Machine (Manual) (M)	X			
Derrick Hoist (Manual) (M)	X			
Ox Shovel/Scraper (M)	X	X		
Wagon (M)	X	X		
Sled (M)	X	X		
Derrick Hoist (Draft Animal) (M)	X	X		
Polishing Machine (M)	X		X	
Gang Saw (M)			X	
Lathe (M)			X	
Overhead Crane (Rope) (M)	X		X	
Wire Saw (M)			X	
Contour Wire Saw (M)	X		X	
Surfacing Machine (Mechanical) (M)	X		X	
Grinder (M)			X	
Sand Blast Machine (M)	X			A and E
Plug Drill (T)	X			A
Quarry Drill (M)				S or A
Derrick Hoist (M)	X			S, A or E
Pneumatic Carving Tool (T)	X			A
Surfacing Machine (Pneumatic) (M)	X			A
Overhead Crane (Electric) (M)	X			E
Polisher (Hand-held) (T)	X			E
Water Pump (M)				S
Grinder (Hand-held) (T)	X			E
Engraving Tool (T)	X			E
Water Channeler (M)				E
Hydrosplitter (M)				E
Flame Channeler (M)	X			A and E