Deborah Jean Warner
SMITHSONIAN INSTITUTION

WILLIAM J. YOUNG FROM CRAFT TO INDUSTRY IN A SKILLED TRADE

WILLIAM J. YOUNG was the leading mathematical instrument maker in the United States in the middle decades of the nineteenth century. He redesigned the basic instruments, adapting European designs for American conditions, and made a good many of those actually used to survey the American continents. British instrument makers rapidly lost the competitive edge they had previously enjoyed. Among American instrument makers, many of whom copied his designs, Young was a pioneer in the industrialization of his craft, leading the way in both the mechanization and rationalization of the work process. These factors, plus a large and expanding market, ensured his financial success. The details of Young's responses to changing market, labor and technological conditions provide the basis for this story.

William J. Young was born in 1800, either in Scotland, or in Philadelphia soon after his parents migrated there.[1] William, Sr. worked as a tailor, prospering enough to purchase a house in Southwark, the immigrant working class neighborhood just south of Independence Hall.[2] At the age of 13 William J. was apprenticed to Thomas Whitney, to learn "The Trade or Mystery of a Mathematical Instrument Maker."[3] Seven years later, upon achieving his freedom, and with $30 lawful money in his pocket, the young man began in business. When Whitney died soon thereafter, Young probably acquired the tools and good will of his trade. In 1825 Young married, set up housekeeping in Southwark, and opened a shop at 130 S. Front, a street that had long housed most of Philadelphia's instrument shops and stores.

Young's timing was good. The United States was then embarking on an unprecedented expansion of both territory and internal improvements, and the demand for precision instruments increased proportionally. The high cost of European instruments and the difficulty of repairs, plus an eagerness for economic independence, led many Americans to want to buy American. Yet few American instrument makers were able to compete with Europeans either in quantity or quality. William J. Young was the first American to do so.

A good many eighteenth century Americans had made surveying instruments, but demand for their products was too small to support specialization.[4] The Rittenhouse brothers, probably the most prolific American instrument makers of their time, made compasses that compared favorably in beauty and precision with the best available in Europe. Yet neither David nor Benjamin engaged in instrument making as a full time occupation. The very few extant compasses by David, combined with the paucity of correspondence or other literary evidence, suggest a very limited output. Benjamin seems to have made more—at least 28 that he made alone or in collaboration with other artisans survive—but he too had numerous other interests.

The low demand for instruments in local markets mitigated against apprenticeships and workshops. Most early American instrument makers worked alone, with only on occasional apprentice or helper. The first and for many years the only instrument maker in the colonies who had served an apprenticeship in Europe was Anthony Lamb, and he was only in America because he had fallen into bad company in London, and chosen transportation over the gallows.[5] A few more European instrument makers arrived soon after the Revolution but, to judge from their advertisements, most earned their money by importing and repairing instruments, not by making them. Thomas Whitney, who was to become Young's mentor, was different in that he worked full time at his trade, and he sold to a national market. A native of London, and presumably trained there, he was in Philadelphia by 1798, advertising that "he makes various instruments in the most approved and accurate manner."[6] By 1820 he was claiming that "he has devoted his attention principally to the making of SURVEYING COMPASSES, for more than thirteen years past, and has made about five hundred of them, the good qualities of which are known to many surveyors in at least sixteen of the States and Territories of the Union."[7]

Most surveying in colonial America was done with a plain compass and chain. As internal improvements became more complex, surveyors increasingly relied on such "engineering" instruments as level, vernier and solar compass, and transit.

The surveyor's Y-level was a relatively new instrument, having been introduced in London, around 1740. Despite various improvements, the level was slow to take hold.[8] David Rittenhouse is known to have made two levels, and his brother Benjamin but one.[9] Thomas Whitney advertised "Instruments for Levelling" but it is not known what these were or how many he sold.[10] The first public notice of Young's level came in 1827, when he showed it and a compass at the Franklin Institute Fair. The judges awarded these an honorable mention, finding them "highly finished, very complete of their kind, and which may be advantageously compared with those imported."[11] The level soon became a key item in Young's product line. Examination of extant examples shows Young's level to be lighter, cleaner and more practical than contemporary English models. Young himself pointed to his level as being "in its principal proportions the copy for nearly every successive manufacturer, and yet remains in its original construction the most approved of all."[12]

The surveyor's compass was primarily a colonial instrument, useful in rapid surveys of vast, loosely populated lands. Around 1770 the plain compass was improved with the addition of a vernier, a short secondary scale indicating subdivisions of the primary divided circle or line. The vernier on a compass was generally used to compensate for variation, the local deviation of the magnetic needle from true north. David Rittenhouse seems to have been the first American to make a vernier compass[13]; similar instruments were advertised in Dublin.[14] Wherever the innovation originated, by the turn of the century the vernier compass was the instrument of choice for surveyors who could afford the extra expense. From extant examples we know that Young made vernier compasses of the standard pattern.

Even with a vernier a compass depended on magnetic north. To circumvent this problem Young devised a compass to measure horizontal angles without reference to the magnetic needle. It had a lower graduated plate which could be clamped so as to remain stationary, and an upper movable member carrying the vernier and sights. As added features Young moved the vernier on to the compass face and under the glass to protect it from injury, and he darkened the face to reduce glare. He applied for a patent on this compass late in 1830. It was granted in 1832, surrendered, and reissued in 1834.[15]

Young's patented compass led directly to the surveyor's transit, his most important instrument. The transit made its first appearance in 1831.[16] Young initially termed it simply "an Improved Compass, with Telescope attached, by which angles can be taken with or without the use of the needle, with perfect accuracy."[17] An early and important customer was the B&O Railroad. Since the telescope was transit mounted, surveyors could take sights forward along the line, and backward, much more expeditiously than they could with the more cumbersome and expensive British style theodolite. And, to the extent the transit was simpler of construction and less likely of derangement than the theodolite, accuracy of observations in the field was improved.

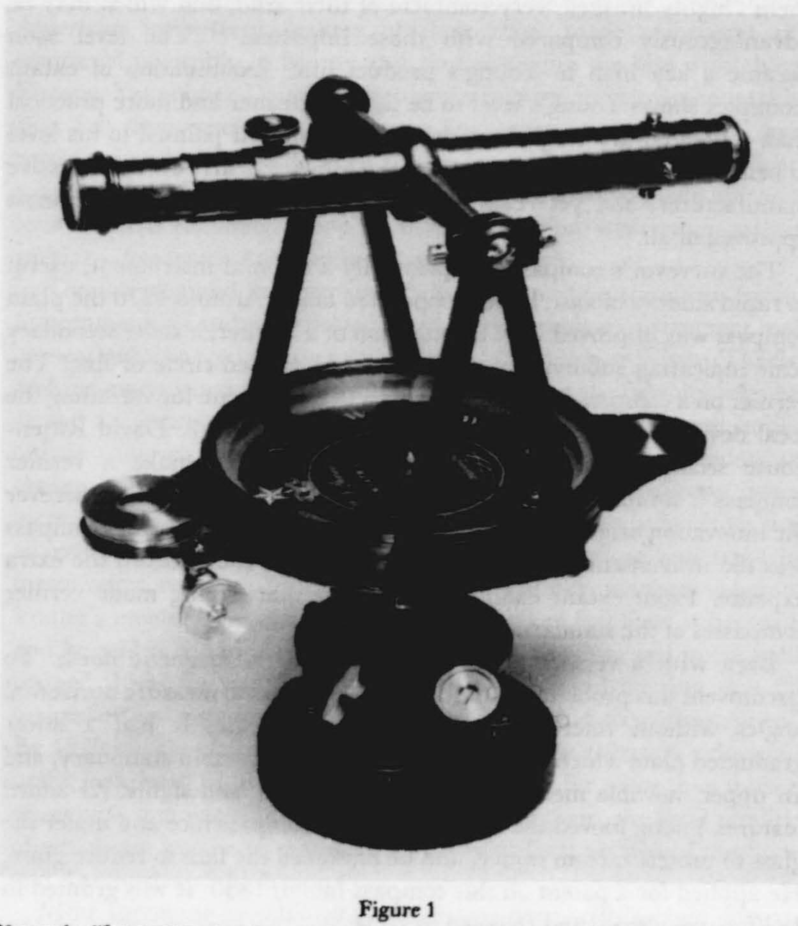

Figure 1

Young's "Improved compass, with telescope attached," circa 1831. This is reputed to be Young's first transit instrument. Photo courtesy National Museum of American History.

Until the 1850s when the first catalogs were issued American instruments were advertised primarily by word of mouth. Young must therefore have been particularly pleased when Samuel Mifflin promoted the transit—he was the first to apply the term to the instrument—as "the instrument to which I have been most accustomed" in his popular *Railway Curves,* published in 1837.[18] The review of Mifflin's book in the *Journal* of the Franklin Institute went even further, describing the transit at length, and concluding that, for railroad purposes, "it serves as well as the theodolite, is used in the same manner, and is much more portable, simpler, and less likely to get out of repair. It is also much cheaper; its cost being $140 or $150."[19] Although Young never obtained a strong position in the overseas market, he did achieve modest penetration. In 1847 a London dealer advertised Young's transit as possessing "many advantages over the theodolite for railroad work."[20]

In the design of the transit there was a trade-off between ruggedness and accuracy. Young's original model was remarkably sturdy. In 1853 he brought out a second model which, as transportation improved and the need for accuracy increased, became the instrument of choice for general work.[21] One other successful invention, worthy of mention, was the shifting head connecting the instrument with the tripod.[22]

Like all good instrument makers, Young worked closely with his customers, developing apparatus to satisfy their needs.[23] In 1835 Young met William Austin Burt, a Michigan surveyor whose frustrations with conducting magnetic surveys in areas with large deposits of iron ore led him to devise and eventually patent an instrument for easily determining the true meridian and the variation of the compass needle. Burt commissioned Young to make a solar compass (as his instrument was later to be called) for submission to the Franklin Institute, for evaluation by its Committee on Science and the Arts. The Franklin Institute quickly recognized the importance of Burt's invention and awarded him a Scott's legacy medal and premium.[24] Despite this honor, the solar compass was yet a good idea in an inchoate form. Over the next several years Young was in frequent correspondence with Burt, suggesting modifications and making new models until, by 1840, they had a truly successful instrument.[25] In 1850, almost coincidentally with the expiration of Burt's patent, the General Land Office adopted the solar compass as a standard instrument for all major boundary lines in regions of magnetic disturbance, and demand rose accordingly.[26]

By the 1830s Young was sufficiently secure to undertake the production of expensive scientific instruments on speculation, with no assur-

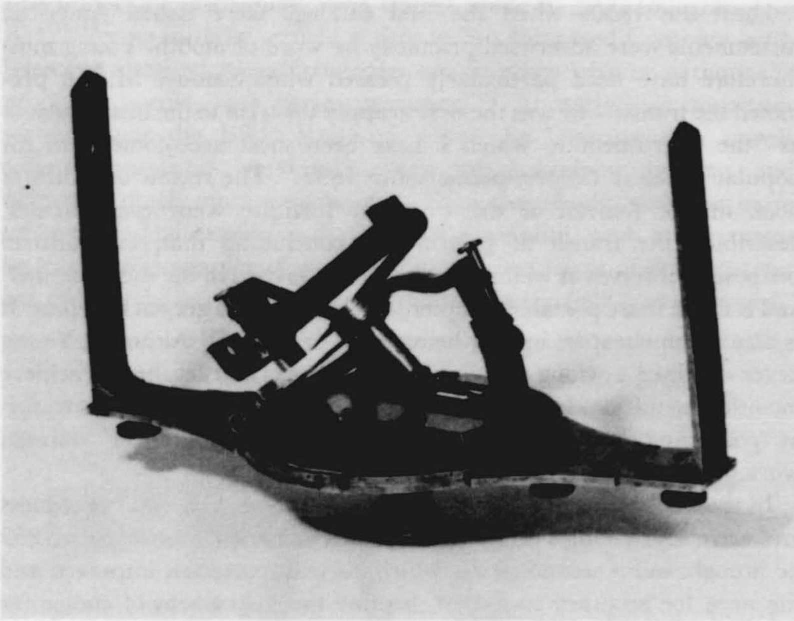

Figure 2
SOLAR COMPASS, CIRCA 1840, MARKED "BURTS PATENT. MADE BY WM. J. YOUNG PHILAD[a]." PHOTO COURTESY NATIONAL MUSEUM OF AMERICAN HISTORY.

ance of a sale. His first venture—duplicating a set of French instruments for observing the properties of light—ended in court when Young's bill far surpassed the French estimate.[27] In the early 1840s Young made a meridian circle for astronomical research, copied after the fine German instrument recently imported for the Central High School in Philadelphia. This time he was more successful. The judges at the Franklin Institute Fair awarded him a silver medal, "expressing their belief that it is the most perfect, as well the most difficult, work of the kind ever executed in this country."[28] This instrument was eventually sold to the privately owned Sharon Observatory at Darby, just outside Philadelphia.[29] He later made similar instruments for Haverford College and for Vassar, and did work for the U. S. Naval Observatory and the U. S. Exploring Expedition to Chile.[30]

With good products and an expanding market Young's business prospered. In 1836 he commented, "I have been counting my orders yesterday, & find that the Levels will keep me about 3 months & my Improved Compasses about 5 months busy with the hands I have now on them. . . ."[31] To keep up with his orders Young contracted with an

English manufacturer to supply parts for some three dozen transits. But the results did not justify the trouble—the brass contained too much iron, and the parts were not well made—and the experiment was not repeated.[32] As no account books survive, precise production levels are unknowable. Young first numbered instruments in around 1853, beginning with #3000, which suggests an output of around 100 instruments per year. In 1855, an unusually busy year, Young turned out over 150 instruments.[33]

Young's productivity came in part from mechanization and in part from an increased number of hands and rationalized procedures. In the 1820s he built a dividing engine—a device for mechanically dividing circles into degrees and minutes.[34] Young was the first American to do so and, indeed, the first American to even own one. He undoubtedly had never seen a dividing engine, but worked simply from a printed description of a British one. The first successful dividing engine had been built in England in 1775 by Jesse Ramsden under the encouragement of the Board of Longitude as a way to mass produce sextants and octants. While dividing engines caused a certain amount of de-skilling, they engendered no opposition. They were seen as a tool to aid the craftsman, not as a machine to replace him.[35] Manual graduation was just too difficult and time-consuming, and trained craftsmen too few, to meet the needs of the new navigation. Precision was also a factor. Compasses graduated to 1 degree of arc could be done with a simple divided plate. Presumably this was what Whitney had used. The inventory of his estate revealed nothing more complex than "3 Turning Lathes" and "Sundry Tools."[36] Young's first instruments were graduated with a plate made by George Adams of London.[37] His first transit, however, was graduated to 30′ and read by vernier to 3′, and later ones had even finer graduations. For such work, turned out in quantity, a dividing engine was essential. By 1870 Young had three circular dividing engines, two linear engines, and 16 lathes, all powered by hand or foot.[38] Steam was not introduced into the shop until the late 1870s.[39]

For surveying instrument makers, dividing engines quickly became a key factor. While an engine did not ensure success, lack of one limited output to compasses, which required only crude graduations, and levels, which required no graduations at all. Yet engines were expensive and/or difficult to obtain, and thus represented a formidable entry barrier to the field. Until the Civil War there were probably no more than six engines in the United States, outside of Young's shop.

Even with an engine, dividing a circle was an exacting task, "making serious inroads upon the constitution of the man engaged in such pursuits."[40] To lessen the labor of the artist, William Simms, a leading London maker, devised a method of making a dividing engine self-acting. Following the publication of Simms' method, Young modified his 24-inch engine, making it automatic. And he included an automatic motion in the design of his 48-inch engine.

Young claimed to have $6,000 invested in his business in 1850, $20,000 in 1860, and $10,000 in 1870.[41] Like all estimates of capital expenditure, these are fraught with uncertainty. Since Young made the dividing engines himself, value would be particularly difficult to determine. According to one account the largest dividing engine cost $7000, "and four years were occupied by three of their best workmen in testing and correcting it."[42] In the inventory of Young's estate this engine was appraised at $500—a figure surely below replacement or fair market value.[43] Ten years later this same engine was appraised at $2,000.[44]

In terms of management practices Young was a typical master craftsman of his era. He continued to work in the shop, taking over day-to-day supervision when his foreman could not. He kept his own accounts and wrote his own letters. Discussing a contract he had written: "I am not just at home, when writing agreements; the form I copied from a printed one, and hope it may answer."[45] For the most part Young operated his business as a sole proprietor. Only briefly did he go into partnership with his eldest son and, towards the end of his life, with his two best employees.[46]

American instrument shops increased in size from one or two hands in the early years of the century, to ten to twenty hands at mid-century, to 100 hands or more in the period 1880–1900. Young's shop led the first expansion. By the mid-1830s Young had several apprentices and several employees.[47] His workforce numbered about ten hands in the period 1850–1870, rising to 19 hands in 1880.[48] Despite this increase Young's shop remained an artisan shop or small manufactory, never expanding to factory status.

Attracting a skilled workforce and holding it in a fluid society was far from easy. With regard to apprentices Young described the problem thus: "On the 17th of Sept. (1836) one of my apprentices, who has been 3 years with, & was getting very useful to me, left without notice. . . . Unless I can regain him, I not only lose all his services, but it will be useless to attempt to keep lads after they take any umbrage with such an example before them."[49] Some young men stayed with Young long enough to learn the business, and then set up shop on their own. One such was Thomas Tennent, proprietor of the leading instrument shop and warehouse in San Francisco, and the West Coast agency for Young's instruments.[50] Another Young apprentice was Charles Shain who, together with Young's foreman, Joseph Knox, "having a very favorable offer made them to manufacture telegraphic machines," went into that business on their own. Knox & Shain made surveying instruments as well as telegraphic ones and, by 1860, their Philadelphia shop was almost as large and prosperous as Young's.[51]

While many nineteenth century craftsmen enjoyed the challenges and opportunities of entrepreneurship, an increasing proportion sought the security of stable employment. Thomas Watson, another of Young's foremen, worked for Young almost continuously for some 50 years.[52] Other examples of long-term service are provided by Heller & Brightly, a firm that spun off from Young and was of about the same size. In 1896, on the celebration of their 26th anniversary, Heller & Brightly noted that none of their present work force had been less than 17 years in their employ, and some had been with them continuously for 24 years.[53]

The men who chose to stay with Young as employees were well aware of their worth, often exhibiting that autonomy characteristic of pre-industrial craftsmen. Of one of these men Young wrote: "his doctrine is, that he only works to live, and does not live to work, and during a goodly part of the time he lived up to his doctrine." Young continued: "I have as a whole as decent a set of men as can be found in any shop, yet they know their usefulness, and when they do not exactly as I wish, I frequently have to say nothing about it."[54] Machinists were elite among craftsmen, and they were paid accordingly. Young's salary structure was competitive with those of other instrument and precision machine shops in Philadelphia. In 1850 Young paid average wages of $528 per year. Printers and compositors, by contrast, averaged $370, and male workers in 14 major industries averaged only $288.[55] There is no evidence that Young's men ever struck. Their power was probably so great they had no need to. Hours of employment are not known. However, as late as the 1910s the men were still sending out for a bucket of beer several times a day.[56]

As Young's business expanded the labor shortage intensified. "If I could find competent workmen, I could at present double my business," Young claimed in 1851.[57] With American craftsmen so scarce Young looked again to Europe. "The impossibility of finding competent workmen I have never found so great as the present time. I have been thinking of having an advertisement put in some of the European papers, stating the certainty of good workmen finding employment here."[58]

At the moment Young was writing this some of the European craftsmen he sought—both the mechanics and the opticians—were already in the United States, many of them having left Germany and Ireland during the upheavals of 1848. Young soon sent his son Alfred to New York to work with Adolph Wirth, an immigrant optician whose lenses for engineering instruments proved "much better than those otherwise obtainable." Before long Young had acquired Wirth's tools and machinery, and installed them in his new four-story brick building in Philadelphia.[59] Wirth and his men came too, probably as inside contractors rather than employees. The Philadelphia city directory for 1855 lists nine mathematical and optical instrument makers—seven Germans and two Irishmen—as well as Young's foreman, Thomas Watson, working at Young's address. Young's regular employees are more difficult to know. Apprentices were never listed in the directories, and those journeymen who were listed were seldom identified by place of employment.

Already at mid-century Young had moved towards specialization. In his own words: "I find they get along full as fast by giving to each a part and the work is done better."[60] There is evidence, however, that such specialization did not prevail for long. Moreover, despite the shortage and high cost of skilled artisans, Young never sought to replace these men with less skilled workers. By the 1860s this labor policy was bringing stiff price competition from forward-looking instrument manufacturers, most notably W. & L. E. Gurley of Troy, N. Y. Established in 1852, Gurley aimed to be the low cost producer. On some major items their price was a third less than those made by Young.[61] The problem intensified in the 1870s when, after remaining fairly stable for twenty years or more, the wages of skilled machinists rose sharply. For Young, wages rose from $600 per year in 1870, to $3 per day ($900 per year?) in 1880.[62]

Young's ambivalence towards mechanization and rationalization is understandable in light of his youthful opposition to industrial production. Bruce Laurie's description of a radical republican as Thomas Paine's Progeny fit Young well.[63] In all probability ideology inspired Young to name his eldest son Jackson (1825) and his youngest son Thomas Benton (1837). In the years 1828–30 Young had been an active participant in the workingmen's movement which aimed "to arrest incipient capitalism and to institute instead a system of small producers in which the journeyman artisan would have a respected place in the community."[64] More particularly, the movement promoted education for workingmen and their children, and it encouraged workingmen to use the franchise to elect candidates who supported their aims. While never as articulate as the charismatic organizer, William Heighton, Young was a valiant footsoldier. He attended meetings, often in the role of secretary, signed petitions, served on the Committee of Vigilance for several elections, and was elected a director of the Mechanics' Library and an officer of the Working Men's Republican Political Association of Southwark. At festivities on the 4th of July, 1830, Young proposed a toast: "Our militia properly organized and equipped—an army of republican citizens—they are the only terror to tyrants—the only safeguard of the liberties of the people. With it our liberties are secure against the power and machinations of the world."[65]

Radical workingmen held the labor theory of value as a central tenet, and instrument makers were no exception. We have no quote from Young himself on this subject. But Samuel Blydenburgh, one of his employees, stated in court, "I know no other value of these articles than by the time and what a journeyman could get making them."[66]

Young's radical activity probably ceased in the early 1830s. In 1857 he mentioned his ignorance of local politicians, concluding "I have attended so little to active politics for several years. . . ."[67] Since we have no evidence of how Young felt about relinquishing his youthful ideals, speculations about Young's falling away might well begin with the general demise of the workingmen's party. As his business became more successful, Young must have had increasingly less in common with a movement that focused more on non-partisan labor unionism and less on politics.[68] Despite the introduction of dividing engines and some division of labor, instrument making remained a skilled trade. Not until late in the century would its workers experience the loss of security and status facing workers in rapidly changing industries. Finally, a man like Young who looked to Europe for skills not available in the United States, not for cheap labor, would have been uncomfortable with the growing nativism of the American labor movement. Indeed, he might have found his immigrant employees who came out of a radical craft tradition more congenial than his fellow American workingmen.[69]

Whatever his vision of America as a nation of small, independent artisans, Young certainly profited from owning the tools of production and organizing the labor of others. With all due respect to the uncertainties inherent in the accounting and reporting systems of the mid nineteenth century it seems clear that Young made about ten times as much as did his highest paid employees. By the 1840s he was sufficiently secure to invest nearly $8000 in an iron foundry and to be disappointed but not distraught on learning that he might lose half this sum.[70] In 1850, 1860 and 1870 the profit from Young's shop (value of goods produced minus materials, wages, and ground rent) was around $8000. In those years his property, real and personal, averaged around $20,000.[71] An 1865 estimate of Young's income ($1750) and an 1870 appraisal of his estate ($7169) suggest a cavalier attitude toward income taxes and probate records.[72] While the myth of the self-made man has been severely challenged, there is little question but that Young falls into this category. His parents were, at best, of the middling sort,[73] and there is no evidence that his wife brought any wealth to the marriage.

After Young's death in 1870 the business remained in family hands much as he left it, still producing fine instruments but steadily losing their competitive edge. A credit rater of 1886 reported that Young & Sons employed "skilled workmen at high prices . . . his expenses are heavy, and he is unable to compete with parties who avail themselves of the advantages of improved machy."[74] While retaining their expensive employees Young & Sons took steps to increase productivity, endeavouring "by more perfect system and increased facilities, to counteract the increased (in some cases almost doubled) cost of skilled labor."[75] This "perfect system" probably entailed batch production. Heller & Brightly regularly made instruments in lots of 20–50.[76] Such batch production might imply deskilling. In fact, however, one man was responsible for a complete lot, and thus was fully capable of making all the parts.[77] By the early twentieth century full scale specialization had taken hold. William J. Young's great grandson recalled seeing "rough castings from the brass founders passed along a line of lathes from man to man, from rough finisher to final."[78] It was, however, not enough. By the 1890s most mathematical instruments were being made in factories, by large armies of anonymous mechanics. It was a step Young and his descendents could or would not take. In 1921 they sold out to Keuffel & Esser, who did.

NOTES

1. Philadelphia Death Register and family history report Scottish birth; U. S. Manuscript Population Census of 1850 and 1860 report American birth.

2. Bond of Administration of William Young (Philadelphia County, 1825, #266, and 1855, #143).

3. William J. Young's indenture is in the National Museum of American History (#81.511.2).

4. Silvio A. Bedini, *Thinkers and Tinkers, Early American Men of Science* (New York, 1975). Charles Smart, *The Makers of Surveying Instruments in America Since 1700* (Troy, N. Y., 1962).

5. Silvio A. Bedini, "At the Sign of the Compass and Quadrant. The Life and Times of

Anthony Lamb, Mathematical Instrument-Maker of New York," *Transactions, American Philosophical Society* (1984).

6. *Federal Gazette,* April 12, 1798, quoted in Harold E. Gillingham, "Some Early Philadelphia Instrument Makers," *Pennsylvania Magazine of History and Biography* 51 (1927): 304.

7. *Whitely's Philadelphia Annual Advertiser* (1820).

8. Art. "Levelling" in Abraham Rees, *Cyclopaedia* (London, 1819).

9. Bedini, *Thinkers and Tinkers, op. cit.,* 217.

10. Thomas Whitney, "Care in the use of the compass," 1817, in compass box (#328,751) in the National Museum of American History.

11. *Journal, Franklin Institute* 4 (1827): 406.

12. Announcement of partnership of William J. Young & Son, 1857, copy in Burt Papers, Marquette County Historical Society.

13. Brooke Hindle, *David Rittenhouse* (Princeton, N. J., 1964), 246.

14. John Hood, *Tables of Difference of Latitude and Departure for Navigators, Land Surveyors, &c.* (Dublin, 1772), 5.

15. The restored patent and drawing survive. For brief summary see *Journal, Franklin Institute* 10 (1832): 34 and 14 (1834): 113.

16. "Invention and Introduction of Engineer's Transit," *The Engineering News* 2 (1875): 129–30 and 154–5; and reprinted in Young & Sons, *Price List of Engineering and Mathematical Instruments* (Philadelphia, 1882, and later editions), 69–75. Young's original transit is now in the National Museum of American History (#339,459).

17. William J. Young ad in *American Railroad Journal* 2 (1833).

18. Samuel W. Mifflin, *Methods of Location or Modes of Describing and Adjusting Railway Curves and Tangents* (Philadelphia, 1837), 9.

19. R. P., "Bibliographical Notice," *Journal, Franklin Institute* 19 (1837): 317–8.

20. Edward Marmaduke Clarke, "Price list of the principal mathematical and drawing instruments" appended to F. W. Simms, *A Treatise on the Principal Mathematical and Drawing Instruments* (London, 1847).

21. "Invention and Introduction of Engineer's Transit," *op. cit.* 154.

22. W. J. Young, "Tripod-Head for Surveyors," U. S. Patent #20,915 of July 13, 1858. Edwin Hulbert's comments in Dunbar Scott, et. al., *The Evolution of Mine Surveying Instruments* (New York: Published for the American Institute of Mining Engineers, 1902), 151.

23. For Parson's patent scales see Franklin Institute "Committee on Science and the Arts" file #606, (Wilmington, Del.: Scholarly Resources, 1977), microfilm; and Franklin Institute, *Catalogue of the Twenty-First Annual Exhibition* (1851), 20. For Kimber Cleaver's protractor see W. J. Young to J. Simpson Africa, July 11, 1855, Pennsylvania State Archives, R. G. 14. Ad for "Nystrom's Calculator, W. J. Young, Calculating Machine Manufacturer," *Journal, Franklin Institute* 41 (1861); "Description of a Calculating Machine, Invented by J. W. Nystrom," *ibid.* 21 (1851): 262–7. These three instruments are listed in Young & Sons, *Manual and Price List of Engineering and Mathematical Instruments* (Philadelphia, 1870s and 1880s). "Description of a beam compass, contrived by John C. Trautwine," *Journal, Franklin Institute* 16 (1835): 145–7.

24. Franklin Institute, "Committee on Science and the Arts," file #79 (Wilmington, Del: Scholarly Resources, 1977), microfilm; and "Annual Report of the Transactions of the Committee on Science and the Arts," *Journal, Franklin Institute* 17 (1836): 193.

25. See letters from W. J. Young to William A. Burt, 1836–58, Burt Papers, Marquette County Historical Society; "Report on Wm. A. Burt's Solar Compass," *Journal, Franklin Institute* 31 (1841); 97–98.

26. John Burt, *History of the Solar Compass* (Detroit, 1878).

27. Copy of Bancker *vs.* Young (1835) at The Historical Society of Pennsylvania; see also "The Bancker Collection," *Journal, Franklin Institute,* 61 (1871): 375–76.

28. *Journal, Franklin Institute* 4 (1842): 349 and 5 (1843): 51.

29. Elias Loomis, *The Recent Progress of Astronomy; Especially in the United States* (New York: Harper & Brothers, 1856), 258.

30. Loomis, *op. cit.,* 396; Edward S. Holden, "Astronomy" in *Annual Record of Science and Industry* (1877): 51. Both the Haverford and Vassar instruments are now in the National Museum of American History (#81.745.14 and #80.318). *Astronomical and Meteorological Observations Made at the United States Naval Observatory During the Year 1861* (1862), viii; J. E. Nourse, "Observatories in the United States," *Harper's New Monthly Magazine* 49 (1874): 530–31. Loomis, *op. cit.,* 262 & 295; see also Young correspondence in "Letters Received by the U. S. Naval Astronomical Expedition to the Southern Hemisphere," National Archives, R. G. 78 (Records of the Naval Observatory).

31. W. J. Young to William A. Burt, Jan. 9, 1836, Burt Papers, Marquette County Historical Society.

32. "Invention and Introduction of the Engineer's Transit," *op. cit.*: 154.

33. Alfred C. Young's comments in Dunbar Scott, et. al., *op. cit.,* 152. The lowest number yet found is 3192; this transit instrument is in the National Museum of American History (#337,244).

34. "Invention and Introduction of the Engineer's Transit," *op. cit.,* 154.

35. This point is made in Eugene Ferguson, "American-ness of American Technology," *Technology & Culture* 20 (1979): 10.

36. Inventory of Estate of Thomas Whitney (Philadelphia County, 1823, #293).

37. "Invention and Introduction of the Engineer's Transit," *op. cit.,* 154.

38. "Wm. J. Young" in U. S. Manuscript Census of Manufactures, 1870, Philadelphia, 6th Ward, p. 25, National Archives, R. G. 29. The listing of 5 "graduating machines" I take to be a mistake. See also Wm. J. Young & Sons, *Manual and Price List of Engineering and Mathematical Instruments* (preface to the sixth edition, 1879).

39. "Wm. J. Young & Sons" in U. S. Manuscript Census of Manufactures, 1880, Philadelphia, p. 36, National Archives, R. G. 29.

40. W. Simms, "On a Self-Acting Circular Dividing Engine," *Monthly Notices, Royal Astronomical Society* 5 (1843): 291-2, and *Memoirs, Royal Astronomical Society* 15 (1846): 83–90.

41. "Wm. J. Young" in U. S. Manuscript Census of Manufactures, 1850, Philadelphia, Dock Ward; 1860, Philadelphia, 6th Ward, p. 29; and 1870, Philadelphia, 6th Ward, p. 25.

42. "Engineering and Other Instruments of Precision" in Balch, *The Mines, Miners and Mining Interests of the United States,* 1191.

43. Inventory of Estate of William J. Young (Philadelphia, 1870, #417).

44. Inventory of Estate of Alfred Young (Philadelphia, 1882).

45. W. J. Young to Lieut. J. M. Gillis, Nov. 30, 1848, Letters Received by the U. S. Naval Astronomical Expedition to the Southern Hemisphere, National Archives, R. G. 78.

46. Announcement of partnership of William J. Young & Son, 1857, copy in Burt Papers, Marquette County Historical Society. Agreement between William J. Young and Charles S. Heller, dissolving their partnership, dated June 27, 1870, xerox copy in National Museum of American History. See also listings for Young's business in Philadelphia city directories for this period.

47. In 1840 the Young household included two free white males aged 15–20, and one aged 20-30, whom I cannot identify as family members, and assume were apprentices. See U. S. Manuscript Population Census 1840, Philadelphia.

48. "Wm. J. Young & Sons" in U. S. Manuscript Census of Manufactures, 1880; *op. cit.*

49. Wm. J. Young to William A. Burt, Nov. 20, 1830, Burt Papers, Marquette County Historical Society.

50. "Thomas Tennent" in *The Bay of San Francisco* (San Francisco, 1892), 142–44. Ad for "Thomas Tennent's Surveying and Navigation Warehouse" in *California Mercantile Journal* (1856): 99.

51. W. J. Young to William A. Burt, March 12, 1850, Burt Papers, Marquette County Historical Society. "Knox & Shain" in U. S. Manuscript Census of Manufactures, 1860, Philadelphia.

52. See testimonial to T. N. Watson in various editions of Young & Sons, *Manual and Price List of Engineering and Mathematical Instruments* (1870s and 1880s). Watson's death notice in the Philadelphia *Inquirer* (Dec. 27, 1891) extended an invitation to "employees of Young & Sons" to attend his funeral.

53. Notice in *Engineer* (Feb. 15, 1896).

54. W. J. Young to William A. Burt, May 11, 1850, Burt Papers, Marquette County Historical Society.

55. "Wm. J. Young" in U. S. Manuscript Census of Manufactures, 1850, *op. cit.* Bruce Laurie, *Working People of Philadelphia, 1800–1850* (Philadelphia, 1980), 12.

56. Alfred C. Young to Robert Miller, Dec. 13, 1977.

57. W. J. Young to William A. Burt, Jan. 27, 1850 (51?), Burt Papers, Marquette County Historical Society.

58. W. J. Young to William A. Burt, Feb. 17, 1851, Burt Papers, Marquette County Historical Society.

59. "Invention and Introduction of the Engineer's Transit," *op. cit.*: 155.

60. W. J. Young to William A. Burt, Jan. 27, 1850 (51?), Burt Papers, Marquette County Historical Society.

61. W. & L. E. Gurley, *A Manual of the Principal Instruments used in American Engineering and Surveying* (Troy, N. Y., 1862), 7. Gurley's statement about the "Low Cost of Our Instruments" was repeated in the *Manual* for at least 20 years.

62. "Wm. J. Young" and "Wm. J. Young & Sons" in U. S. Manuscript Census of Manufactures, *op. cit.*

63. Bruce Laurie, *op. cit.*, chapter 4, "Radicals: Thomas Paine's Progeny."

64. Louis Arky, "The Mechanics' Union of Trade Associations and the Formation of the Philadelphia Workingmen's Movement," *Pennsylvania Magazine of History and Biography* 76 (1952): 142–176.

65. *Mechanics' Free Press,* 1828–1830; W. J. Young is mentioned at least once a month during this period. "Address of the City and County Convention to the Working Men of the State" signed by W. J. Young and others is reprinted in John R. Commons, et. al.

(ed.), *A Documentary History of American Industrial Society* (New York, 1958), vol. V, pp. 114–23.

66. Testimony in Bancker *vs.* Young (1835), copy at The Historical Society of Pennsylvania.

67. W. J. Young to J. Simpson Africa, Nov. 28, 1857, Africa Papers, Pennsylvania State Archives, R. G. 14.

68. Bruce Laurie, *op. cit.*

69. Bruce Laurie, *op. cit.*, 163–68. Carl Wittke, *Refugees of Revolution* (Philadelphia, 1952).

70. W. J. Young to William A. Burt, April 4, 1847, Burt Papers, Marquette County Historical Society.

71. "Wm. J. Young" in U. S. Manuscript Census of Manufactures and in U. S. Manuscript Population Census, 1850, 1860, and 1870.

72. Inventory of Estate of William J. Young (Philadelphia County, 1870, #417).

73. In 1855, after the death of his wife, William Young's estate of $4881.87 was divided among his five children; see Bond of Administration of Estate of William Young (Philadelphia County, 1855, #143).

74. R. G. Dun report on Young & Sons, 1886, Baker Library, Harvard Business School.

75. Wm. J. Young & Sons, *Manual and Price List of Engineering and Mathematical Instruments* (Philadelphia, 1875, and later editions), 4.

76. "Stroll Through an Engineers' Instrument Manufactory," *Engineer* (March 1874), reprinted in Heller & Brightly, *Remarks on Engineers' Surveying Instruments* (Philadelphia, 1886), 29.

77. Conversation between George Kegelman and Bob Miller.

78. Alfred C. Young to D. J. Warner, Sept. 15, 1983.