In what ways can the problems be alleviated? To keep the chemist in touch with related fields a chemical newspaper is required, perhaps of the form of the *Nature* News Sections, devoted to recent advances in chemistry as they are published. Difficulties of editing such a publication can be foreseen, nevertheless it would be a considerable improvement over present "browsing" methods. The problems of retrospective literature searches are more difficult to solve, being of human origin. Use of a parallel search based on a keyword method would eliminate past problems, though resulting in some time-consuming duplication. Continuance of such practices can only be prevented by more efficient refereeing.

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Quantitative Characteristics of Patents, Inventions, and Innovations

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Based on a survey of the literature published since 1962, quantitative information is presented which relates to sources and geographical origins of inventions, the time interval from conception to innovation, and the use of patents as evidenced by licensing. Of 33 examples of innovations since 1917, only six showed the same geographical origin for invention and innovation and had a time span from discovery to innovation of less than five years. Eleven examples showed different geographical origins for invention and innovation and a time interval of 10 or more years from date of invention to date of innovation.

One measure of America's technological strength is its number of inventions. The number of U. S. patents exceeds that of any other nation. Since 1950 when approximately 43,000 patents were granted, the number of U. S. patents issued annually increased to 50,000 in 1960 and 67,000 in 1970.

At the end of 1970, there were approximately 900,000 unexpired U. S. patents. About 60% of these live patents are owned by domestic corporations and 10% by foreign firms.[2] In 1964, 80% of all U. S. patents were of local origin. The remainder were divided as follows: 4% to firms from West Germany, 4% to British firms, 2% to French firms, and 10% to inventors from more than 25 other nations. In contrast, approximately 62% of all West German patents were of local origin. The remainder were issued to: firms from the U. S. (15%), Great Britain (5%), France (4%), and from more than 25 other nations (14%). In another example, only 19% of all patents granted in the Netherlands were of Dutch origin; while patents of U. S. and German origin each accounted for 22% of the total documents.[8]

Presently, about three out of four U. S. patents are assigned to corporations. The remaining one-fourth are owned by individuals, with a small proportion held by the federal government.[2] This ratio differs from 20 years ago when 55.2% of U. S. patents were assigned to corporations and 42.8% were issued to individuals.[7]

SOURCES OF INVENTION

Aluminum is a striking example of an industry created by invention. In a study of the American aluminum industry from 1946 through 1957, Merton Peck of Harvard found that primary producers of aluminum were an important source of inventions for new product applications and alloys but contributed relatively little toward advances in welding, fabricating, and finishing. Primary producers concentrated their inventive efforts in alloys which can be directly incorporated into the product line and which yield profits that are relatively immediate compared to profits from inventions in fabricating and manufacturing techniques. In comparison, equipment makers were the major source of fabricating inventions. Again, the more immediate and certain profits from invention for such firms appear to be the stimulus for invention.[6] The sources of inventions in the U. S. aluminum industry for 1946–1957 expressed as percentages of all inventions in four technical areas are shown in Table I.

In another study, Willard Mueller of the University of Wisconsin analyzed the sources of inventions underlying Du Pont's major product and process innovations during the period 1920–1950. He showed that of 25 important Du Pont product and process innovations (Table II), ten were based on inventions of Du Pont scientists and engineers.[5] Of the 15 non-Du Pont discoveries, only four originated in the United States. The origin of the other 11 inventions is distributed as follows: Germany (5), Great Britain (3), Sweden (2), and France (1).

Table I. Sources of Inventions in the U. S. Aluminum Industry for 1946–1957

	Technical Area			
Source, % of Total Inventions	Joining	Finishing	Fabricating	Alloys
Primary Producers	12%	4%	13%	75%
Equipment Manufacturers	50	50	48	—
Aircraft Manufacturers	12	26	7	—
Independent Fabricators	—	—	17	5
Foreign Sources	12	—	9	10
Other[a]	14	20	6	10

[a] Includes government laboratories, commercial R&D laboratories, and individual inventors.

TIME INTERVAL FROM INVENTION TO INNOVATION

In proceeding from invention to innovation, several functions are involved. After an invention is recognized, capital, equipment, and materials are acquired, labor and management are employed, markets are recognized and developed, production techniques implemented and channels of distribution established. At any point in the sequence, failure may occur, delays may result, and alterations made in order to make the original conception more amenable to commercial realities. These circumstances plus many other factors contribute to the time lag from invention to innovation.

Examples of intervals of time between conception and innovation based primarily on information found in the book, "The Source of Invention,"[1] are tabulated for both chemical and mechanical and electrical innovations (Tables III & IV).

Although there appears to be no systematic chronological trend or pattern, exactly half of the chemical examples showed an innovation time interval of less than 10 years. In seven of these eight examples, the geographical origins of the innovation and the invention were the same. By comparison, in the eight cases where the time interval exceeded 10 years, only three innovations and inventions shared the same geographical origin.

In the field of mechanical and electrical innovations, only five of the 17 examples revealed a time interval from invention to innovation of less than 10 years. Of the five innovations, three had the same geographical origin as their respective inventions. The geographical origin of innovations with a time span between conception and innovation of ten or more years was the same as the geographical origin of the inventions in six of 12 examples.

THE ROLE OF UNITED STATES

Of the 16 chemical innovations, 12 came from United States. Of these dozen innovations, seven were based on domestic inventions, four were British inventions, and one came from Italy. In contrast, there was a lower percentage of U. S. innovations among the 17 mechanical and electrical innovations. Of the nine innovations credited to the United States, seven were derived from domestic inventions and one each was based on discoveries in Russia and France.

When the total number of innovations is considered, it is observed that 21 of the 33 innovations are credited to the United States. Geographical origins of invention for the 21 innovations are: U. S, 14; Great Britain, 4; and France, Italy, and Russia, one each.

Table II. Sources of Inventions for Du Pont's Product and Process Innovations

Du Pont Innovation	Date	Source of Invention	Date of Invention
Viscose Rayon	1920	Great Britain	1892
Duco Lacquers	1923	Du Pont	1920
Tetraethyl Lead (Bromide Process)	1923	U. S. A. (General Motors)	1921
Tetraethyl Lead (Chloride Process)	1924	U. S. A. (Esso)	1924
Cellophane	1924	U. S. A. (Weston)	1882
Synthetic Ammonia	1926	Germany (Dobereiner)	1823
Moistureproof Cellophane	1927	Du Pont	1926
Synthetic Methanol	1927	France (Sabatier)	1905
Dulux Enamels	1928	Sweden (Berzelius)	1847
Acetate Rayon	1929	Germany (Bronnert)	1899
Freon	1931	U. S. A. (General Motors)	1930
Neoprene	1931	Du Pont	1931
Titanium Pigments	1931	Germany	1795
Cordura High-Tenacity Rayon	1934	Du Pont	1934
Lucite	1936	Germany (Rohm)	1912
Nylon	1939	Du Pont	1928
Polyvinyl Acetate	1940	Germany	1913
Rutile Titanium Dioxide	1941	Du Pont	1941
Fermate Fungicides	1942	Du Pont	1942
Teflon	1943	Du Pont	1941
Polyethylene	1944	Great Britain	1933
Titanium Metal	1948	Sweden (Nilson & Peterson)	1887
Orlon	1948	Du Pont	1942
Polyester	1949	Great Britain	1941
Polymeric Color Film	1949	Du Pont	1949

Table III. Time Intervals from Date of Invention (Same geographical origins for innovation and invention)

Innovations	Less Than 5 Years, %	Less Than 10 Years, %	More Than 20 Years, %
Total examples	18	31	12
Chemical examples	31	44	6
Mechanical and electrical examples	6	18	18

Table IV. Time Interval between Inventions and Innovations Since 1917

Innovation	Date and Origin	Date of Invention and Origin	Interval, Years
CHEMICAL INVENTIONS			
Freon	1931 (U. S.)	1930 (U. S.)	1
Crease-resistant fabrics	1932 (Gr. Brit.)	1918 (Gr. Brit.)	14
Nylon	1939 (U. S.)	1928 (U. S.)	11
DDT	1942 (Switz.)	1939 (Switz.)	3
Silicones	1943 (U. S.)	1904 (Gr. Brit.)	39
Teflon	1943 (U. S.)	1941 (U. S.)	2
Penicillin	1944 (U. S.)	1928 (Gr. Brit.)	16
Streptomycin	1944 (U. S.)	1939 (U. S.)	5
Polyethylene	1944 (U. S.)	1933 (Gr. Brit.)	11
Chlordane	1945 (U. S.)	1944 (U. S.)	1
Orlon	1948 (U. S.)	1942 (U. S.)	6
Polyester fiber	1953 (U. S.)	1941 (Gr. Brit.)	12
Polypropylene	1957 (U. S.)	1954 (Italy)	3
Float glass process	1958 (Gr. Brit.)	1902 (U. S.)	56
Synthetic penicillin	1959 (Gr. Brit.)	1957 (Gr. Brit.)	2
Polyimides	1962 (U. S.)	1908 (U. S.)	54
MECHANICAL AND ELECTRICAL INVENTIONS			
Zipper	1918 (U. S.)	1891 (U. S.)	27
Radio oscillator	1920 (U. S.)	1912 (U. S.)	8
Self winding watch	1928 (Switz.)	1922 (Gr. Brit.)	6
Power steering	1931 (U. S.)	1925 (U. S.)	6
Helicopter	1932 (U. S.)	1909 (U. S. S. R.)	23
Torque converter	1933 (Gr. Brit.)	1904 (Germany)	29
Converter coupling	1934 (Germany)	1924 (Gr. Brit.)	10
Radar	1935 (France)	1922 (U. S.)	13
Fluorescent lamp	1938 (U. S.)	1859 (France)	79
Television	1941 (U. S.)	1919 (U. S.)	22
Cotton picker	1942 (U. S.)	1889 (U. S.)	53
Jet engine	1943 (Gr. Brit.)	1929 (Gr. Brit.)	14
Turbo jet engine	1944 (Germany)	1934 (Germany)	10
Ball point pen	1944 (Argentina)	1938 (Hungary)	6
Long playing record	1948 (U. S.)	1945 (U. S.)	3
Xerography	1950 (U. S.)	1937 (U. S.)	13
Air cushion vehicle	1968 (Gr. Brit.)	1928 (U. S.)	40

THE USE OF PATENTS

In 1965, more than 50% of all chemical process patents were put into use before their expiration date.[9] Recently, a survey of 39 U. S. corporations showed that 10% of the firms sell their patents and ideas. Fifty per cent of the firms exchange their unwanted patents and ideas for inventions and conceptions more important to their product lines. The survey also revealed that 87% of the companies engage in the licensing of patents. According to the survey, the average percentage of patents for which a licensee is found when one is sought is 46%.[4]

Owing to stringent tariff barriers, many U. S. firms have chosen to license foreign manufacturers rather than sell abroad through exports. By 1969, 900 U. S. corporations were reporting royalties and licensing fees from their own foreign branches, affiliates, and subsidiaries.[13] Data on the extent of overseas licensing has only been compiled since 1961. A study of 1745 licenses from 1961 to 1967 showed Europe as the prime target for licenses. Of the total licenses, 772 (44%) covered operations in Western Europe, 456 (26%) in Asia, 367 (21%) in the Western Hemisphere, 86 (5%) in Oceania, and 64 (4%) in Africa.[3]

Another survey of 191 companies conducted by the National Industrial Conference Board showed that licensing contributes to over half of foreign income for 20% of the firms. However, more than 50% of the firms received less than 10% of their total foreign revenues from licensing.[11]

Revenues from licensing are expressed in two ways—revenue from licensing a firm's own subsidiaries, affiliates, and branches and revenue from licensing independent foreign firms. Income from the former increased from $157 million in 1961 to $438 million in 1967 and $640 million in 1969. The rise in income from the latter has been smaller, from $263 million in 1961 to $348 million and $360 million in 1967 and 1969, respectively.[11, 13]

Licensed technology has largely been responsible for transforming Japan into the world's third ranking industrial power. In 1970, Japan bought 10 licenses for each license sold.[12] Of a total of $348 million spent on licensing, Japanese industry paid $209 million to U. S. firms.[10]

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