

September 11, 1963 Southbridge, Mass.

TO: S. M. MacNeille

Attached is the first typed draft of a history compiled by A. H. Bennett (retired) with contributions by O. W. Richards and (Miss) G. Pool. This draft is for internal use only and not intended for publication.

There are three objectives in making this circulation. The first, of course, is to be certain that we have no errors in transcription. The second is to be certain there are no significant omissions. The third is to establish publication requirements.

(Signed): Technical Info. Staff / J. E. Allen

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The Spencer Lens Company

American Optical Company

History with Reference to the Research Dept.

Compiled by

Alva H. Bennett

1960

PERSONAL RECOLLECTIONS

Some few years prior to 1928 Spencer Lens Company decided to build up their scientific facilities. At that time Mr. H. N. Ott was President; L. M. Potter, Vice-President in Charge of Sales; A. O. Potter, Secretary; a Mr. Ryan, Treasurer; and Mr. H. N. Ott's son, Harry G. Ott was Scientific Director. For many years Mr. H. N. Ott had originated practically all the mechanical designs of instruments, and for many years later he continued to do so. In the factory Mr. Henry Sandmann was Superintendent, and Mr. Frank Bangert was in charge of all optical production.

In the autumn of 1928 I was working at the U. S. Bureau of Standards, having started there in May 1918 as a laboratory assistant, and reaching the grade of associate physicist by 1928. It was almost by chance that I got into optical work. It was during World War I that I completed my undergraduate work at Ohio State University, and had taken a course in general optics under Prof. Cole. Early in 1918 Prof. Cole asked me if I would like to work at the Bureau of Standards upon graduation. I was glad to accept this opportunity for two reasons, as I see it now. First, I wanted to be a physicist and in the second place I was now going to do military research. On the strength of my having studied at least some optics the Bureau decided to place me in the Optical Instrument Section which was a newly formed group. During my years at the Bureau of Standards I was very busy doing research on the performance of optical instruments, devising optical testing methods and writing and presenting papers, instrumentation; and after hours taking graduate courses in physics and mathematics at George Washington University and at the Bureau of Standards Graduate School. Here I might add that Dr. I. C. Gardner had given a course in geometrical optics at the Bureau of Standards which I attended.

In the fall of 1928 there was a meeting of the Optical Society of America held at the Bureau of Standards. Harry Ott came from Buffalo to attend the meeting and, I suppose, to do some recruiting. At any rate he offered me a position at Spencer Lens Company which was to lead immediately to that of Scientific Director. I paid a visit to Spencer Lens Company soon thereafter but did not immediately accept the position. After some dickering over salary I accepted within a few months. In the early spring of 1929 I visited Buffalo and Spencer Lens Co. again to rent a house and to become better acquainted with the new surroundings. At that time the Scientific Department consisted of Harry Ott as Scientific Director and Chief Optical Designer. He had as assistant in optical design a high school graduate, Miss Eleanor Johnson, who was a reliable computer using a desk calculator, John Rooney was chemist, Charles Gary, a high school graduate, was engaged in optical testing and trouble shooting, John Small adjusted microscope objectives and did trouble shooting in this field. Besides there were four or five people assembling and adjusting microscope and projection objectives. The quarters consisted of four or five rooms walled off on the same floor and adjacent to the lens grinding machinery. The outlook looked quite black as compared to the Bureau of Standards. I couldn't or wouldn't turn back now, and to make matters worse, Harry Ott, who intended to turn the Scientific Directorship over to me, as he was going to be Factory Manager, had had a short fling at the latter, was now ensconced again as Scientific Director. I could take some other title. What would I like? Chief Physicist; good! So in May 1929 we moved from Washington to Kenmore, N. Y., a suburb of Buffalo, and I started a job that was to keep me there for the next twenty years.

The surroundings were pretty drab, especially in contrast to those I had just left. I was given two absolutely empty rooms and given permission to set up a laboratory. Of course, I knew I couldn't go to too much expense, and it didn't occur to me that it was necessary. Large and expensive research budgets were in general a much later phenomenon. I did very well, though. The laboratory already had a good precision spectrometer, and a lens bench, both made in the plant. Fortunately, the products of the company, such as microscopes, projectors, and refractometers were available for the asking. With little effort and time sufficient laboratory facilities became available.

One consideration that prompted me to make the move from the Bureau of Standards to Spencer was my guess that the management, i.e., H. N. Ott, L. M. Potter, and Harry G. Ott, were in earnest in wanting to build up the scientific activity of the company. In this I was not mistaken. The entire personnel of the plant, about 500 in number, looked hopefully and cooperatively to the Scientific Department. This more than compensated the loss of my coming from "big time" research to the "backwoods." However, this last term is meant without approbation. I was encouraged to attend scientific meetings, for example. But we didn't have time to do what today is known as research. We had a whole line of products to improve and enlarge.

H. N. OTT

Mr. H. M. Ott was a man of extraordinary technical and administrative abilities. As a young man he graduated from

Albion College in Michigan, and then took a master's degree in biology at the University of Michigan. He then taught biology for some years. He was very much interested in microscopy and in the microscope as an instrument. His teaching was terminated because of poor health and he felt the need of more outdoor life. Accordingly, he became a microscope salesman for the Bausch and Lomb Optical Co. and had held this position for 7 ½ years when he came to Spencer Lens Company in 1904.

HARRY G. OTT

Harry G. Ott, like his father H. N. Ott, attended Albion College, and later did some graduate work at the University of Chicago under Michaelson and Millikan. In 1918 Harry terminated his work at Chicago and came to Spencer and started to develop their own lenses. In those days optical design was not taught in any college and ability in this activity had to be largely self-acquired or obtained by working with others. By the time I left the Bureau of Standards and came to Spencer (1929) Harry Ott had developed and put into production almost all of the achromatic type of microscope objectives and also the line of projection objectives of the Cook triplet and Petzval types. In 1929 he was completing designs of some of the apochromatic microscope objectives. Of the entire management of Spencer Lens Company at that time Mr. Harvey N. Ott and Mr. Harry G. Ott were the ones who had the most initiative in supporting development along scientific lines.

L. M. POTTER

Mr. L. M. Potter was vice-president in charge of sales. He was Mr. H. N. Ott's brother-in-law, and Mr. Ott, when he became General Manager, had brought Mr. Potter into the organization as the best microscope salesman he knew.

PETER DUKELOW

The Scientific Director just prior to Mr. Harry Ott was Mr. Peter Dukelow. The latter had left the organization just before I came there. It seems that Mr. Dukelow had a collection of lens formulations of unknown origin. He was empirical in his methods of attempting to improve microscope objectives by changing radii and refractive indices. It appears that no progress was made in this direction and it remained for Mr. Harry Ott later to design anew the entire optical line then in existence. However, I have heard Mr. H. N. Ott say that when they obtained Mr. Dukelow from Bausch and Lomb his help was invaluable.

HERMANN KELLNER

Sometime between 1900 and 1905 Spencer Lens Co. obtained two Germans, one of whom was Dr. Hermann Kellner, an optical designer. Dr. Kellner was a man of excitable and nervous temperament. There are no records to show just what he accomplished while at Spencer but I gather that he did some optical design and attempted to keep up the quality of optical manufacture. Because of ill health Dr. Kellner returned to Germany. Under date of July 10, 1905, Dr. Kellner wrote to Spencer Lens Co. from Berlin as follows:

Spencer Lens Company
Buffalo, New York

Gentlemen:

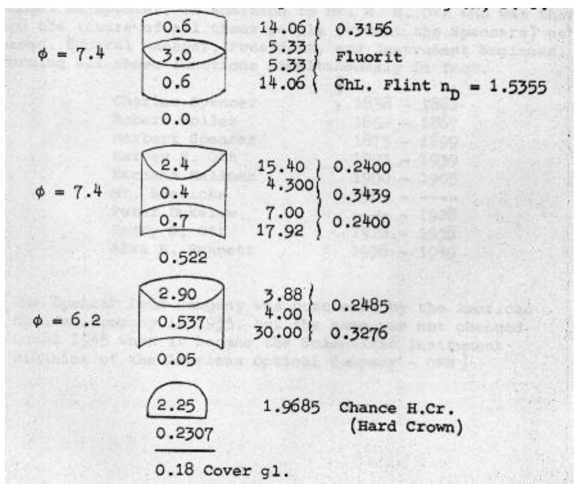
I am in receipt of your letters from May 26th and June 23rd and beg your pardon for not answering sooner, but I had a bad nervous collapse of the good old Buffalo style and was utterly unable to write a decent letter.

I went off for a short vacation to the seashore, but unfortunately, business called me back before I really got the needed recreation.

Mr. Bielicke sailed yesterday and I hope he will fulfill all your expectations. I wrote him about coming to Berlin and having some instructions, but he thought he would be able to get along with what I had told him, when he called on me some months ago and I must confess, that I hardly thought I hardly could have told him much more in the line of testing and judging the quality of objectives, for one of course can only show faults in bad objectives and they are only to be seen and to be had in the factory by watching the manufacturing of the lenses.

Mr. Kollmorgen called on me the other day and what he said about Mr. B. was very encouraging indeed. So I hope that everything will round out to your satisfaction. Mr. K. himself is negotiating with another American firm who are looking for a scientific man. And funny enough I had two offers, since I am here, to go to foreign countries again. But I love Berlin too much and then matters in my family have turned so unfortunately (in financial respect) that I cannot afford to leave here unless I am offered a very high compensation.

I am, of course, glad to give you that other 4 mm apochromatic formula “528” as you call it. The objective was made by me simply as a study, not as an object for the manufacturing. The focal distance is 4.12 mm instead of 4.00 mm; therefore, the lens gives less magnification, and the num. aperture is only 0.86 instead of 0.95. The apochromatic correction if not quite as perfect as in the “52” construction, and there is not enough distance between the doublet and the next triplet as to correct for variation in the thickness of cover glass within the necessary range. The sample objective has been sold either to Philadelphia or to Washington, D. C.



Concerning the glass No. 112 I will write you tomorrow. This letter has to go as to catch tomorrow’s boat.

With kind regards to you all

1905 July 10 H. Kellner

MR. BIELICKE

Mr. Bielicke came to Spencer but left to join Kellner at Bausch and Lomb some time later. This left Spencer without a scientific man. Then Mr. Peter Dukelow, who has already been introduced, came from Bausch and Lomb to work for Spencer and Mr. H. N. Ott who was then General Manager.

SUMMARY

To summarize, we had the following key scientific personnel at Spencer, in addition to Mr. H. N. Ott who was there during the tenure of all these people (except the Spencers) as Salesman, General Manager, President, and Instrument Engineer, performing all these functions simultaneously in fact.

Charles Spencer	1838 – 1881
Robert Tolles	1852 – 1867
Herbert Spencer	1875 – 1899
Harvey N. Ott	1903 – 1939
Hermann Kellner	1900 – 1905
Mr. Bielicke	1905 – ------
Peter Dukelow	------ – 1928
Harry G. Ott	1928 – 1936
Alva H. Bennett	1936 – 1949

CHARLES A. SPENCER *

When Charles A. Spencer, the father of American microscopy was born, in 1813, the English made microscopes were supreme. Spencer was born in Lenox, N. Y., descending from a well known and respected family. His father was a General, one of his uncles a Judge, and another uncle was a physician and professor in the Geneva (N.Y.) Medical College. It is not surprising that Charles Spencer started his education in the conventional way. He attended Cazenovia Academy and then Hobart College for less than a year and soon thereafter he entered Hamilton College. It appears that the classical Latin and Greek education, prevalent at that period, didn't appeal very strongly to him, so after a short stay there he went back to his home in Canastota, N. Y., to study and experiment for himself. In later years Hamilton College conferred upon him an honorary A. M. degree. Even before he left college he had been absorbed in designing, grinding and polishing lenses. At the early age of 12 years he constructed the first achromatic doublet made in America. By the age of 16 he had constructed a compound microscope, after reading an article in the Edinburgh Encyclopedia on Optics. Throughout his entire life he had a constant vision of improving the performance of microscopes beyond any that existed.

In 1838, at the age of 25, Charles Spencer announced his first optical business as a manufacturer of telescopes and microscopes in Canastota, N. Y. His line of products consisted of reflecting telescopes, and the reflecting microscope, known as Dr. Goring's engioscope. In about 2 years he issued a catalog of "Optical, Philosophical, Mathematical, Chemical and Other Instruments and Apparatus." The telescopes were chiefly reflectors 3" to 10" in diameter priced from $8 to $75, and achromatic telescopes from 1" to 3" diameter priced from $12 to $200. At this time he also listed the Amician Reflecting Microscope and the Compound Achromatic Microscope. In his catalog he explained that the microscopes were tested by examining the scales on the wings of Podura, the white cabbage butterfly, and the brown moth. In the present age in which diversification in business is so keenly sought, it is interesting to note that Spencer was far in advance of his time. In fact it appears that he was too advanced in this respect, because he kept losing money, until he was forced to concentrate on making and improving the refracting microscope and telescopes. This concentration of his efforts was a most fortunate occurrence for the whole of the art and science of microscopy.

The first American made microscope that attracted real attention was made by Spencer nine years after he had set himself up in business. Among the very few microscopes in use in America at that time were those made by Chevalier in France and by Powell and Ross in England. Dr. C. R. Gilman, a professor at the College of Physicians and Surgeons in New York City wished to buy a compound microscope. There were only 4 or 5 compound microscopes in New York at that time, all of foreign manufacture. Dr. Gilman decided to give Spencer a chance, but to make certain that he would get a good one he showed young Spencer one made by Chevalier. Mr. Spencer examined it using the Podura as a specimen, and promptly remarked that he could make a better one than that. So Mr. Spencer went back to Canastota and made the microscope, then set out for New York to deliver it to Dr. Gilman. Instead of going directly to New York, however, Spencer stopped off at West Point to see J. W. Bailey, Professor of Biology. Mr. Spencer had heard of the use of diatoms as excellent test objects for the microscope and he was aware that Prof. Bailey was an expert in both diatoms and microscopy. Spencer let Prof. Bailey test out the new microscope. The result of this visit between Spencer and Bailey can best be described in Spencer's own words in one of the few Spencer letters extant, written October 21, 1847 to Dr. John Frey of New York.

"Now, between ourselves, I did not make as good an instrument for Dr. Gilman as I know I can make. I used the Swiss Flint, with the intention of beating the foreign instruments with their own materials. Knowing that Prof. Bailey's Navicula Hippocampus (name later changed to Pleurosigma Hippocampus) test would prove the matter well, I called upon him. I had some misgivings, so I set up my instruments for the scales of Podura. He almost instantly exclaimed with warm earnestness: "I am sure that it will show the Hippocampus: I replied that I feared not, so I had not one of my best highest powers with the instrument. Prof. Bailey insisted upon finding the object on the slide, and the instant his eye caught it, he exclaimed, "It shows it beautifully – this is a perfect treat. ("I looked at it, and must confess almost instantly lost my reverence for the English test object par excellence."

Prof. Bailey's impression of this Spencer microscope is revealed in one of his publications, stating "I do not think Spencer's microscope quite equal to the far more expensive ones made by Ross or Powell, and I cannot positively assert that it is superior to the best of those made by Oberhauser (Paris) or Plossl (Vienna) as I have not had an opportunity to compare them properly side by side in the same light. My impression, however, are that the microscope made by Mr. Spencer for Dr. Gilman is in no respect inferior to any of Oberhauser's that I have seen, and I am by no means certain that it is not superior. I certainly had a better view by candle light, of the transverse lines of N. Hippocampus, by means of Spencer's instrument, than I was able, subsequently, to do by day-light by means of Oberhauser's. I look upon the results obtained by Mr. Spencer as a proud triumph of American art."

Mr. Spencer (1848) promised to make an objective that would show the lines of N. Hippocampus under the most adverse illumination. He not only fulfilled his promise but went beyond. Prof. Bailey had a diatom of the sigmoid naviula variety whose lines were so difficult to resolve as to make the resolution of all other known test objects mere child's play. Spencer's new objective easily resolved this diatom which Bailey named Navicula Spencerii. Prof. Bailey then sent some samples of Navicula Spencerii to microscopical friends in London, with a statement of what Spencer's objective could do. This caused great consternation among the English microscope makers, Powell and Ross. Spencer, the back woodsman, now had his name established among the best, but not as yet, the best.

At this time two doctors in Philadelphia, C. A. Beck and Paul Goddard each owned a 1/12" objective made by Powell of England, considered by their owners to be the best in the world. Dr. Beck took his objective to West Point in order that he and Prof. Bailey could test it on Navicula Spencerii. For two or three days and nights they tried to see the longitudinal and transverse lines on this diatom but they had only a suggestion of them. But when oblique light was tried the lines were very visible, although the obliquity of illumination was less than required by the Spencer objective. Prof. Bailey and Mr. Spencer readily conceded the superiority of the English made objective. Later with the use of oblique illumination of Smith, Ross, and Powell could resolve Navicula Spencerii.

But before Spencer had heard of these later successes of the English, he had announced that he had discovered a more difficult test and had improved his objectives to meet it. The new test was the resolution of the diatom Grammatophora Marina collected at Greenport, Long Island, in November 1848. Spencer produced a 1/16" objective which resolved this diatom, and no other foreign made objective could do this. We may well ask how Spencer was able to accomplish this improvement. He attached the problem from three fronts: First, the flint glasses of that day did not have sufficiently high indices and dispersions. Spencer accordingly set up a small glass plant at Canastota and produced glasses to meet his needs. Secondly, Spencer discovered how to grind and polish aspheric surfaces on his lenses, and thirdly, he was continuously increasing the angular aperture of his lenses. For these advances Spencer received praise from the microscopists, but was accused by his competitors of being both unsportsmanlike and ignorant. The year is now 1850 and Spencer at the age of 37 produced the world's finest microscope objectives.

* [Based on "Three American Microscope Builders," American Optical Company, Buffalo, New York, 1945. 77 pp. – OWR.]

ROBERT B. TOLLES*

A man whom is always associated in our memory with C. A. Spencer is Robert B. Tolles. Born in Winchester, Litchfield County, Connecticut, in 1822 he was 9 years younger than Spencer. As a lad he worked hard on the poor, stony, soil-depleted farm of his grandfather, trying to help the poverty stricken family eke out a mere subsistence. He had no formal education beyond that afforded by the public school. His greatest ambition was to go to college, but this was out of the question. At the age of 18 as a result of such strenuous labor and an unbalanced diet he contracted a stubborn case of pleurisy from which recovery was never fully complete causing life-long suffering. Tolle's father was an inventor but his inventions never brought in any money. However, he did impart to his son a legacy of ingenuity, perseverance, and dedication. After the death of his mother in 1943, Robert Tolles, then 21 years of age, traveled by foot to visit his Uncle who resided near Rochester, N. Y. After his visit was completed Tolles started to walk to New York City. In Canastota he happened to walk by the open shop door of Charles Spencer. He noticed Spencer working at his simple polishing machine completely absorbed in polishing a tiny lens for one of his microscope objectives that he was trying to improve. Tolles entered, introduced himself, and asked Spencer what he was doing. Spencer in his usual enthusiastic manner told young Tolles of his work and ambitions. Tolles was completely engrossed and said to Spencer, "Here is the place and the work for me." He became Spencer's apprentice, and later a journeyman, and remained with Spencer for about 15 years until 1858. He then set up his own business in a loft in Canastota, but after about 9 years he accepted an offer from several Bostonians to set up the Boston Optical Works of which Tolles was made superintendent.

Like Spencer, Tolles' great aim in life was to improve the microscope. He acquired a considerable amount of theoretical and practical knowledge of this instrument and under the supervision of Charles Spencer; he developed extra-ordinary skill in the grinding, polishing of and figuring of optical surfaces.

Tolles made a number of significant improvements in the microscope. Together Spencer and Tolles invented a means for correcting the objective for different cover-glass thicknesses by moving the back and middle lenses with respect to the front lens. This movement is actuated by a rotatable, external collar around the barrel of the objective. The position of the collar is indexed to indicate the proper setting for a designated thickness of the cover-glass. This method is still in use with dry, apochromatic objectives.

In 1854 Tolles invented and patented a solid eyepiece.

Although the principle of immersion objectives was not original with Tolles, he introduced the idea of obtaining large numerical apertures in combination with, and as a result of immersion. In 1873 Tolles completely startled the microscopical world by producing a 2.5 mm objective having a numerical aperture greater than 1; in fact, it was 1.25. Almost simultaneously he produced a 5 mm glycerine immersion objective having also a numerical aperture of 1.25.

This increase in numerical aperture beyond a value of one, as accomplished by Tolles, created a revolution in microscope making, but not without ensuing arguments over the desirability and even the possibility of such large numerical apertures. The most famous and bitterly fought of these arguments was the famous Wenham-Tolles Controversy. Wenham was an English microscopist who completely underrated Tolles' superior understanding of the practical and theoretical principles of the microscope. Wenham argued against the value of immersion objectives by publishing the following statement. "The same optical law that limits the aperture of any object glass to near 82^o (N.A. = 1.0) in a balsam mounted object also determines the angle in the lens at which the rays diverge after being refracted from the plane surface of the front. I challenge Dr. Piggot (a supporter of Tolles), or anyone else to get through the object-glass with an immersion front, a greater angle, or any portion of the extraneous rays that would in any other case (dry objective) be totally reflected, as no object-glass can collect image-forming rays beyond this limit." The literature and correspondence of that time is replete with arguments, not without heated words and some name-calling, between Wenham and the supporters of Tolles. Tolles remained quiet and dignified but won the argument by producing an immersion objective having an angular aperture of 110^o (N.A. = 1.23) in balsam, the immersion medium, together with calculations to prove his point.

* [Based on "Three American Microscope Builders," American Optical Company, Buffalo, New York, 1945. 77 pp. – OWR.]

PARTNERSHIP*

In 1854, Mr. Spencer formed a partnership with Mr. A. K. Eaton. The firm was expanded to include the making of astronomical apparatus, the most notable of which was an equatorical telescope for Hamilton College. The objective for this telescope had an aperture of 13-1/2 inches and a focal length of 16 feet. In the course of making plans for a large heliometer for Albany College Mr. Spencer spent 6 months in Europe where he was well received and acclaimed for his outstanding work in improving the microscope. While he was away Mr. Tolles managed the factory.

The partnership between Spencer and Eaton was dissolved after a few years. Tolles had set up a separate business, and

Mr. Spencer and his son Herbert continued to carry on the business in Canastota. In 1873 there occurred in Canastota a disastrous fire which destroyed every shop and the three hotels in the village, and wiped out all of Mr. Spencer's belongings. He lost nearly all his tools and machinery which he had developed over the years and a large amount of finished and unfinished stock.

Mr. Spencer, now 60 years of age, started out anew in a little barn for a workshop. In 1875 they moved to Geneva, New York, and for 2 years were connected with the Geneva Optical Works. After this for about 3 years the business was conducted under the name of C. A. Spencer and Sons. It was during this period that they received the Paris Expositions' highest award, a huge gold medal, for the excellence of their microscope objectives. The award of this medal to Spencer and Sons was entirely unexpected by them as they themselves had not sent any objectives to the Exposition. This had been done, without Spencers' knowledge, by Prof. Bernard of Columbia College who was so convinced of the excellence of Spencers' objectives that he took it upon himself to enter them.

About 1875 it was noticed that the strenuous work and long continued strain were taking their toll on Mr. Spencer. He decreased the amount of work that he did and spent most of his time reading and experimenting. About a year before Mr. Spencers' death, his son Herbert set up a separate shop in Geneva. After a short illness, Charles Spencer died in 1881.

* [Based on "Three American Microscope Builders," American Optical Company, Buffalo, New York, 1945. 77 pp. – OWR.]

SPENCER LENS COMPANY

The Spencer microscope objectives made by Herbert Spencer are said to have been as good and in as great a demand as those made by his father. In 1889 Herbert Spencer moved to Cleveland and organized the H. A. Spencer Optical Company. In 1891 Spencer moved to Buffalo, N. Y. and the Spencer and Smith Optical Company was organized with Dr. Roswell Park, an eminent Buffalo surgeon, as President, Herbert Spencer as Superintendent and optical expert. A number of physicians and microscopists were interested in the new company. William H. Glenny was Vice-President and Henry R. Howland was Secretary and Treasurer. Herbert Spencer was keenly interested in developing and perfecting the several types of Spencer microscopes and in increasing the line of Spencer microscope objectives and accessories. He gladly gave all his know-how to the Spencer Lens Company and trained assistants to carry on the work as he had learned it partly from his father and partly by his own study. In the autumn of 1899 he announced that the work was in capable hands and retired for reasons of health. In February 1900 he died.

Herbert Spencer was no less painstaking in his work than was his father. The results which he obtained in applied optics placed him among the foremost microscope makers such as Leeuwenhock, Amici, Hartnack, Zeiss, and the elder Spencer and Tolles. However, Herbert Spencer was not a good businessman and upon his death bad times attended the Spencer Lens Co. for a time. Herbert Spencer's lack of financial success was due to the fact that he concentrated almost solely on making only superb objectives for which he had an ardent and enthusiastic, but limited clientele. He catered only to the microscopist and did not have the vision to see that the volume of business was in the schools. At the time when Dr. Roswell Park took over as President, as already mentioned, he was an accomplished microscopist and pathologist and was Professor of Surgery in the medical department of the University of Buffalo. His reputation and influence were favorable factors not only in selling the objectives but in getting sufficient capital to revitalize the business. Dr. Park and a few of his friends in the medical profession, together with some Buffalonians, put up a modest amount to start the business. Thus, the Spencer Lens Co. was established in 1895, with Dr. Park as President, from the remains of the original organization of the Spencers. They soon found that they could not break even with a business that made objectives only; that they must make a complete microscope or nothing. This meant more capital, raised through the efforts of Mr. William H. Glenny who took a lively interest in this struggling concern. He furnished the necessary money to go ahead and from time to time loaned money to the firm as they needed it. Without him the firm would have collapsed.

MORE ABOUT KELLNER AND BIELICKE

Upon Herbert Spencer's death in 1900 Spencer Lens Co. obtained two men from Germany one of whom was Dr. Hermann Kellner; the other, whose name I cannot determine, was a mechanical engineer. With these men they made a new start, backwards according to Mr. H. N. Ott, because there was nobody in the organization who knew intimately what the man in the college laboratories needed and wanted. Although their instruments were fairly well made they were not properly designed. From 1890 to 1900 the American manufacturers were just emerging from the idea of playing up to the microscopist, to giving serious consideration to the volume demand from the laboratories.

Dr. Hermann Kellner was born July 20, 1873. He studied at the Universities of Berlin and Jena, receiving the doctorate from the latter in 1899. He spent several years in the optical industries in Germany, then came to America and worked at the Spencer Lens Co. as an optical designer and controller of optical quality. As we have seen he was back in Germany in 1905 because of ill health, but returned to America and became Director of the Scientific Bureau of the Bausch and Lomb Optical Co. where he remained until his death on January 18, 1926. Throughout his life the microscope was always his favorite optical instrument. His interests were not confined to his professional work. He was very fond of music and art. Watchmaking was also a favorite hobby, and he had an extensive collection of watches and chronometers that date back to the early history of the art.

Mr. Bielicke, who succeeded Dr. Kellner, did not stay long at Spencer. It is difficult to determine just what contributions Dr. Kellner and Mr. Bielicke made to the optical design of microscope objectives while at Spencer. It is certain, however, that they did not produce any first rate apochromatic objectives. But on the background of microscope objective design supplied by the Spencers, Kellner and Bielicke, the Company's deficiency was not so much in lack of breadth of optical design as the lack of progress in general functional design of the microscopes. At that time Spencer Lens Co. had no man familiar with laboratory technique and with ideas of the microscopical instrumentation needed in the college laboratories. At this critical period Mr. Henry R. Howland, who now was President, was more fortunate than he probably knew, in obtaining the services of Mr. Harvey N. Ott.

THE LIFE AND WORK OF H. N. OTT**

Mr. Ott was born in Walker, Wisconsin, on September 18, 1868. He attended Albion (Mich.) College and there received a Ph.B degree in 1884. He took graduate work in Biology at the University of Michigan where he was awarded the degree of Ph.M. in 1891. He taught biology from 1891 to 1893 at the Puget Sound College, Tacoma, Washington. From 1893 to 1895 he was Professor of Biology at the South Dakota State College. Because his health required more outside employment he became a microscope salesman for the Bausch and Lomb Optical Co. and held this position from 1896 to 1904 when he became connected with the Spencer Lens Co. Fortunately, we have available Mr. Ott's own words regarding the circumstances of his becoming affiliated with the Spencer Lens Co.

"I came with the Company in 1903 after having spent 7-1/2 years as a salesman for the Bausch and Lomb Optical Company. I soon found that they needed more than a sales manager, for no salesman could sell in sufficient volume to succeed, the apparatus as they were making it. My previous experience both in the laboratories and in visiting them had given me many quite definite ideas as to what was wanted. Indeed, it was with the hope that I might in some way have a chance to get these ideas in definite material form that I started with the small struggling firm, for being a biologist I was anxious to see my fellows in America given the best equipment possible. Gradually I was given the chance to revamp the apparatus and design new. We were not known to the biological fraternity. We had no outstanding apparatus with which to appeal. It was an up-hill job. One of the first things to do was to win the confidence of the laboratory men both as to our sincerity – and our ability to put the apparatus in their hands which would really help solve the problems and make teaching easier. It was a struggle and it was a tussle to make both ends meet. We were chronically hard up. About 1905 we desperately needed two new machines, each costing $500.00. I told the Board I would buy one if they would buy the other. We got three."

"In 1907 we lost our factory Superintendent, a good man, to a competitor. Then Mr. Glenny came to the factory one morning thoroughly discouraged, ready to give up. He asked my advice. I told him that it was not in my make-up to lie down and die – that I felt sure that we could fight it through. He wanted to know what would be necessary for a reasonable assurance of success. I told him that we needed $25,000 worth of new machinery. That about floored him. Nevertheless, he said he would see what he could do. For a day our destiny hung in the balance. He and one of his friends decided to risk some more money. I put in every cent I had, and whereas we did not get the $25,000 by a long shot, it was the turning point. From that time we went forward – but the money was not the only element. A greater element entered in. Mr. Glenny asked me what we could do for a Superintendent. I told him that with his consent I would take on that responsibility for awhile in addition to my then other burdens, for I had been called in to take charge generally because of the serious sickness of the General Manager."

"That noon we quit work a bit early and called all the men – about 40 together. I told them frankly the situation just as it was. That I was inexperienced as a Superintendent, that I was only temporary; that each foreman and each man knew his job and that I was depending on them for loyalty and cooperation. I got it; and that leaven has worked down through 30 years from 40 men to over 400 resulting now in the most loyal bunch of men any firm ever had. Not only loyal, but they are interested to think, plan, and if need be, sacrifice for the good of their company. They had a chance to put the last mentioned into effect during the past six years until it hurt. Yet they stuck. Ten of the 40 mentioned are still with us (1937)."

"I throw this in for two reasons. First, we are in troublous times especially so far as labor is concerned. Where a firm is so fortunate as to have an intelligent class of labor such as ours, the management can appeal to the men and reason with them, and furthermore, should do so. Men like to be recognized as a personal part of the institution, with a personality, with individuality and thinking power which is recognized. Second, a product must be judged by the spirit back of it manifested by every man from the management to the janitor."

"Just after the incident just mentioned I was made General Manager, and we brought on Mr. L. W. Potter, the best microscope salesman I knew to take the position of Sales Manager. We worked together to surmount the obstacles until his death 2-1/2 years ago (1934). In 1918 my son just out of the University of Chicago where he worked under Drs. Michaelson and Milliken, started to develop our own lenses."

"I hope you will pardon so much of the personal and so much detail with reference to the Spencer Lens Co. I say most about it because I know most about it, and after all, we know the spirit of any concern only as we know its personnel. It has always been our aim to find out the needs as definitely as possible and fill them as scientifically as possible."

At the turn of the century, and even a few decades before, the microscope makers of the world over solicited two kinds of trade. Continental Europe sought the college laboratory business with the small stands, while England and America looked to the microscopists giving him the large stands with the long tubes with all sorts of joints, bearings and graduations. With many microscopists the microscope itself seemed to be the aim. The microscopists' clubs (nearly every city had one) met monthly to report on some of their more or less serious research and to compare microscopes, report on new purchases, and what they were able to do with certain new objectives. They took pride in the microscope itself and what they could do with it. They knew their microscope as a scientific instrument and most of them could out-manipulate and get finer detail than most of the biologists of today. Their meetings were more or less of a social function and the man who had the biggest microscope with the biggest battery of lenses was the best fellow. Nevertheless, these men in the early days kept the interest in research in this field alive, where many scientists were indifferent and men in the medical profession, both in the medical schools and out, treated the microscope slightly if not in actual contempt.

In 1877 Dr. Oliver Wendall Holmes, speaking at the annual meeting of the Boston Microscopical Society, voiced the highest praise for Charles A. Spencer and Robert B. Tolles, and at the same time gave due credit to the early European makers. However, he gave the following warning to the members: "An association formed with these objects may give much entertainment to its members, and if conducted in a truly scientific spirit, some real instruction. But there is a great danger that such a body will lapse into a kind of aimless dilettantism which will keep the more genuine students of science away from its meetings."

These "earnest workers" took pride in their microscopes just as a few years ago the wealthy man took pride in his Packard, Pierce, Rolls, or Loco. Now the demand for transportation is turning to the cheaper and comfortable "compacts." So in the laboratories the demand came for the smaller microscope, because they were handier for novices, and because they were so much cheaper that a greater number of students could be accommodated. For this reason the smaller German instruments became the favorites in the laboratories.

Thus, when Mr. Ott came to the Spencer Lens Co. it was necessary for him to inaugurate the change to smaller, cheaper, laboratory microscopes in accordance with the German practice. The following observation by Mr. Ott throws further light upon the nature of this change:

"When I was at the University of Michigan most of our stands had no inclination joint, a sliding tube served for coarse adjustment and the stages were about 2-1/2" x 3", - no nosepiece, no condensers. These represented fairly well the instruments in all the colleges and Universities. Gradually, the racks and pinions came into vogue, then the substage condenser and then the nosepiece. When the nosepiece came out nobody thought of parfocalizing or centering. The first side fine adjustment was brought out by Feiss about 1900. It was used only on their research microscope. The mechanism was such that they afterward abandoned it. Spencer Lens Co. was the first to use it generally on laboratory microscopes. They began with the micrometer screw and bell-crank lever principle and are still using it in certain models. We believe that there is nothing like the micrometer screw for accuracy, responsiveness, sensitivity and durability.

** Based on H. N. Ott's address to "a biological group in Pittsburgh around in 1937." Ms. At Instr. Div.# The Spencer record minutes state that Ott came in 1904 and Harry Ott in 1917 according to Miss Poole. June 1962 – OWR.

MR. DUKELOW'S TENURE

The foregoing paragraphs tell something of Mr. Ott and the early struggles he encountered at Spencer Lens Co. While Mr. Ott was superb at functional instrumental design and detailed mechanical design, he was the first to admit that optical design was not one of his abilities. In those days the term "scientific man" was equivalent to "optical expert." So when Mr. Bielicke, Dr. Kellner's successor, left Mr. Ott was fortunate in obtaining the services of Mr. Peter Dukelow, then employed at Bausch and Lomb. It is difficult for me to make much of an evaluation of Mr. Dukelow and his work as there are no records available, and he had left Spencer Lens Co. when I arrived there in 1929. Mr. Harry Ott made occasional references to him. Mr. Harvey N. Ott (the elder) once told me that the Company owed much gratitude to Mr. Dukelow for coming when the company needed him badly. In those days the relation between the scientific and the production activities were extremely close; so close, in fact, that it was difficult to tell where one left off and the other began. Mr. Dukelow spent much of his time in the factory giving close attention to the quality of the products. He made improvements in the quality of achromatic microscope objectives, taking an empirical approach, by experimentally changing curvatures and glasses. Mr. Dukelow retired in 1928.

LATER RESEARCH ORGANIZATION

In 1917 Mr. Harry G. Ott, the only son of Harvey N. Ott, came with the Spencer Lens Co. as Scientific Director. On his coming to Spencer, he took over the entire task of optical development. He set about to get new designs for practically every old optical system and to design many new ones. He resigned as Scientific Director on October 20, 1936.

To Harry Ott and his father must be given the credit for introducing long term scientific activities into Spencer Lens Co., for modernizing their products, and for building up a scientific organization which has lasted.

When I went to Spencer in 1929 there were several members of the Scientific Department who did outstanding pioneering work. These men had been hired by the Otts.

Charles Gary was a self-trained optical physicist. He had no formal education beyond high school but he possessed a wealth of originality and intelligence. Through industrious application and vast experience he had a fine ability for trouble shooting in production. By graphical methods he could do some optical design, especially prism, and condenser systems. About 1938 he was placed in charge of all the inspection and final adjustment of the finished products in which capacity he did valuable work. His death on October 30, 1941, was a serious blow to the company especially as at that time Mr. Gary was engaged in inspection and trouble shooting in the production of much needed military instruments.

Another of these men was John T. Rooney, who was Chief Chemist. Mr. Rooney and an assistant dealt with all the chemical problems of the plant. He prepared all the pitches, and optical cements, did all the cathodic shuttering, etching of reticles, and for a long time made the haemacytometers. All the metallurgical work came under Mr. Rooney's preview. These operations from time to time required some applied research work for which Mr. Rooney was quite well prepared. He had graduated in Chemistry from Queen's College and had been a consulting chemist before coming to Spencer. He left Spencer December 31, 1945.

John Small was already with the company in 1929. He was without a superior in adjusting microscope objectives to obtain best performance, and in spotting the errors of workmanship in defective objectives. To him can go much credit for the high degree of performance in Spencer optics of that period. Later Mr. Small was made an optical designer which gave him an increased understanding of instrument optics. He deserves much credit in going through college on his spare time, until he had obtained a Master's Degree. At the time of this writing (1960) he is still with the Company. [Small left 1960 or 1961 – OWR]

Thus, it was that largely through the imagination, ability, and initiative of the Ott's, a company, starting with practically no modern line of products in 1903, had been built up in the course of a quarter of a century into one of international prestige and a reputation, in most of its products, for quality. There remained gaps to be filled, and organization to be strengthened in order to keep abreast of current requirements.
Before going into further developmental and scientific accomplishments I will continue with the matter of personnel. In order to supply a background for this, it is necessary to relate some outstanding facts in the history of the Spencer Lens Company about the great depression exacted its toll on the company's financial structure by 1933 or 1934, resulting in outside efficiency experts being sent in to put the company on its feet. As a scientific worker, I knew practically nothing regarding the detailed cause of this, nor the investigations involved. Some of the results, however, were plain for all to see. Mr. L. N. Potter was replaced as General Sales Manager, by Mr. Harold D. Rhynedance, at that time in charge of the New York branch of the Company. Mr. H. N. Ott was placed on a technical capacity only. This latter, fortunately, lasted only for a limited period. The reader may well wonder what is the connection between this reorganization and the scientific work of the company. As long as Mr. H. N. Ott was the power behind all the company's activities, through his extensive contacts and mutual friendship with the leading scientists in the country, he knew what was needed in instrumentation. Furthermore, he went ahead and had it developed under his close supervision. If the development met with successful sales (and it generally did), well and good; if it didn't, there was nobody to censure him. This produced results, without in any way stifling initiative on the supporting personnel because H. N. Ott's mind was always open to suggestions, and also because of the wide range of abilities necessary in the design of instruments there was room for all the ability each of us had. Now, with the new arrangement mentioned above, the Sales Department insisted on having

complete say regarding what was to be developed including such matters as cost, precision, and functioning. This introduced a strong element of caution, and conservatism, which the scientific staff had not known before. I merely make this observation without comment on its necessity or lack thereof, whether it represented progress or not.

AMERICAN OPTICAL CO. BUYS SPENCER LENS CO.

The Spencer Lens Co. was purchased by the American Optical Company in 1935. In 1935 Mr. H. N. Ott was replaced as General Manager by Col. Burton Witherspoon. Mr. Ott remained as President until 1939, and was Chairman of the Board of Directors until 1941 when he retired. In 1936 Harry G. Ott resigned as Scientific Director. Thus, it was that after the purchase of Spencer Lens Co. the Otts' activities soon ended. Upon Harry Ott's resignation, Mr. Charles Barton was named by Mr. Witherspoon to be Manager of Research and Development, and I was asked to be Director of Research, a position which I held from 1937 to 1949. The Spencer Lens Company went through the transition from a small, but world-renowned, independent company to the Scientific Instrument Division of American Optical Company.

During the period from 1929 – 1935, I held the title of Chief Physicist and Assistant Scientific Director. I did a lot of instrument testing, devising testing methods, factory trouble shooting, instrument design, design and production of special jobs. One of the things I recall with quite a bit of satisfaction was the perfection of the design and manufacturing processes of the "Bright Line" hemacytometer. The chamber of this hemacytometer had the fine lines ruled through a semi-transparent film of rhodium applied to the glass by the arc sputtering process. The finest lines were only 2.5 microns apart. After the ruling had been done, we baked the hemacytometer at about 1025^o F. to harden the rhodium film and to fuse it to the glass. During the first two years of manufacturing, this item we didn't show either a profit or loss. There was considerable feeling on the part of management that we should discontinue it. I explained that we were getting the "bugs" out of the manufacturing process and at least not showing a loss and asked for one more year. We succeeded, and a few years later, about 1939, the profits were so good on this item, and so poor on so many others, that Mr. Glenny remarked, "Thank God that we have the hemacytometer."

At the beginning of 1937, Mr. Witherspoon was General Manager; Harold Rhynedance, Sales Manager; Charles Barton, Manager of Research and Development; Bryant Glenny, Treasurer; William F. Peck, Director of Engineering; I was Director of Research; John T. Rooney, Chief Chemist; and Charles Gary, Head of Inspection. On March 1, 1937, Dr. Oscar W. Richards joined our staff. Dr. Richards came to us from Yale. He was a biologist with keen interest in instrumentation. Then in rapid succession, we obtained the services of Dr. Harold Osterberg as a physicist, Dr. Roger Estey, physicist; Mr. Arthur Kavanagh, mathematician; Dr. Rudolf Luneburg, mathematician.

So far I have discussed the scientific development of Spencer Lens Company, i.e., the Instrument Division of American Optical Company. This development was a tributary stream to the main stream of events pertaining to the parent company. We will now look into the events comprising the American Optical Company's initial scientific efforts.

In 1916 American Optical Company was fortunate in obtaining the services of Edgar D. Tillyer. The following synopsis of Dr. Tillyer's life, writing and patents is taken directly from the archives of the American Optical Company.

EDGAR D. TILLYER: HIS LIFE, WRITING AND PATENTS

Edgar D(erry) Tillyer, born December 7, 1881 in Dover, New Jersey.

SCHOLASTIC BACKGROUND

B. S., Rutgers, 1902; M.S., George Washington, 1903; M.S., Rutgers, 1905; Honorary Doctorate, Sc.D., Rutgers, 1928. The Honorary Degree from Rutgers was in recognition "of his outstanding contributions in science in the field of optics, and for his accomplishments in radio, motion pictures, and television."

HONORARY AWARDS

Modern Pioneer Award, National Association of Manufacturers, February 1940; Certificate in recognition of service for the American Standards Association for "service to government, management and workers." A Fellowship for distinguished service to optometry in 1935. This fellowship is awarded in recognition of research in inventive and educative work by practicing optometrists, physiologists, physicists and illuminating engineers. The Beverly Myers Nelson Achievement Award in Ophthalmic Optics, 1952. This award is bestowed upon persons who have made Meritorious Contributions or who have rendered Outstanding Services to the Field of Ophthalmic Optics, particularly Prescription Opticanry, or to undertakings and interests germane thereto.

MEMBERSHIPS

Optical Society, Physical Society, Cermaic Society, Institute of Radio Engineers, Washington Academy of Sciences, and A.A.A.S., (American Association for the Advancement of Science).

CAREER AND WORK HISTORY

Assistant, "Nautical Almanac" office, 1902-1906; Astronomical Observer in the Naval Observatory in Washington, 1906-1911. During this period Dr. Tillyer contributed two important developments. One an improved clock vault temperature control, resulted in more accurate standard time for the United States. The other, a system of reversing prisms for the meridian circle observations eliminated personal error, providing more consistent data, simplicied techniques and saved time in making observations.

Bureau of Standards, 1911-1916. Here, he was responsible for the design and improvement of all image forming instruments. He redesigned and revised the old types of submarine turret periscopes and by so doing, increased their illumination by about fifteen times. He originated the first specification to standardize periscopes and gun sights used by the Navy, and served as consultant for both Army and Navy.

AMERICAN OPTICAL COMPANY, 1916 TO-DATE

At the American Optical Company, Dr. Tillyer worked as an optical designer and later acted as Director of Research. "Typical of Dr. Tillyer's World War I work, directly after his affiliation with AO Company in 1916, was his contribution to the manufacture of the 36 mm French telescopic gun sight in the United States. Due to the absence of uniform domestic barium glass from which these French sights were made, lens manufacturers had been unable to make them. Within a few days, Dr. Tillyer submitted the solution to the government, having redesigned the sight to use a common type of domestically available ophthalmic glass. The Tillyer modification of the French gun sight was adapted to large scale production and was more efficient than those made of barium glass. In addition, the French collimator sight, previously an individually, handmade product, was completely redesigned for mass production."[1]

During his 38 years of research with the American Optical Company, Dr. Tillyer has made important contributions, many of them basic, to the advancement of better vision in industrial eye protection, and the optical science in general. He has made more than 150 inventions and his patents are listed on the accompanying list by L. L. Gagnon, under general types of patents assigned.

His development of the Tillyer Principle of balancing oblique aberration in ophthalmic lenses has been one of his major contributions. The work was a result of years spent in translating the Principle into a complete series of spectacle lenses for the correction of all types of vision defects. This Tillyer Principle offers the solution to the problem of correcting both spherical and cylindrical marginal errors to a practical minimum. He also has been responsible for improvements in bifocal lenses, and the design of Iseikonic lenses as well as in the invention of a glass screen which will transmit light rays and retard heat rays which has resulted an improvement of design in the field of moving picture projectors.

His research has led to the development of improved retinoscopes through his development of a transparent reflector for transmitting light while permitting vision through it, which made possible the elimination of light shock to the patient's eye while affording the ophthalmologist a better view and a more accurate diagnosis.

Dr. Tillyer was responsible for the new method of cutting quartz crystals parallel to an electrical axis instead of perpendicular to that axis resulting in greater crystal activity which has been the foundation for considerable advance in research in this field. Practically all crystal controlled radios in World War II used this type of crystals.

Dr. Tillyer's contributions during World War II were also highly important. In addition to those already named, he developed a new method of determining the temperatures to be used in compacting glass for the finest instruments.

Another development was the process of quantity production of aspheric surfaces like the Schmidt corrector plates for military use in World War II. This has recently led to the theater projection television systems.

Other War developments included a new type of glass which resists corrosive hydrofluoric acid that disintegrates conventional glass; new techniques for controlling light reflections in glass and other materials; and a new technique for manufacturing speedily highly complex Schmidt corrector plates used in military night-viewing instruments. These corrector plates and companion spherical mirrors have been adapted for use in home television receiving sets. A more recent development from the American Optical Company Research Laboratory has been the successful grinding of Polaroid sunglass prescriptions after years of intensive experimentation. As well as being a scientist of note, Dr. Tillyer was Director of American Optical Company Research for many years prior to his present position of life tenure as General Research Consultant. In all these capacities, he has always been an inspiring leader and teacher in the laboratory. His broad scientific knowledge, coupled with his informality of approach and eagerness to help others, has resulted in the successful solution of many problems with resulting benefits to mankind.

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Mary D. Quint
Librarian

October 8, 1952

October 7, 1952

RE: DR. E. D. TILLYER'S INVENTIVE CONTRIBUTIONS

Of the many inventions to which Dr. Tillyer contributed, approximately 150 have been patented.

These inventions relate primarily to improvements in the ophthalmic field such as:

The Tillyer Lens Series;
Ful-Vue Bifocal
Design of all lenses to a given effective power;
Nokrome Bifocals;
Monaxial Bifocals;
Worked out a mathematical theory of Iseikonic Lenses;
Deep Curve Zero Power Lenses for correcting higher order spherical aberration;
Several different glass compositions and improvements in glass compositions for use in forming Corrective and Eye-Protective Lenses;
Lens Testing Instruments for use in testing lenses;
Instruments for Use in Testing Eyes;
Processes of Producing Lenses;

Discovered Sheer Vibration of Quartz Oscillators;
Method of Finding Annealing Temperature for Fine Annealing (Compacting) Glass;
Made inventive contributions as to Heat Screens for Use in Moving Picture Machines;
Process of Producing Dropped Schmidt Plates;
Improvements in Machines for Forming Lenses;
Improvements in Hearing Aids;
Improvements in Lens Gauges;
Improvements in Eye-Protective Goggle and Lenses Therefor;
Improvements in Radio Receivers;
Improvements in System for Wide Area Distribution of Ultra-High Frequency Transmissions;
Improvements in Moving Picture Sound Reproduction; and
Variable Light Modifying Devices for Phase Contrast.

L. L. Gagon (signed)
Legal Department

LLG:MJB/ls

Following is a chronological listing of the early researches and developments done at the Southbridge Laboratory of American Optical.

About 1900 to	American Optical produced a trial lens set designed by Charles Prentice at G. W. Wells' request. This set was composed of biconcave minus lenses of true curve, but the biconvex plus lenses were designed to neutralize the minus lenses. This meant that the lenses were almost exactly true vertex refraction or effective power – the first lenses so made.
About 1912	Started production of one piece bifocals by the English Line Contract grinding and polishing methods. This uses a cup shaped sharp edge tool which is essentially the same for all powers. Others in this country used the "Cathead" method which was not as good, and did not give as good quality.
1914	American Optical obtained from Chance Company Sir, Crookes Glass which was the first nearly colorless Ultra-Violet Absorbing Glass.
1916	Started design of the Tillyer lenses for the Ophthalmological requirements as described by A. S. Percival, Senior Surgeon Northumberland and Durham Eye Infirmary.
1917	American Optical made the first commercial glasses for welding which really protected the eyes from Infra-Red under Pfunds process.

1917 Started to change all lenses from neutralizing power to effective power or vertex refraction – First, for factory run of lenses. Previously only special lenses were so made.

1917 Redesigned two French gun sights to use Ophthalmic crown and flint glass because special glasses were so poor and scarce. Actually got better performance than the original French sights.

1919 American Optical made Lensometer which measured accurate vertex refraction or effective power, also licensed others to make them. This measured sphere, cylinder, axis of cylinder and decentration. The spherical and cylinder process had to be measured separately, then subtracted to get the cylinder power. Later, the senior lensometer measured both at the same time and the readings on the dials gave the complete Rx with either transposition required. Also, an auxiliary optical system permitted viewing the lens in the measuring position.

The Senior Lensometer production was soon stopped because of the necessary higher selling price.

The Friedenwalds Ophthalmoscope was produced. This was the design of Dr. Jonas Friedenwald who made a model that worked. However, it was found desirable to redesign this for greater convenience using Dr. Friedenwald's principles. By saving light, we changed from a lamp using 120 watts to one using 20 watts – quite a lot cooler instrument to handle.

Crooke Glasses had didymium in it in addition to Cerium. The former made shadows under ones eyes. It was found that pure Cerium could be obtained and a pink color was added to blend with the complexion.

About this time, I do not remember the year, real production started on Tillyer lenses and in order to get the most satisfaction, the additive trial set was designed. The spheres which are next to the eye read true power on the Lensometer. The cylinders which fit in a cell in the trial frame in front of the spheres, will not read true power, but when in position in the trial frame and the sphere lens in place, then the combination will read true power on the Lensometer.

The American Optical purchased De Zeng Instrument Company and the instrument line had to be revised. The Phoropter as made by De Zeng was better than most, but very far from additive. One competing instrument gave the patient the equivalent of +20 D when the reading was +15 D. Now it is not possible to make more than two lenses in sequence theoretically additive, but by careful selection of position and the balancing of errors, it was possible to make the Phoropter with errors in the strongest powers of less than 1/8 D.

Most of the De Zeng instruments were redesigned. A radical step was taken on the Retinoscope so that the patient would not be blinded by the intense light from a silvered mirror. A plain mirror of fling glass was used, later replaced by a crown with a moderate high reflection coating. An interesting problem was to get rid of the unwanted transmitted light, the best black velvet was not black enough so two specular reflections from a black surface made possible this system. (During World War II, some of the scientists reinvented this in some military instruments although it had been patented for ophthalmic instruments years before.)

The regular welding glasses excepting the Pfund, had quite high transmission in the infrared. The best was AO Noviweld, the darkest shade transmitted 20% to 25% of the total energy from a 100 watt gas filled tungsten run at normal voltage. Poorer glasses transmitted as much as 60%. This was investigated and Noviweld was changed so that the dark shades transmitted less than 0.01%.

Calobar was the first sunglass to absorb both WV and IR.

The ferrous iron in a light shade for sunglasses transmitted too much ultra violet so cerium was added, result Calobar. Glass making was not good enough to clean up bubbles, so when the first Calobar was sold, there was attached a note saying that "it was impossible at that time to obtain this glass free from bubbles." We never had a complaint. Calobar was sold by the Safety Division at first because the Sunglass Division did not want to change from amber or amethyst colors.

Solid gold frames were much used before the U. S. went off the gold standard. One problem was breakage of the frame under ordinary conditions. This was worked very hard because 12 K gold is very strong but sometimes it would break. Actually it broke for the same reason that steel rails did fifty years ago. A “pipe” was formed at the upper end of the cast bar. The breakage stopped when the “pipe” was cut off. Another, though rarer form of breakage was caused by mercury being given as medicine. Dr. Glancy picked this by a spectroscopic examination of some broken frames.

Something that seems very minor, but is not, is the materials that produce tarnish. All methods of testing were tried out. Most methods would reject some materials that didn’t tarnish, others would pass materials that should be rejected. A very simple and quick method was worked up by C.H.O. and this has been adopted by many industries.

The metallurgy section was continuously working on the improvement in the gold field, the core material, methods of hard soldering this to the gold shell, and the best gold alloy. One thing that people not connected with gold filled rarely think about, the uniformity of the gold outer layer around the base metal core, the thinnest part determines the wearing quality. In poor gold filled, this thinnest part is almost nothing in thickness.

As more and more lenses were being ground with diamond laps, metallurgy worked very hard on the bonding material in which the diamonds are embedded. This material must wear at the corrected rate. If too little, the diamonds will not do any work, if too fast a wear, the diamonds will fall out and be lost. Also, the bonding material should wet the diamond if possible, in order to hold the diamond in place until the diamond is worn out completely. The difference is so marked that the factor from very good to poor is in the thousands. These laps are made by powder metallurgy, the outer layer, say 1/8 inch contains the diamonds, the lower part, maybe ¼ inch, contains no diamonds and is soldered to support ring or disk or whatever shape is desired.

Glass research in a minor way was conducted from the start. However, in the early thirties, more attention was given to this. Better glasses were brought out for the fused bifocals. The cost of glass in the Nochrome and Fulvue types was reduced greatly by changing the crown to a type which is easier to produce and make a barium which fused with it. Stain on the segments was eliminated because people objected. Actually, a stained segment transmitted more light.

Many new types of glass were produced experimentally which have not been commercially yet. Glasses of moderate cost of an optical position above the ordinary barium crowns and almost up to the rare Morey and Kodak glasses. Heat absorbing glasses of very high efficiency were developed. Hydrofluoric resistant glasses were produced and some used in the Manhatten Project. At present, arsenic trisulphide glass is now being made.

Reflection reducing coatings and reflection increasing coatings by the solution method were investigated. These are particularly useful for large surfaces. There, efficiency is at least equal to the vacuum deposition method when a narrow ring about 1 w/m wide of poor appearance is not objectionable. One side development is a pretty good antistatic coating for electrical instruments. Weston and others is using this.

One project during the war was the study of annealing glass. This seemed a hopeless task. However, we found that previous theory was not complete. A strain free piece of glass might not be compacted to uniform index. Actually, the measurement of absence of strain in glass is rather useless. What is required is the reconcentration of the molecules to their low temperature state. The glass then has a higher index and will remain stable.

The theory of aniseikonia or size difference lenses was worked out, and patented. Simple instruments were developed to measure the size difference of a given lens. The relationship between near and distance size difference investigated because this was a controversial subject. Results were very pleasant. Same thickness of glass in front of each eye, lenses not separated too far; tested for near with distance test lens, size lens designed for distance will give the correct results for near.

Last, but not least, developed method for making Schmidt plates for BOB Metascope.