Memorial Volume

COMMEMORATIVE OF

THE LIFE AND LIFE-WORK

OF

CHARLES BENJAMIN DUDLEY, PH.D.

LATE PRESIDENT OF

THE INTERNATIONAL ASSOCIATION FOR TESTING
MATERIALS AND OF THE AMERICAN
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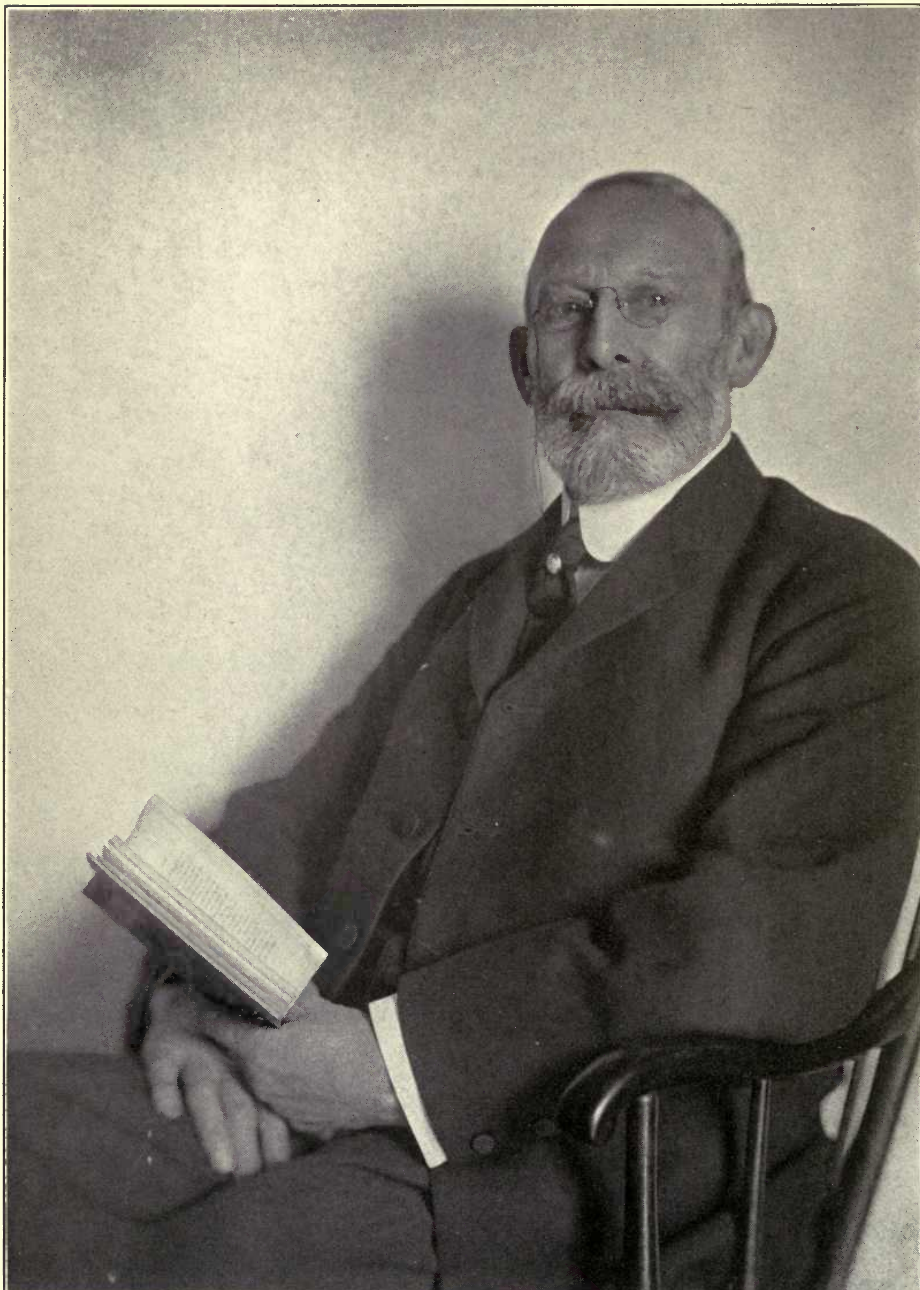


Chas. B. Dudley

In Memoriam

Charles Benjamin Dudley

Obiit December 21, 1909

By Harvey W. Wiley

Well have you done the labors of a life,
Of service for your country and for God,
Whether the paths of flaming fields you trod
In battle for the Nation rent with strife
Where cannon's thunder smothered drum and fife,
Or following the plow across the sod,
Or tarrying where sons of science plod—
A fount of cheer for comrade, friend and wife.
The ripple of your laugh, the clear sweet light
Of those dear eyes forever closed to earth
Shall glad and guide me as I near the night
Now closing on my day of deeds and mirth,
Its glowing glory waxing ever bright
In th' unfathom'd shadows of the second birth.

Charles Benjamin Dudley.

BIOGRAPHICAL SKETCH.

By Edgar Marburg.

Charles Benjamin Dudley, son of Daniel and Miranda (Bemis) Dudley, was born at Oxford, Chenango County, New York, July 14, 1842. He was descended on both sides from sturdy New England stock, his father being a native of New Hampshire and his mother of Connecticut. In the trend of the westward movement of that period, his parents had come to join the host of New England settlers in New York state.

Boyhood and School Days.

By the contemporaries of his boyhood days, Dr. Dudley is remembered "as a boy full of life and fun, fond of sports, and a general favorite." His early youth was given over largely to rugged labor in field and shop, with such educational advantages as the country school, and later the Oxford Academy and Collegiate Institute, afforded. His parents, to whom his allegiance through life was one of absolute, childlike devotion, were staunch Methodists, and it was in that faith that he was reared. In later years, in the remodeling of the Oxford Methodist Church, he had a memorial window installed in honor of his father and mother, who had worshipped there for many years. The pastor at that time, Rev. A. W. Cooper, had been his classmate at Yale.

Dr. Dudley's pronounced literary tastes—which were to him a never-failing source of enjoyment and inspiration, and to which his breadth of view was doubtless largely due— stood out clearly in his early youth. To attend the meetings of a literary society to which he belonged, he was wont to trudge a mile and a half from his home to the village. On one occasion, remembered by his family to this day, he braved a fierce blizzard on his homeward trip despite the protestations of his friends, for fear that his sick mother might worry over his absence over night.

He managed to reach his home, though in a thoroughly exhausted state.

A charming specimen of the writings from Dr. Dudley's boyhood pen in those far-away Oxford Academy days has by some happy chance escaped the obliterating hand of time, and will be received, it is believed, with keen relish by his friends. The essay, undated, runs as follows:

THE ETHICS OF SMILING.

AN ESSAY ADDRESSED TO THE EDITOR OF THE "GARNER OF TRUTH."

A SHORT TREATISE ON HOW, WHERE AND WHEN TO DO IT, THE VARIETIES, CAUSES AND EFFECTS, AND SUCH MORAL REFLECTIONS AS MAY ARISE IN THE MIND THEREFROM.

Smiling is an art. By practice the painter approaches perfection or the musician improves his talent. By practice and observation a smile may become a powerful agent in the hands or rather the mouths of many. The tippler is an expert smiler. He enters the bar-room and smiles profusely, he goes out and smiles, he re-enters and smiles several times till he gets jolly drunk, when he smiles more than ever.

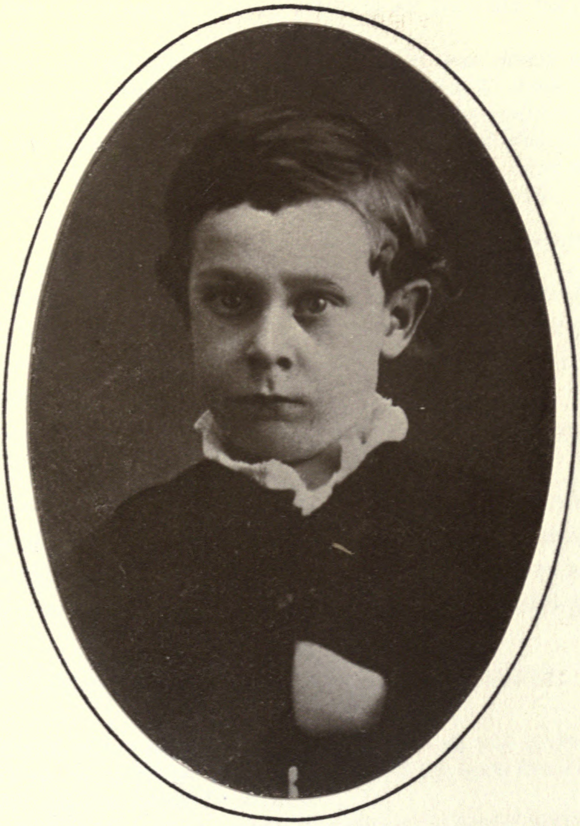
Smiles are opposed to frowns as tears to laughter; yet sometimes the human face is all smirks and sunbeams before company to be changed to scowls and thunder storms afterwards. Better to dwell in a corner of the housetop than with a brawling woman in a wide house.

Laughter is more demonstrative and shows more plainly its nature and cause. A forced, unmeaning laugh can be more easily detected. Its very sound betrays it; but a smile may mean everything or nothing, we cannot tell. A hearty jolly laugher cannot be a deep-dyed villain. Some never smile. Gum chewers can seldom spare time from their regular occupation to smile. They are strong in the jaws, however, and probably could smile mightily, bite off a tenpenny nail, or give an awful "jawing" if necessary. Tobacco chewers should not try to smile, nor large-mouthed individuals.

It is well to observe carefully when and where we smile. We read once of a conquered prince who happened to smile at something at the moment he was bowing in homage to his captors. The conqueror, thinking this meant for an insult, had his head taken off at once.

The varieties of smile are as numerous as the leaves that line the brooks of Vallambrosa. There is the smile sarcastic, which stump speakers use to annihilate an opponent, and fair damsels to annihilate a bashful swain mittenwise, although this last would perhaps come more properly under the head of the smile sardonic. The lovely smile that wreathes the lips of beauty is the most dangerous species and has caused more trouble in the world than anything else.

There is the withering smile of scorn which abounds in novels, the sneering smile of contempt and the smile of disbelief. We believe there



Charles Benjamin Dudley

At the Age of Eight

is no record of the first smile or its cause, but think the old snake must have smiled furiously just after he had got Eve to eat the apple, and that is as early as we can go back. The strongest smile we ever heard of was in the case of a robber who entered a house to rob, saw them all smiling away, and directly left without robbing. What terrific contortions must these have been which scared him so, but it is all true, for the Ladies' paper last week said so.

Smiles are often deceitful. There is more truth than poetry in those words. A man may smile and smile and be a villain still. Look out for the sleek, smooth scoundrel who worms himself into your confidence, then turns again and rends you. Look out for the smiling syren who lures you on to the verge of matrimony, then says "I never knew you." Some say that babies smile. We should like to see them smile—a good ways off.

Yours smilingly, HEZEKIAH.

Who can fail to perceive in this boyish, bubbling effusion the same Dr. Dudley whom we knew and loved in later years? It is discerned even in the use of the personal pronoun in the plural number which came to be a fixed habit with him. It was a straw—one of the many—indicative of a marked trait in the modesty of his make-up, that of self-effacement.

No less characteristic are the following arguments that have come down to us on the momentous question whether the Oxford Academy should or should not be surrounded by a fence, written by young Dudley in a semi-philosophic and semi-jocular vein:

WHY WE SHOULD NOT HAVE A FENCE AROUND OUR ACADEMY.

1. Learning should be or appear to be free to all who desire it. A fence around an institution of learning would seem too much like excluding the multitude and this should be avoided.

2. It would cost too much, now that we propose to have a railroad, and the money hitherto raised has all gone to the prince of the power of the air.

3. The boys now mark upon and deface the academy. They would do the same with a new fence and it is an imperative duty not to expose them to temptation.

4. There are now several short cuts in going to and from the academy and these would be prevented if a fence were built. Shoe leather would be worn out and a tremendous expense incurred to the students.

5. So important an undertaking requires thought and calm contemplation, the investigation of plans, etc. We hope therefore that radical members will cease their rant and useless endeavors to hurry matters, and leave this affair to work out its own completion.

In early youth Dr. Dudley developed ideals founded on basic principles of right, to which he adhered unswervingly and with apparent ease through a life fraught with trials of no ordinary sort.

ARMY DAYS.

In 1862, in response to President Lincoln's call for three thousand volunteers, young Dudley resolutely put aside for the time his cherished ambition for a college training, and promptly volunteered for service. He was moved in this, not by a youthful spirit of adventure, but by a sense of patriotism founded on a deep conviction of the righteousness of the cause. Though under age he gained his father's consent by the plea that he *must* follow the promptings of duty. He enlisted at Oxford, on August 6, 1862, as a private in the first company raised, Company A, 114th Regiment, New York Volunteers. On September 3, the regiment was mustered into service and a few days later embarked for Binghamton, in open canal boats, continuing the journey to Baltimore in box cars. Here the regiment was equipped and drilled, and then transported by water to New Orleans to begin its active service under peculiarly arduous conditions. The command to which it was attached participated in 1863 in the battles of Bisland, Bayou Vermillion, the siege of Port Hudson, at which the 114th Regiment led the advance, the Sabine Pass expedition, and in various minor engagements. During the following year the regiment took part in the Red River campaign, including notably the battles of Sabine Cross-Roads and Pleasant Hill, at which it acquitted itself so gallantly that it was publicly thanked for its services. At the close of that campaign the regiment was transferred to Virginia to participate under General Sheridan in the Shenandoah Valley operations. On September 19, 1864, at the Battle of Opequon Creek, near Winchester, Va., known also as the first battle of Winchester, the regiment led the battalion of the first brigade, suffering terrible carnage, but doggedly continuing its advance until its ammunition was exhausted. Its loss in this battle was nearly three-fifths of the entire number of men taken into action. Dr. Dudley, who had meanwhile been advanced to the rank of Corporal, was so severely wounded that the surgeons at first thought it necessary to amputate his leg, but in the end managed to save it. In consequence of this wound he was confined to various hospitals for over six months, and not only incapacitated for further service in the army, but lamed for life.

In 1897 the Legislature of the State of New York made an appropriation providing for the erection of a monument in the National Cemetery at Winchester, Va., "in commemoration of the distinguished services and sacrifices of the soldiers of said regiment during the battles of Winchester, and Cedar Creek, Va., September 19 and October 19, 1864." Dr. Dudley was a member of the Committee charged with the selection and erection of this monument, which was dedicated on October 19, 1898, and bears the following remarkable inscription:

ERECTED BY THE STATE OF NEW YORK

IN HONOR OF HER SONS

OF THE ONE HUNDRED AND FOURTEENTH REGIMENT

NEW YORK VOLUNTEER INFANTRY.

A TRIBUTE TO THEIR DEVOTION TO DUTY, THEIR UNFALTERING COURAGE AND GLORIOUS SACRIFICES.

TESTED ON MANY FIELDS, THEIR VALOR WAS MOST CONSPICUOUSLY SHOWN IN HOLDING ADVANCED DEFENSIVE LINES, IN THE BATTLE OF WINCHESTER, VA., SEPTEMBER 19, 1864, WITH A LOSS, KILLED AND WOUNDED, OF 188 OF THE 315 ENGAGED, AND RESISTING FLANK ATTACKS AND JOINING IN THE FINAL VICTORIES IN THE BATTLE OF CEDAR CREEK, VA., OCTOBER 19, 1864, WITH A LOSS OF 127 OF THE 250 ENGAGED.

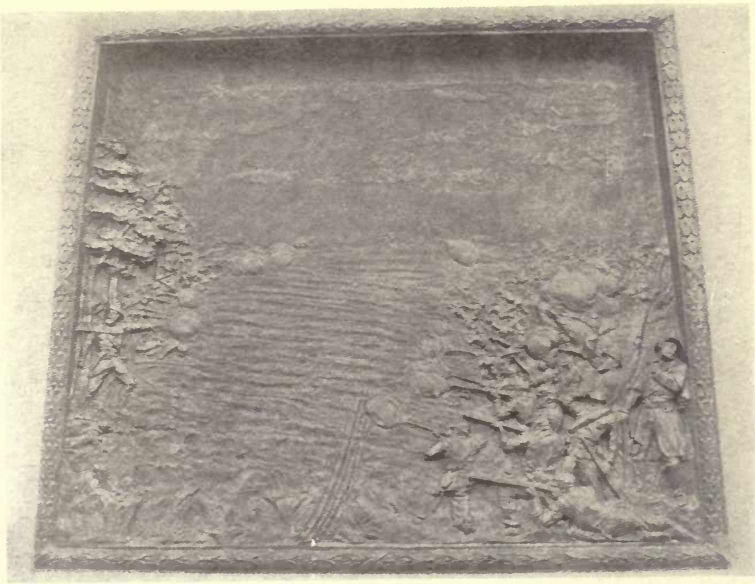
TIME CROWNS THEIR MEMORIES WITH UNDYING HONOR.

General Dwight, commanding the First Division at the battle of Winchester, refers to the loss sustained by "the heroic 114th New York Volunteers" as being "almost without a parallel in the history of the war," and in an official order, expressed "his high appreciation of the noble conduct displayed and signal service rendered" by this regiment, "exposed as it was for three hours to a heavy cross-fire of musketry and artillery. While regretting the severity of the loss, he rejoices that so gallant a body of men is attached to his command." The regiment had the proud distinction "that it never broke under fire, that it never lost a color, and that while 424 of its members fell in battle, but 19 were taken prisoners of war."

In 1894, the regiment held a reunion on the battlefield of Opequon Creek, for which the veteran survivors received transportation from the Pennsylvania Railroad through the offices of Dr. Dudley. On this occasion his comrades presented him with a gold-headed cane as a token of their appreciation and esteem.

COLLEGE DAYS.

The war ended, his duty to his country, as he had seen it, done, Dr. Dudley returned to the home of his boyhood to embark at once on a longer and no less arduous, though to him gladsome struggle, in the attainment of his long-deferred desire—the winning of an education. He had improved his leisure hours in camp, as best he could, in the study of Latin, and he now applied himself seriously to the task of completing his preparation for college. In the fall of 1867, with no financial aid save a hundred dollars given him by his father, but sustained by the same spirit of cheery, dauntless fortitude which had won the admiration of his comrades during the wearing and wearying trials of army service, he entered Yale resolved to make his way as a self-supporting student. Obliged to practice rigid economy in time and means, to forego many pleasures and to renounce all indulgences of college life, his classmates quickly discerned the sterling qualities of his manhood, and accorded him a unique place in the democracy of the campus. More mature in years and in the experiences of life than his fellows,



BATTLE OF WINCHESTER, VA.

SEPTEMBER 19, 1864

BAS-RELIEF ON THE MONUMENT
ERECTED IN HONOR OF
THE ONE HUNDRED AND FOURTEENTH REGIMENT
NEW YORK VOLUNTEER INFANTRY
AT WINCHESTER, VA.

they held him in affectionate regard as "Pater," a name which clung to him through life. At a class reunion within recent years a toast was proposed, first to our married men, second to our bachelors, and third to "Pater" Dudley. At his death there appeared in the *Yale Alumni Weekly* an editorial tribute to his memory under the heading, "An Ideal Yale Life,"* in which perhaps the rarest distinction lay in the omission of the name of him whose life was held up for emulation. It is worthy of note that this article was written not by one who knew him only at long range, or by reputation, but by a classmate. Another classmate in a recent communication to the *Yale Alumni Weekly* entitled "A Self-made Man of the Seventies,"† refers to Dr. Dudley's life as "an example for all time." The universal esteem in which he was held by the members of his class is attested by numerous letters from his surviving classmates, from which the following passages are quoted:

"Dudley was of more value to me than any other of my classmates."

"He always impressed me by his genuine manhood, kindly spirit and great pluck."

"We all loved him much. His sincerity, earnestness and strong moral character blended happily with vivacity, good temper and good fellowship."

"He was a general favorite in his class. All the boys loved 'Pater.' He had always an encouraging word, a friendly smile and a hearty greeting for every one. He was an optimist, always looking on the bright side of life, making the most of everything. To be with him made one feel that life was worth living."

"He was the oldest man in the class, and withal so fatherly, kindly and ready to advise us younger fellows, that we naturally called him 'Pater.' It was a genuine term of affection which we felt for him all through our college course. He was so philosophical that we loved to talk with him whenever we wished to dive down into the reason of things. We were sure of his looking at every subject candidly and thoughtfully, even though his views sometimes seemed to us 'crotchety,' as was natural while he was working out his convictions of things."

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*See p. 99.

†See pp. 108 ff.

"He was original, inclined to take his studies seriously, and to discuss involved points. While a faithful worker, he found time to keep abreast of men and things in the city in a practical way. He was one of the best-known men of the class and one of the most influential, though he had little to do with its social life. He was regarded as a man of established and sound character and he exercised much influence. He was always genial, sympathetic and gifted with a hearty unconventional spirit of camaraderie. He was fun-loving, always in good spirits, and never said or harbored a mean thought."

"Though he took little part in the social life of the College, no member of his class was better liked or more highly esteemed. The death of no member could have sent a deeper gloom over the class than his. One of the jolliest fellows I ever knew, but clean and pure and determined to get all he could out of his college life. His first and highest aim was study; to this he subordinated all else. I would place him in the class of which Abraham Lincoln is the type; rough, ungainly and uncouth on the exterior, but with a kind, lovable and genial nature within. His intimate friends were not surprised at the high stand he took in his chosen work. He held within him the germ of success and what followed was only the legitimate development of the qualities of mind and heart that he exhibited while in college."

"Dudley was singularly amiable and considerate in disposition, broad-minded and liberal in the view he took of life and conduct, and free from affectation or mean pride of any sort. He was a dutiful son and particularly fond of his mother. On his return from one of his vacations, he was attired in a suit of brown homespun, which he exhibited with great pride. He said that the cloth had been spun, woven, cut out and sewed by his mother. The suit was neat and well-fitting, although not cut or finished in the height of prevailing fashion; but he was as proud of it as if it had been made by the most fashionable tailor in New York.

"As I look back at Dudley in all his characteristics, he seems to me to have been an Abraham Lincoln sort of man, a type of manhood of which American citizenship cannot be too proud."

"He was spontaneously and essentially kind. That, together with his wider experience and maturity, held him in paternal standing with us. We, for instance, had our young anxieties over the future, while he had outlived all such concern. He used to say that if he found himself among strangers and down to his last dollar, there was always work enough to do, and he could and would immediately put himself on his feet again.

"Many of us in those days were still shy of persons unless they were of our sort, but already his army experience had carried him far beyond such parochialism. Every man, tramp or foreigner was to him in some way attractive. We caught from him something of neighborliness and good fellowship.

"'Pater's' insight seemed to many of us in those years not less than wonderful. He seemed to know our troubles as well, or even better, than we could have stated them ourselves. He helped me to discover the principle, 'You can't deceive a wise man, and a fool is not worth the trouble.' Wholly true and loyal, we looked upon him as an ideal friend."

"Though forty years have passed since we were classmates under the elms of Yale, there is none whom I remember better, because of the many pronounced, impressive qualities of manly character. We were proud of our soldier classmate, who seemed to us more like a father. We knew him by no other name than 'Pater' Dudley, not because of his years, but because of his kindly treatment and pleasant ways towards his classmates. He accepted the name in the spirit in which it was given, and was always pleased to be called by it. When 'Pater' entered a student's room in the old brick row with his genial smile and cheery 'Hello, fellows', he came as a ray of sunshine, and none received a gladder welcome. In point of scholarship he stood among the foremost, although never known or referred to as a 'dig' or 'grind.' The basic rock of his character was truth; his integrity was adamant. All who knew him believed in him and trusted him, because they knew that he was sincere, candid, honest, and that his heart was right. Of vices he had none, and dissipation of any kind was unknown to him. His was a worthy example of pure, upright daily living and no man in the class, in following 'Pater' Dudley, could go astray.

"Passing from life he may not have left a fortune in the amassed wealth of this world's goods, but he left a far more priceless heritage. He left a character without spot or blemish; he left in the hearts of all who knew him a loving memory of a model type of true American manhood; he left the world better because he had lived in it."

At Yale Dr. Dudley was a member of the Alpha Delti Phi Fraternity, the Gamma Nu (literary)Society, the Linonia, and a graduate member of Wolf's Head. During his senior year he was an editor of the *Yale Courant.* In recognition of his scholarship, he was elected to the honorary society of Phi Beta Kappa and selected to deliver an oration at the commencement exercises of his class in 1871, at which he was graduated with the degree of Bachelor of Arts.

Undaunted by the fact that he was then twenty-nine years of age, and determined to lay the foundations for his life-work broad and deep, he tightened his girth and pressed forward pluckily on another three-year stretch of hard work, study and self-denial. The first year he devoted to journalistic work with a view of paying off a small indebtedness and of obtaining means for continuing his studies. During this period he was connected with a New Haven paper, and was for a time Managing Editor of the *Yale Courant*.

In the fall of 1872, he entered upon a course of graduate study, devoted chiefly to chemistry, in the Sheffield Scientific School, Yale University, serving at the same time as night editor on the *New Haven Palladium*, a position which made large drafts on his time and energies. In 1874, his efforts were rewarded by his Alma Mater with the degree of Doctor of Philosophy. His graduating thesis, published in full abstract in the Proceedings of the American Association for the Advancement of Science, was "On Lithium and a Glass Made with Lithium."

On leaving Yale, Dr. Dudley found himself at the age of thirty-two, on the threshold of a productive life for which he had planned and labored so assiduously. His first engagement, which he held for one year, was that of instructor in physics at the University of Pennsylvania under Professor George F. Barker. In September, 1875, he accepted the appointment of teacher of sciences at the Riverside Military Academy, Poughkeepsie, N. Y., which he relinquished shortly thereafter to take up, on November 10, 1875, what was destined to become his life-work in the service of the Pennsylvania Railroad.

SERVICE WITH THE PENNSYLVANIA RAILROAD COMPANY.

This appointment to the position of Chemist, which was tendered him by Mr. Theodore N. Ely, then Superintendent of Motive Power, on the recommendation of Dr. Coleman Sellers, carried with it the double responsibility of organizing a new department of chemistry of a kind for which no precedent existed, and of proving its practical value as a permanent feature in the organization of a railroad.

With characteristic enthusiasm, energy and resourcefulness, and with a keen appreciation of the boundless possibilities for useful service that stretched out before him, Dr. Dudley threw himself into his new work. Remarkable as it may seem in the light of what has long since come to be general practice, the principle of purchasing materials on the basis of specifications and subject to tests was at that time practically unknown. Soaps, oils and paints, for example, were bought as soaps, oils and paints, with reference to little more than their general classification. The relation between the chemical composition of these and numerous other materials to their efficiency, under general and special conditions of service; the effects of adulterants and ready means for their detection; these and many similar questions which had their origin essentially in chemistry or physics were little understood or wholly unknown. Chemical tests, conducted then by chemists outside the service, were the exception rather than the rule, and were carried on without continuity or unity of purpose.

The problems by which Dr. Dudley found himself confronted were practically fourfold. First, to ascertain what material was best for a given purpose; second, to prepare specifications under which such material might be purchased in the widest markets under conditions of the freest competition, but with the certainty of getting exactly what was wanted; third, to devise the best methods and the most efficient organization for carrying on routine or acceptance tests on an extensive scale; and fourth, both to conduct independent research work and to keep in touch with the latest scientific and practical developments in a vast field, with a view of profiting by whatever might be safely utilized to secure increased efficiency or reduced cost. The successful discharge of these responsibilities demanded not only great scientific knowledge and ability, but tact, sound judgment and high moral courage. The possession of these qualities in a truly superlative degree enabled Dr. Dudley to win and to hold the complete confidence not only of his associates in all branches of the service, but that of the manufacturers as well, without whose support and cooperation impaired usefulness, if not outright failure, would inevitably have resulted.

Some of the many notable accomplishments of Dr. Dudley in the service of the Pennsylvania Railroad Company are set forth briefly elsewhere in this volume.* An added appreciation

*Address by Mr. Theodore N. Ely, on "Charles B. Dudley as a Railroad Man," pp. 50 ff.

of the wide range of his activities may be gained from his bibliography, especially the series of titles under the general heading "Chemistry Applied to Railroads."* Perhaps his greatest work—epitomizing as it did the results of the researches and observations of himself and others—was the preparation and constant revision of what came to be known as "standard specifications," governing the purchase of materials on a basis of definiteness and fairness to manufacturer and consumer alike. In framing these specifications Dr. Dudley recognized both the justice and the wisdom of frequent conferences with manufacturers. If opinions clashed, he demanded proof, which he was no less ready to adduce himself. His attitude was always marked by fairness and moderation, but when convinced that he was right, nothing could swerve him. The guiding principles which Dr. Dudley had constantly before him in the framing of these specifications, and in the protection of the interests of the service without injustice to manufacturers, are admirably presented in the series of his presidential addresses before the American Society for Testing Materials reprinted in this volume, notable alike for their wisdom and moderation, and their direct appeal to common honesty and common sense.

Dr. Dudley's first important investigation, which attracted world-wide attention, was that on "The Chemical Composition and Physical Properties of Steel Rails," which was completed within two years of the beginning of his connection with the Pennsylvania Railroad. Originally in the form of a report to the Superintendent of Motive Power, it was published a year later with a supplementary paper entitled "Does the Wearing Power of Steel Rails Increase with the Hardness of the Steel." The object of the investigations was to discover if possible the causes of the variable life of steel rails and means of ensuring a better and more uniform quality of material. The studies were conducted on twenty-five samples of steel rails which had been in actual service, with records ranging from "good" to "very bad." The history of these rails as to tonnage carried

*See pp. 118 ff.

and location in the track, and the results of chemical and physical tests, constituted the data from which the deductions were drawn. This investigation seemed to indicate that mild steel gave a better rail than harder steel, both as to safety against breakage and wearing quality, and led Dr. Dudley to recommend a formula for the chemical composition of rails for the use of the Pennsylvania Railroad. The validity of this formula was strongly attacked by some of the leading steel makers, on the ground that its experimental basis was inadequate, that it failed to agree with the experiences and observations of others, and that it would greatly increase the cost of manufacture.

Although these early conclusions of Dr. Dudley have necessarily been modified in the light of later investigations by himself and others, they were consistent with the data which he then commanded. His formula had been put forward as a tentative rather than final safeguard against a recognized evil. The discussion to which these papers led, and the investigations which they stimulated in this country and abroad, were important factors in the development of a field of inquiry in which Dr. Dudley's labors had been largely those of the pioneer. In this connection the generous words of that great steel master, Captain W. R. Jones, of the Carnegie works, as expressed in this discussion, in which he and others had taken issue with some of Dr. Dudley's findings, deserve to be quoted:

> "A word in regard to Dr. Dudley's formula of phosphorus units. Before he proposed this formula how many of those who condemned it as being egregiously wrong had any idea whatever of the relations of carbon, silicon and manganese to phosphorus? Although the Doctor may be wrong, and I believe he is only partially correct, yet he was the first to endeavor to establish a formula of this kind, and is therefore entitled to the thanks of steel makers; for although it may not be correct, it is much nearer the mark than what others have simply guessed at; and the direct results of his investigations have been to stimulate investigations by others and throw much light on a dark subject."

Again, as Dr. R. W. Raymond put it:

> "It is self-evident that Dr. Dudley's paper covers, and was meant to cover, but a limited range. . . . We all agree that in the determination of

the limited data available for his purpose he has been thorough and precise; and we must admit that he has a right to try to express the results in a formula which, within certain limits, will give the chemical constitution of a good rail. . . . Gentlemen who underrate the labor involved in arriving at such an hypothesis, and deem it easy to guess out a formula like this, are invited to give us out of their abundant facility, a guess that will do half as well."

And finally Dr. Dudley's own closing words, so characteristic of the fairness and modesty of his nature, should be recalled. Captain Jones, he said, had done him full justice in stating that he (Dr. Dudley) had brought the matter forward with the intention of trying to get better steel. He should be more than gratified if they succeeded ultimately in advancing their knowledge of steel as regards its wearing qualities, no matter whether the formula he had given did or did not make the best rail.

Dr. Dudley's effort to reach at least an approximate solution of this perplexing problem rather than none at all, was strongly characteristic of the man. He was intensely constructive. He believed always in turning the data at hand to serviceable account rather than to await the millennium of complete knowledge of a subject. He had the courage to assume the hazard of mistakes when presumptive partial or complete success seemed to his analytical mind to justify such hazard. His usefulness to the Company in matters referred to him for prompt decision was greatly enhanced by this trait, which might have been dangerous in one less gifted.

In 1881 Dr. Dudley published a third notable paper on "The Wearing Capacity of Steel Rails," based on the study of sixty-four rails removed from the track and subjected to chemical analysis and physical tests, which was again a model of careful research and clear reasoning.

This was followed some years later by a paper on the general subject of "The Wear of Metal as Influenced by its Chemical and Physical Properties," in which, with characteristic frankness, Dr. Dudley revised some of his earlier conclusions. In this and a later paper he presented the results of his fruitful investigation of the bearing properties of metal alloys which had led to his discovery of an alloy, both cheaper and better than phosphor-bronze. This discovery involved new principles, to which further reference will be made in connection with Dr. Dudley's inventions.

It is hardly necessary to state that much of Dr. Dudley's work in research and in the framing of standard specifications was done in cooperation with other branches of the service, notably the department of physical tests, and that the result of his labors were embodied largely in reports to the officers of the Pennsylvania Railroad and not published. Thus, as Chairman of the Research Committee on Rails he acted in an advisory capacity on this subject till the end. Again, he devoted much time and labor to the study of steel axles, steel springs, and many other subjects, the results of which found practical expression in the standard specifications which formed such a conspicuous feature of his work.

None recognized more clearly than Dr. Dudley the importance of standardizing methods of chemical analysis, nor labored more earnestly in that direction. He was the first to embody a description of the methods of chemical analysis in specifications for materials. He was a member of the Committee on International Standards for the Analysis of Iron and Steel and Chairman of the Sub-Committee on Methods, under the auspices of the American Society of Civil Engineers; and also one of a committee of three appointed by the American Chemical Society to report on Coal Analysis. Each of these committees presented valuable reports based on labors in which Dr. Dudley had prominently participated. The advanced and courageous stand which Dr. Dudley took in this important field as in all professional matters which he had near at heart, is best shown by his own words in closing an address on "Standard Methods for the Analysis of Iron and Steel:"

"To conclude, let me say that in any attempt to introduce standard methods, there will doubtless be a great deal of friction. Prof. Langley told me that when he first proposed the question of making an international standard for the analysis of iron and steel in the British Association for the Advancement of Science, the proposition was met with the most bitter feeling until he placed himself very firmly and plainly on record that he did not propose to prescribe methods in any shape or form. There is no question that the attempt on the part of anybody to say that work shall be done in a certain way is certainly going to meet with antagonism. All I can say is, that I think the results to be obtained are worth the struggle. I do not see any other way out of our difficulties. We must stand before the world in a better way than we stand to-day. The profession of analytical chemistry cannot exist and occupy the field that it ought to occupy until commercial men can send their steels to chemists of fair reputation and get the same result from them on the same sample. You may turn it around as you choose; it is our own fault if we have to occupy a subordinate position, and if anybody will suggest any other method by which agreement can be brought about, I will abandon the whole work of standard methods instantly."

It is not possible to refer here in detail to the results of Dr. Dudley's studies in each of the numerous important lines of consumption of the huge railroad system with which he was so long connected, such as coal and water, paints and varnishes, burning and lubricating oils and many others; nor is the writer unmindful of his incompetency to do so in an adequate way. It would be difficult to estimate the direct money value of these researches, or the indirect effect on the comfort, health and safety of untold millions of passengers, of his studies in such matters as the lighting, ventilating and disinfecting of passenger cars, in each of which he rendered notable services.

Perhaps Dr. Dudley's greatest service—viewed as a broad service to humanity—was rendered through his indefatigable and self-sacrificing labors for the promotion of safety in the transportation of explosives. His first investigations in that line date back nearly thirty years, and from that time until his death there was no problem to whose solution he applied himself more earnestly or to better purpose. The organization in 1906 of the "Bureau for the Safe Transportation of Explosives and Other Dangerous Articles," under the auspices of the

American Railway Association, may be regarded in a very direct sense as the culmination of Dr. Dudley's long-sustained and vigorous strivings to some such end. Nothing could have been more fitting than his election to the first presidency of that bureau, an office which he continued to hold until his death. In planning the organization of this bureau he became convinced that its permanent success was largely dependent on the possibility of securing the services as Chief Inspector of a certain army officer who had won distinguished recognition for his achievements in the study of explosives. A forceful representation to that end was at first disapproved by the Government authorities at Washington. Nothing daunted, Dr. Dudley renewed his efforts with redoubled vigor. He put his plea on the highest grounds; namely, that the welfare and safety of the traveling public were at stake, that the difficulties in obtaining the services of any other man of the right qualifications were insuperable, and that much as this officer might be needed in the Bureau of Ordnance, the people of the United States had an even higher claim than the army, which after all existed for the protection of the people. Through his aggressive campaign, supported by the American Railway Association, he succeeded in having the matter brought to the attention of President Roosevelt and considered at a cabinet meeting, at which the desired detail of Col. B. W. Dunn was finally authorized. Dr. Dudley felt convinced that by this act the success of the cause for which he had labored so long and strenuously had become assured, and the sequel served only to confirm the soundness of that judgment.

The history of the movement to secure greater safety in the transportation of explosives, as related informally by Dr. Dudley at the Annual Convention of the National Association of Railway Commissioners in 1908, forms a chapter of absorbing interest which appears elsewhere in this volume.* The conspicuous services which Dr. Dudley rendered in that connection are

*See pp. 257 ff.

also alluded to in another place,† and at the request of the writer have been summarized by Colonel Dunn as follows:

"The first regulations which covered 'less than an ordinary letter-size sheet,' written for the Pennsylvania Railroad by Dr. Dudley in 1883, mentioned many of the general principles that underlie the more voluminous regulations of the present day. During the twenty-two years following 1883 his work in this line was confined to revising these rules for his company. In 1905 a very serious accident, involving the explosion of a carload of dynamite, occurred on the Pennsylvania Railroad at Harrisburg and steps were taken by the American Railway Association to secure concerted action by all railroads to minimize the chances for repetition of such catastrophes. A committee, of which Mr. James McCrea, then First Vice-President, Pennsylvania Lines West of Pittsburg, was chairman, was appointed to prepare regulations. The first step was to secure reliable information of the characteristics of the explosives offered for transportation and the volume of the business. Although three chemists of high reputations were employed to assist in this work, they did not find it necessary to do much more than endorse the report prepared by Dr. Dudley.

"The regulations submitted by Mr. McCrea's committee, and adopted unanimously by the American Railway Association in October, 1905, were written by Dr. Dudley and they were simply an extension of his previous work in this line for his company. Many prominent railway officials considered the uniform adoption of these regulations by all railroads in the United States and Canada to be a final and satisfactory solution of the problem. Dr. Dudley's exceptional intuition taught him that provision had still to be made for uniform enforcement of the rules. A 'Bureau for the Safe Transportation of Explosives and Other Dangerous Articles' was organized for this purpose November 21, 1906, and Dr. Dudley was its president from that time until his death. The success of this bureau was of absorbing interest to him during this time. He expressed frequently a desire for the physical energy of his younger days, that he might devote himself entirely to directing the practical work of the Bureau. As it was, he studied attentively all reports emanating from the Bureau, and endeavored to attend the important conferences of its officials with manufacturers and shippers of dangerous materials. In these conferences his presence and wise counsel were always useful in securing the desired cooperation of transportation and shipping interests.

"One of the most important of Dr. Dudley's services to safe transportation was rendered at Washington, where he succeeded in convincing the Committee on Interstate Commerce of the House of Representatives of the necessity for a modern substitute for antiquated federal legislation. The impression made at that time (Hearings on H. R. 7557, Feb. 7, 1908)

†Address by Col. B. W. Dunn, on "Charles B. Dudley as a Mentor," pp. 65 ff.

caused the present Chairman to remark during a hearing January 18, 1910, on another bill affecting interstate transportation of dangerous articles, that Dr. Dudley's memory was held in very affectionate regard by the members of his committee."

In 1886 and again in 1900 Dr. Dudley was delegated to represent the Pennsylvania Railroad Company at the International Railway Congress. In 1886 he was also commissioned to investigate the use of oil for locomotive fuel by the Urquhardt system on the Grozi Tsaritzin Railway in Southern Russia. His report showed that the substitution of oil for coal on the Pennsylvania Railroad was physically but not economically practicable, and it was, in fact, proved by actual tests that with oil at thirty cents a barrel its cost for the same performance was fifty per cent. greater than that of coal. He pointed out further that the substitution of oil for coal on the Company's entire system would mean a consumption at the rate of nearly one-half the entire production in the United States, a condition which would immediately result in higher prices.

Inventions.

Some of the fruits of Dr. Dudley's experimental research are indicated by Patent Office records. From the list printed elsewhere* it is seen that between the years 1882 and 1901, thirteen United States patents were issued in Dr. Dudley's name, in two of which he was associated with others. The writer is indebted to Mr. M. E. McDonnell, Bacteriologist with the Pennsylvania Railroad Company, for this list as well as for detailed information concerning the patents, from which the following extracts are quoted with slight modifications for the sake of continuity in the somewhat condensed form in which they are here presented:

"From the tabulated list of Dr. Dudley's patents it will be seen that six separate patents were issued on his developments in the field of the improvement of water for use in boilers. Considerable loss was being experienced owing to the corrosion of boilers by water which had become acid through the entrance of mine drainage or manufacturing wastes into the

*See p. 120.

supplies. Loss was also due to the incrustation of boilers through water unnaturally high in sulphates and carbonates of calcium and magnesium. Dr. Dudley's first patent was for the use of caustic soda which was added to the water in tanks and the water agitated, which resulted in the neutralization of acid salts, and the more or less complete precipitation of calcium and magnesium oxides, when the clear water was drawn off for use and the precipitated sludge allowed to run off.

"It was soon found that while caustic soda was a valuable constituent in many cases for a boiler compound, it was for various reasons not suitable for general use in the majority of water supplies. Dr. Dudley accordingly devised a method of making soda lime in such proportions of lime to soda as were best adapted to the particular water under treatment. This method, covered by two patents, which was found applicable to almost any natural water usually encountered, is used in many places to-day in its original or slightly modified form.

"A fourth patent was granted to Dr. Dudley on a device for heating and adjusting the water to be treated by means of steam and compressed air in which two tanks were used alternately, which resulted in a constant supply of good water in one tank, while impure water was being prepared in the second. This was found to be an excellent device, which is still used in some localities.

"Dr. Dudley's investigations showed that barium hydrate in connection with soda lime or carbonate of soda is in some respects an ideal agent in the purification of water, since it removes sulphates as well as lime and magnesia. Owing to the high price of barium hydrate this process, originally covered by two patents, has not come into extensive use.

"Six of the patents issued to Dr. Dudley pertained to valuable improvements in the illumination of cars by means of the carburetor system. Electric lighting had not at that time come into practical prominence and lighting with city gas was found to be unsatisfactory for various reasons.

"As is generally known, many of Dr. Dudley's investigations which led to valuable results were not protected by letters patent. During the later years of his life he did not take much interest in patent affairs, and was not disposed to so protect new inventions. As an illustration of an unprotected invention, which was an important one, we would cite that of his thin wick burner to be used without a chimney and with an all-mineral burning oil. If an oil of this character is used in a lamp with an ordinary burner it does not get sufficient air to burn it as it should, and the result is the production of a dense black smoke. The use of a chimney would cause a draft of air to pass through the burner, which would burn the oil sufficiently to prevent smoke, but in certain places a chimney was objectionable. Dr. Dudley devised a burner with a comparatively wide but very thin wick. This arrangement exposed the thin film of oil to a relatively large amount of air, which was sufficient to cause satisfactory smokeless combustion. This burner was devised in the early eighties.

"Another very striking illustration is that of his work on bearing metals. His discovery of the principles that the wear of a bearing metal was diminished by the addition of lead, that the wear diminishes with the diminution of tin, and that the tendency to become heated decreases as the lead increases, were all more important than any of those inventions which he patented. This work is now a matter of court record and is generally known.

"Other similar inventions might be cited. Most of these are described in literature and have thus been made public. He gave many valuable ideas to those engaged in the industries. These might properly have been used to his personal financial gain. His reward was in the satisfaction derived from having helped others meet difficulties which they encountered."

Civic Activities.

The story of Dr. Dudley's devoted and unselfish labors in every movement for social betterment in the community in which he lived for a third of a century, and till the end, is told elsewhere with rare discernment by a fellow citizen.* Recognizing that success in such matters could come only through co-operation backed by an enlightened public sentiment, Dr. Dudley made it his business to keep in touch with the newspaper men of the town and to assist them in presenting municipal problems to their readers in the right light. While his fertile brain was always ready to suggest arguments, he was content to remain in the background and to let the credit of achievement go to others who had really been inspired to action largely through his efforts.

Dr. Dudley held at various times many positions of honor and trust in the city of Altoona. He was one of the incorporators and a member of the board of directors of the City Passenger Railway, the Central Trust Company, of which he afterwards became Vice-President, and the Juniata Club. He was also a director of the Mechanics' Library and Reading Room Association, the Second National Bank, and of several building and loan associations. He served for a time as a member of the Board of Trade, and for many years (1885 to 1897) he was one of the most active and efficient members of Altoona's first Board

*Address by Mr. W. H. Schwartz on "Charles B. Dudley as a Citizen," pp. 71 ff.

of Health. In connection with the latter he was indefatigable in his advocacy of progressive municipal policies in matters affecting the health and comfort of the entire community, such as water supply and sewage disposal. He also took an active part in the formulation and introduction of wise sanitary regulations.

Among the many worthy things to which Dr. Dudley gave so generously of his leisure time and thought, the Altoona Mechanics' Library easily held first place. A director for nearly thirty years and chairman of the library committee, he gave his personal attention to the selection and purchase of books and periodicals, and labored constantly to make the library a vital force in the intellectual life of the community. Largely through his efforts the library was brought into direct relations with the public school system, and under the stimulus of the University Extension movement to which he lent his hearty support, its general helpfulness was materially increased. To assist the host of young men connected with the Altoona shops, laboratories and offices of the Pennsylvania Railroad Company in their efforts of self-improvement, Dr. Dudley gave his especial attention to the upbuilding of the scientific and technical branches of the library, particularly in lines pertaining directly or indirectly to railroading. During the thirty years that Dr. Dudley was its leading spirit, the Altoona Mechanics' Library enjoyed a fifteen-fold growth in membership as well as in books. At his death the library contained nearly fifty thousand volumes, and its membership had grown to nearly fifteen hundred.

PUBLIC SERVICE.

Dr. Dudley's labors as a public servant were not confined to municipal affairs, but he was ever ready to respond to demands on his time and talents from state and nation in so far as these could be reconciled with his regular duties. Thus he served on the Pennsylvania State Board of Health from 1886 to 1893 as Inspector for the City of Altoona and environs;

from 1893 to 1895 as Inspector of the Central District embracing the counties of Center, Clearfield, Clinton and Blair; and from 1895 to 1899 as Inspector of Blair County. In his relations to the Board, Dr. Dudley was "most energetic and faithful, and in his reports of inspection were models of thoroughness, clearness and conciseness."

On two occasions Dr. Dudley was appointed a member of the United States Assay Commission, once in 1888 by President Cleveland and again in 1897 by President McKinley. He was also honored by an appointment as Collaborator in the United States Bureau of Forestry.

Dr. Dudley's most conspicuous service in national affairs was rendered in connection with the National Advisory Board of Fuels and Structural Materials by direct appointment from President Roosevelt, who deemed it wise that the Government should have the benefit of the advice of eminent engineers and scientists. The general considerations which prompted the creation of this Board were indicated as follows in the letter of appointment from President Roosevelt to Dr. Dudley:

"My Dear Sir:

The United States Government, through the Geological Survey and the Forest Service, is engaged in investigating the properties and best methods of use of the building materials and fuels of the United States. These investigations are so intimately connected with the industries and welfare of the nation that they should be carried forward as rapidly as possible and should have the advantage of the best advice and cooperation which it is possible to secure. Accordingly, I have invited selected members of the national engineering societies and allied organizations to form with representatives of such Government bureaus as are carrying on actual construction work, an Advisory Board on Fuels and Structural Materials, and I appoint you a member of this Board as representing on it the American Society for Testing Materials."

The National Advisory Board consisted of the chiefs of the several Government bureaus extensively concerned with the use of fuels and structural materials and leading experts in various branches of engineering or applied science, to a total number of about forty-five. It was a significant tribute to Dr. Dudley's worth and standing that he should have been elected to the chairmanship of this large group of eminent experts, an office which he continued to hold until the end. He never failed to attend a meeting either of the Board or its Executive Committee, and occasionally he went to Washington to attend and preside at meetings of Government officials in connection with the investigation of fuels and structural materials for the use of the Government.

A prominent member of the Board writes as follows of Dr. Dudley's connection with the same:

"At the meetings of the Board, in spite of his modesty, he was always the largest contributor to both the pleasure and the information of the members. His large experience as a chemist and testing engineer for the Pennsylvania Railroad; his powers of careful, accurate observation; his discriminating caution, and his ability to grasp the full meaning of all the facts developed; and the ease and readiness with which he could state the results of any investigation and discuss the meaning of these results, together with his delightful personality,—all these combined caused Dr. Dudley to be considered, by common consent, the Board's 'most useful member,' and his advice was often sought and acted upon by the individual officers in charge of large Government building and engineering projects."

In pursuance of its instructions from President Roosevelt, the Board reported its findings and recommendations directly to the President. In the preparation of these reports the far-sighted wisdom and the masterly hand of Dr. Dudley were always strongly in evidence. It was largely through Dr. Dudley's influence that the Board came to play an important rôle in the withdrawal of Government coal lands, which was a prominent feature in the general conservation policy championed by President Roosevelt.

President Roosevelt directed the Board to recommend to him "a more uniformly efficient basis for the purchase of fuel supplies by the several departments of the Government, and for securing the highest attainable efficiency in the use of these fuels." In its preliminary report on this subject, which dealt mainly with the matter of coal supplies used by the Government in the District of Columbia, the Board recommended the purchase of such coal on the basis of its heating value, through a central purchasing committee, and the establishment of a central heat and power plant to supply heat, light and power to the executive public buildings. To-day practically all coal used by the Government in the District of Columbia, and much of the coal used by the Navy Department, at army posts and in numerous other branches of the Government, is purchased under Government specifications. Dr. Dudley's counsel in the preparation of the original specifications for coal was of great value to his associates, both by reason of his extended experience in drafting specifications, and his special knowledge of the material under consideration.

The Board also rendered useful service to the Government through its endeavor "to arrange such consolidation or cooperation of the various laboratories or other agencies of the Government for the testing and investigation of fuels and materials of construction as will avoid unnecessary duplication of work and expenditure," which was one of the subjects which President Roosevelt had specifically referred to its attention. The immediate effect of the Board's activities in this matter was the consolidation of the laboratories under the Supervising Architect of the Treasury Department and those under the Technologic Branch of the Geological Survey. An agreement was also reached with these consolidated laboratories, the Bureau of Chemistry, the Bureau of Forestry, the Office of Public Roads, and the Bureau of Ordnance, by which certain work was to be conducted under a cooperative plan in such a manner as to avoid duplication either in equipment or labor.

In this connection the Board also recommended the establishment of central laboratories for the investigation of building and engineering problems for the Government at one of the larger industrial centers rather than at Washington, for reasons clearly set forth in its report to the President, in which it expressed its belief that "such investigations should prove of great value in the general movement for the conservation of the nation's resources through the development of less wasteful or more efficient uses of materials throughout the country."

In alluding to Dr. Dudley's services on the Board, the Secretary, Mr. R. L. Humphrey, writes:

"Dr. Dudley's influence on the Board and on the work which it accomplished cannot be over-estimated. As a presiding officer, his charming personality, his tact and his wonderful store of knowledge relating to the problems under consideration imparted a degree of interest and vigor to the meetings which will never be forgotten by those present. Every member of the Board felt impressed by the high ideals and lofty character of the Chairman and entertained the highest respect for his depth of knowledge and broad-minded way of receiving and imparting information."

At the Conference of Governors called by President Roosevelt and convened in the White House May 13-15, 1908, Dr. Dudley delivered a forceful address entitled "Use of Some of the Natural Resources of the Country and Possible Economies in Their Use."

SOCIETY ACTIVITIES.

The wide range of Dr. Dudley's interests and activities is strikingly exemplified by the long list of scientific, technical, educational and social organizations in this and foreign countries with which he was connected. Although a man of moderate means, he is known to have held membership at some time in no less than fifty societies,* with most of which he was connected till his death. He was particularly active for many years in the American Chemical Society, by which he was twice honored with the presidency, and in the American Institute of Mining Engineers, of which he was Vice-President for one term.

During the later years of his life his interests of this kind were centered chiefly in the American Society for Testing Materials, to its lasting benefit. He held the highest office in that society from 1902 until his death. In its activities, especially those relating to the standardization of specifications, he

*For a list of these organizations, which is believed to be incomplete, see pp. 113 ff.

could not fail to perceive the fruition of that for which he, more than any one else, had planted the seeds many years before. His presidential addresses before that society are destined to become classics. As a presiding officer he had no superior. His breadth of knowledge, his versatility, his grace, wit and pervading kindliness of look and manner fairly illumined the sessions at which he presided. The members revered and loved him. At the tenth annual meeting of the Society, in 1907, the general feeling of affection and respect found expression in the presentation of a silver loving cup "in appreciation of his sterling personal and professional worth."

The cabled tidings of Dr. Dudley's unanimous election in 1909 to the presidency of the International Association for Testing Materials were received with enthusiastic acclaim by the American members as a fitting tribute to one in whose leadership at home they had long felt a peculiar pride. They saw in this choice the happiest promise for the next Congress of the International Association which was to be convened in this country in 1912. Dr. Dudley's appreciation of this great honor was voiced by him at the Copenhagen Congress in the following simple words:

"*Gentlemen:*

Pardon that I speak now only in English. Before the next Congress I hope to do better. I thank you from the bottom of my heart for this great honor. I have spent my life in testing, and now as I approach the end of my work, you have conferred on me the Presidency of this international body of testing engineers, which I cannot but regard as the greatest honor that has ever come to me.

"With regard to the next Congress, I will only say now that we shall do our best to make it a success, and if we succeed as well as our Danish friends have done, under the leadership of our President who is just leaving us, I am sure you will be more than satisfied."

Soon after Dr. Dudley's return to America, and not long before his death, he gave expression as President of the Association to the following generous sentiments in a communication addressed to Mr. Alexander Foss, his immediate predecessor in that high office.

"My Dear Sir:

It is with feelings of inward satisfaction and sincere pleasure that all those who took part in the Congress at Copenhagen look back upon the delightful days spent in that city. Each of them has carried away with him the proud consciousness of having been witness to a stirring manifestation of intellectual activity, such as does not pass away with the day, but will be powerfully efficacious towards the accomplishment of those ends aimed at by the Association.

The scientific results of the Congress would not have been possible without the splendid organization which we owe, my dear Sir, to you and to the various committees under your presidency. Your powerful appeal called together the first experts of the whole world, and gained members to take part in the Congress from distant countries which had till now been wholly ignorant of the Association and its objects.

By means of this Congress the number of the adherents of the Association has been as much increased as the general understanding of its scope and intention has been deepened and widened.

Not only, also, did you succeed by means of your well-planned organization in giving clear aim and direction to the willing work of hundreds, but you likewise understood how to display, in a short time, the rich treasures of your beautiful country after a fashion unforgettable to all.

The Congress members have learned in Denmark to admire with their own eyes a country standing, through its own high culture, in one rank with the first civilized nations of the world, a country dedicated to the furtherance of public prosperity under the wise rule of a sovereign, himself a lover of progress.

We beg you therefore, my dear Sir, to accept the most sincere and cordial thanks of the Association and to convey the same to all those kind cooperators, both ladies and gentlemen, who have given you their assistance in this laborious work.

May the consciousness of having powerfully promoted the objects of the Association and of having gained new friends for Denmark in every part of the world be the true reward of your great and unselfish labors!

With the expression of the highest esteem.

THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS,

ERNST REITLER, *General Secretary.*

CHARLES B. DUDLEY, *President.*

As a Teacher of Men. While to the world at large Dr. Dudley was known perhaps chiefly as a chemist, those privileged to gain a nearer view, recognized in him, first and foremost, a tireless searcher for the truth, and second, a teacher of extraordinary stamp. Endowed with keen powers of observation and analysis; patient, honest and orderly in his mental processes; devoid of pride of opinion and of pedantry; graceful, lucid and charmingly frank of speech; a firm believer in young men and an ardent lover of his fellows—there was blended in Dr. Dudley's make-up every quality of the teacher in his best estate. His audiences were not bounded by the school room, but wherever he appeared, in neighborly intercourse or at formal gatherings, he found men willing and eager to profit by his thoughtful and stimulating utterances. The impression he made upon his hearers was that of a man wholly unconscious of superior knowledge, striving earnestly to stimulate their interest in something worthy, and to enlist their help to some useful end. His whole tone and manner was that of one fellow-worker to another, rather than that of one who felt that he spoke with deeper insight or from a higher level. He seemed equally free to speak of his perplexities and failures, as of any achievements to which he might modestly allude. His sole aim was to bring out the truth, irrespective of any personal credit to himself, although no one was more generous in praise of others. In his discourses he had a habit of establishing a few pivotal points around which he would group his facts and marshal his arguments, and to which he would recur with sufficient frequency to keep them prominently before his hearers till the final summing up, when he would bring them forward with cumulative effect.

Dr. Dudley's laboratory at Altoona, the prototype of many of that class, became in a large sense a training school for young chemists and metallurgists and a bureau of information on the most generous lines. Dr. Dudley's counsel was sought by letter and in person by men from all over the land and from foreign countries. To the officers of the Pennsylvania Railroad and to the citizens of Altoona he was a veritable mine of information. He had so trained his memory that he could recall facts and events of the most diverse sort with apparent ease and accuracy. He was wont to say, "The only thing, I think, that I am miserly or sparing of is time—that I treasure." Yet he never grudged the time and effort necessary to satisfy legitimate questions. The most approachable and democratic of men, people of every station came to him for advice and inspiration, and of what he had, he was ever ready to give with open hand.

An ardent believer in education in its best and broadest sense, Dr. Dudley lost no opportunity to encourage young men in the self-helpful pursuit of knowledge. He regarded self-sacrifice as the keystone in true character building. His own early struggles enabled him to speak with the insight of personal experience when he admonished young men to do without a gratification of the moment for a future good. His pleasure was to learn something new each day, and for many years it had been his daily practice to render an account to himself of the lessons of that day. To him the phrase "too old to learn" held absolutely no meaning. Thus on his election to the presidency of the International Association for Testing Materials at the age of sixty-seven, he plunged into the study of German with the buoyant ardor of youth.

A man of Dr. Dudley's extraordinary personality and gifts would have achieved distinction in any one of the numerous fields of human effort that fell within the wide range of his tastes and sympathies. The teaching profession, for which he evinced an early predilection, and for which he seemed originally to be destined, never ceased to command his warm interest. The sphere of his activities with the Pennsylvania Railroad was, however, so strongly to his liking that he declined at least two flattering invitations to return to an academic career; once when he was offered the presidency of a technical school, and again when he was tendered the chair of applied chemistry at another institution of first rank.

PERSONAL TRAITS.

Dr. Dudley's choicest qualities were after all not those which brought him world-wide renown as a scientist and an investigator—the attributes of true greatness lay in the man himself. His countenance bore the blended stamp of gentleness and rugged honesty. Men recognized intuitively the simplicity and the fineness of his nature, and were held willingly enthralled by the magnetic spell of his exquisite personality. It was said of Dr. Dudley that he had no acquaintances—only friends. Those who knew him best would be the first to affirm the wondrous truth of that statement.

As a man Dr. Dudley was an unfailing optimist, but never a dreamer. He believed in doing the best, under all circumstances, with the means at hand. The greatest word in the English language, he sometimes declared, is "Manage." With him work was a passion; idleness and self-indulgence, an abomination. "It's work done overtime that counts!" was his cheery way of putting it. He delighted to help men, especially young men, to help themselves. He said he fairly envied young men just ready to "go on." He tried above all else to instill in them the spirit of moderation and self-sacrifice.

In his contact with men his penetrating eye did not fail to perceive the dross, but he searched always for the gold, and aimed to bring that to the surface. He bent men to his will, neither by force nor artifices, but by appealing straight to their reason and their innate sense of justice. At his promptings men won victories over themselves which they could hardly have achieved without that subtle aid. Fearless and plain-spoken when occasion demanded, he was pre-eminently a pacificator. In an argument, his keen sense of humor and aptness of illustration by homely anecdote—perhaps from the rich store of his own experiences—charmed and often won his opponents. He saw in all men the human and the immortal rather than distinctions of birth and station. "*Esse quam videri*"—to be rather than to seem—was among his favorite maxims, and none, indeed, was better suited to himself.

Honors could not fail to come to such a man in large numbers, but he bore them easily and seemingly unconsciously. His delight lay in the doing, not in the acclaim. His advice to others was to let their work speak for itself, to waste no time and energy in struggles for recognition. His own acts in this, as in all things, tallied with his precepts.

Just as Charles B. Dudley, the man, loomed even greater than Dr. Dudley, the scientist, so it was fitting that to the former there should come in time in happy wedlock the rarest of all earthly prizes, which lent to the sunset of his life a glow beautiful to behold. On April 17, 1906, Charles Benjamin Dudley and Mary Virginia Crawford were joined in marriage at Bryn Mawr, Pa. How fondly memory recalls the radiant smile, the tenderness of look and voice, the artless simplicity, with which, some time before, Dr. Dudley had confided to the writer the secret of the great good fortune that had at last been vouchsafed him. In that, as in the lesser things that came to him, he seemed possessed, after the manner of the truly worthy, by an overwhelming sense of his own unworthiness.

Dr. Dudley died at his home in Altoona, Pa., on December 21, 1909, after a short illness, of pneumonia, at the age of sixty-seven.

SOME GLIMPSES OF DR. DUDLEY AS HE APPEARED TO HIS FELLOW-WORKERS AT ALTOONA.

By M. E. McDonnell

One of the qualities which contributed so largely to the hold which Dr. Dudley had on people was the spirit of helpfulness which he showed on all occasions. He gave the best he had to any who came to him, regardless of whether they were young and starting on a career, or old authorities of repute. He talked as well to a few boys at a meeting as he did to the most important gatherings. It was indeed a pleasure to listen to him, and one could always carry away the essential substance of his talk. This was also true of his private conversation. When going over certain questions with him in his office, he would frequently say "now stick a pin there," when he came to what he considered established points in the problem, and we soon learned to hold fast to points so designated. His success was due to a considerable extent to his ability to see the crucial points in a problem under consideration. He quickly realized the points at which "pins should be stuck," and he could hold his audiences by keeping these points conspicuously before them.

On one occasion he was asked for advice as to what to do in case of a controversy with other interests which was likely to arise. He then entered into a talk which revealed a strong characteristic of the man. He said that in all cases involving scientific matters, to follow the Baconian method of procedure and to avoid the Aristotelian, also to refuse to accept Aristotelian logic if presented by an opponent. He could cite numerous instances where injustices had resulted due to those in power enforcing principles based on purely deductive reasoning. Inductive methods were essential to the establishing of facts, and he said to "always demand proof of each claim" in a chain of reasoning. He has probably made the statement "prove your point" oftener than any other when discussing scientific matters. His respect for Bacon, the father of the inductive method, was very great.

A very important factor which probably aided him much in his work is revealed by the rule which he has given, namely, "Learn something new each day, and at the close of each day's work think over those new lessons." He also said on one or more occasions that this had been his life's practice, and that those days which had taught no new lessons were considered failures. The application of this rule probably accounts in a marked degree for his wide store of information and his remarkable memory. Those who knew him well were frequently surprised by his accurate recollection of statements which were made to him years before. Illustrations of this could be given, and in some instances there was no possibility of his having heard statements, which he remembered, more than once.

A more or less extended application of Dr. Dudley's rule has shown us its value. If it could be frequently repeated to college students in particular, we believe they would more rapidly succeed in taking their proper places in the world. A rule which he considered worthy of retention throughout the active career of a life time, and one to which his success is believed to be due in no small measure, is certainly worthy of a trial by every one.

Memorial Session

in honor of the memory of

Charles Benjamin Dudley

HELD BY THE

AMERICAN SOCIETY FOR TESTING MATERIALS

JUNE 29, 1910.

Program of Exercises

THE LIFE AND LIFE-WORK OF CHARLES B. DUDLEY

1842-1909

President Henry M. Howe presiding, the Vice-President of the Society, Mr. Robert W. Lesley, offered some introductory remarks on behalf of the Executive Committee. The life and life-work of Dr. Dudley in its different phases was then presented by the following speakers:

As a Railroad Man............Theodore N. Ely
As a Chemist...................Edgar F. Smith
As a Metallurgist..............Henry M. Howe
As a Mentor......................B. W. Dunn
As a Citizen...................W. H. Schwartz
A Personal Tribute............Robert W. Hunt

The following minute, prepared by Dr. Henry M. Howe, was then adopted by a rising vote:

"Let us record at once our deep grief and our deeper gratitude, our grief indeed at the loss of a great leader and dear friend, but above all our gratitude that we have had the privilege of being led.

Such measure of usefulness as our Society has had it owes in very large part to that leadership. Here was a most rare combination of qualities, the sterling, the intellectual, the human, the judicial, each on a high level, all combining to form a character, a personality, whose like we shall not look upon again.

With a clear head to see the world's needs, to part the essential from the accidental and the merely concomitant, went the skillful and persuasive tongue to make clear to the rest of us what he had first made so clear to himself. With these went the perfect fearlessness, apparently even the unconsciousness of either danger or fear, which made him lead on where others would have flinched. With these again went his calm, clear, good judgment, which seemed to tell him spontaneously which among the good things that needed doing were the most worthy of being done, and what were the best and surest ways of doing them.

With all these admirable qualities went that which was necessary to the accomplishment of his high purposes, his kindness of heart, his sympathy, and his tact, which made us all his allies in what he undertook. Had he a proposal? Our affection and veneration for him made us almost its advocates before it was unfolded. Its intrinsic wisdom, and the clearness with which he expressed it, found an audience ready, almost anxious, and certainly expecting to be convinced.

Great as were his tangible works, his greatest was the imponderable. Standing on a high platform, his call raised us towards his level, all the more effectively because of his complete unconsciousness of his own height. We who have known and loved him are for that knowledge and that love the better and the higher—how much, ah, who shall say?"

ADDRESSES DELIVERED AT THE MEMORIAL SESSION IN HONOR OF THE MEMORY OF CHARLES BENJAMIN DUDLEY.

INTRODUCTORY REMARKS BY THE VICE-PRESIDENT,

MR. ROBERT W. LESLEY.

In the printed report before you to-day, there is a minute prepared by Dr. Howe, our honored President, and adopted by the Executive Committee as a memorial to Dr. Dudley. It is so expressive and so full of beautiful thought and feeling that it leaves but little to add. However, as your Vice-President, and one who has been associated with Dr. Dudley from the earliest days of our Society, I cannot let the occasion pass without adding my mite to the monument of love and affection we will erect to-day to the memory of one of the greatest men this country has ever known. He was a *man*—a versatile and many-sided man. When we think that he is to be described by those who knew him best as he appeared in the various branches of science, in his capacity as a railroad man, as a chemist, as a metallurgist, as a mentor, and as a citizen, how can we fail to realize that this was a man of giant intellect and sterling character? But say of him what we will, in every relation of business and scientific life, he was, above all, the man—kindly, true, affectionate and loving. He was a diplomat of the heart, a nobleman of Nature's handiwork, a man of the broadest outlook and widest perspective. No Marius he, immersed in the mire of petty and narrow things, but a soldier of light, with his head on high, seeing all sides of every question and deciding rightly and clearly from his elevated point of view, his worldly experience, his Christian impulses and his rare judgment.

In our Society his manly, melodious voice, his irresistible smile and musical laugh carried everything before them. Who could resist them, combined as they were in the delightful personality of Dr. Dudley? No difficulty ever arose that his presence could not compose, no trouble that his instinctive tact could not brush away. A member of the International Association for Testing Materials in 1896, one of the members of the American Section of the International Association for Testing Materials at the time of its organization in 1898, and President of the American Society for Testing Materials at the time of its formation in March, 1902, Dr. Dudley's career with us was synonymous of and synchronal with the development of the Society.

In his connection with our organization Dr. Dudley stood at all times for the best and the highest. To him, as the exemplar of the art of testing, and as the pioneer in that most important field, we owe largely the growth of our Society. In honoring him by making him our President we honored ourselves by putting at the head of our organization a man who stood in the forefront of the art for which our Society stands, and as we look back at the various meetings of the Executive Committee at which Dr. Dudley presided, we see a great work well planned and well executed. When we think of occasions where petty strife and small jealousies or rivalries arose, we remember how, with the mind of the philosopher and the genius, he was able to quell all difficulties and bring order out of disorder. When we think of him presiding at the meetings of our Society, we recall how we were impressed with his knowledge of every subject presented. Whether the question related to metallurgy, chemistry, railroading, or the manufacture of paint, glass, cement, or iron and steel, Dr. Dudley was always ready with an apt question, a well-applied story or a practical illustration. Such knowledge as this on the part of the presiding officer was an inspiration to the speaker, who always felt that he had our President's sympathy and intellectual appreciation of his efforts. It was this wonderfully keen knowledge and incisive speech—always the right word at the right time—that made our meetings so interesting to all, both young and old. Dr. Dudley's love of youth, his passion for developing and uplifting minds, and his encouragement to budding genius—the prize crop of our Society—

were the kindly lights that always led the younger men forward in the work of our organization, making them feel at all times that they had a warm and appreciative friend in the chair, while to us older men he was the incarnation of sympathy, fairness and sound judgment.

Again do we look at Dr. Dudley as a President-host. No matter how high his place in our Society, he had always a kindly smile and sincere greeting for each member of our organization. His friendly and altruistic impulses were manifest in convention and informal discourse alike, just as we chanced to meet him. But above all, it was as presiding officer at our annual dinners that Dr. Dudley occupied a place peculiarly his own. Let us look back at one dinner which stands pre-eminent in the hearts of all of us, the dinner given to Dr. Dudley when he and Mrs. Dudley returned from their European trip. How full of life, of boyhood spirits, he was, how proud of his wife and of her enjoyment of our pride in him. How keen his sense of appreciation and enjoyment of the occasion, and of the assembly about him, which had gathered to do him honor and to welcome him home. Every one of us was made to feel that Dr. Dudley was our individual host, was brought almost to believe that the whole thing was in honor of each individual and not of Dr. Dudley. His enjoyment of the speeches, his genial face lighting with affection for associates and friends, we hold as among the most cherished memories of our late President.

How truthfully does his career illustrate these words of Bryant:

> "So live, that when thy summons comes to join
> The innumerable caravan, that moves
> To that mysterious realm, where each shall take
> His chamber in the silent halls of death,
> Thou go not, like the quarry-slave at night,
> Scourged to his dungeon, but, sustained and soothed
> By an unfaltering trust, approach thy grave
> Like one who wraps the drapery of his couch
> About him, and lies down to pleasant dreams."

CHARLES B. DUDLEY AS A RAILROAD MAN.

BY THEODORE N. ELY.

Fellow Members and Guests:

We have come together this evening as a sympathetic company of admirers to commemorate the distinction of our friend and fellow member, Charles Benjamin Dudley, about whose life as related to his railroad work, I have been asked to speak. I have known it from the beginning, but I can give you no just or adequate idea of its extent and importance in the limited time at my disposal.

When one through character and ability has greatly advanced his profession, it is fitting that we who knew him should join in recording our appreciation of him, and in this particular case it is our wish that Dr. Dudley through all time may be remembered as one who was foremost in proving the value of chemical research as applied to the wants and needs of a great transportation company, and the importance of bringing it into closer relations with the manufacturers and merchants of the country.

Dr. Dudley spent his entire railroad life in the service of the Pennsylvania Railroad Company, for it was in November, 1875, that he began the work that was to continue without interruption for thirty-five years; and inasmuch as at that time there was no department of railroad chemistry in this country, nor, I think, elsewhere, Dr. Dudley may be said to have been the first head of a chemical laboratory devoted exclusively to railroad work.

It will interest you to know that it was upon the recommendation of his friend, the eminent scientist, Dr. Coleman Sellers, that Dr. Dudley was employed by the Pennsylvania Railroad, and I wish to record the words of Dr. Sellers, who said, "I know just the man to organize and carry on a department of the kind you have in mind." Thus early in his career Dr. Dudley's abilities were recognized.

Now, what was that department, and what character of man did it need?

As to the department: At the time of which we speak the Pennsylvania Railroad had some little apparatus for carrying out physical tests, but it had made no provision for conducting chemical examinations. Analyses had been made occasionally by outside chemists, but the work had not reached the dignity of systematic investigation. An engineering laboratory in its broadest sense having been authorized, a department of physical tests, and one of chemical tests were decided upon, which, although separate in their specialties, should work in collaboration. The first was organized with the staff and appliances already at hand as a nucleus; the new department of chemistry was organized with Dr. Dudley at its head.

Now, as to the character of the man who could be safely entrusted with this responsibility: It was necessary that he should be honest, above reproach, loyal to the company he served, perfectly fair-minded, patient, enthusiastic, with strong initiative, and with health and strength for great exertions; it was necessary that he should have the faculty of working in harmony and in the right spirit of cooperation with other departments; that he should be possessed of ability in the selection and training of his assistants; and that he should be preeminently a student, with a facility for clear expression.

Dr. Dudley came to the service with many of these powers already proven. As a volunteer soldier during the Civil War, with honorable wounds received in action, he had given proof of his loyalty and bravery. At Yale University, where he went at the close of the war, the record he made for hard and faithful study, under financial conditions that would have discouraged most young men, won for him academic and scientific distinction, and testified to the fact that he was worthy to be entrusted with important duties.

And I will say in passing that Dr. Dudley did not make his decision to enter the railroad lightly; it was a struggle for him to relinquish the strong desire he had to make the study of physiological chemistry his specialty. But the extent and importance of the new field of endeavor, and the fact that his service would be with a railroad managed from its beginning by professional men, sympathetic with his efforts, determined his decision, and he entered upon his new work with his characteristic enthusiasm.

It should be kept in mind that the undertaking was largely an experiment, the permanency of which depended both upon the energy and ability of the man who conducted it, and upon his success in making himself a necessary part of an organization already complete in most respects. That the duties of this post had to be cooperative to a large extent, would for many men have constituted an insuperable objection; but not for Dr. Dudley.

I have dwelt at considerable length upon the circumstances connected with the employment of Dr. Dudley by the railroad company, because it should not be overlooked that thirty-five years ago the attitude of the public mind was one comparatively antagonistic and skeptical regarding the work of scientific men as applied to the practical affairs of life, and for that reason the company was fortunate in the selection of a man like Dr. Dudley, whose strong personality turned these narrow prejudices into a broad spirit of mutual helpfulness.

I doubt whether those of you who are not familiar with the needs of a railroad company appreciate the variety and magnitude of its physical requirements, and realize that almost every conceivable article of commerce and manufacture is required for its construction and operation. An endless number of questions and problems find their way to the laboratory for solution. A knowledge of physics and chemistry is constantly brought into requisition, and must be supplemented by good sense and clear thinking to meet the difficulties constantly arising, and to aid in devising new and improved methods for the greater safety and economy of operation. That the interests of the railroad may be protected, the examination of the enormous quantity of supplies purchased and consumed by it, both as to quality and fitness, is in itself a great work.

Very early in his service Dr. Dudley found that in the purchase of supplies, the certainty of obtaining uniform or suitable quality could be insured only by describing to the seller in plain language exactly what was wanted; that, again, if the sources of supply were to be multiplied, it was necessary that the Company's wants should be so stated that every seller would know he was making his offer upon exactly the same basis as his competitors; that it was necessary, also, for merchants and manufacturers to have implicit confidence in the honesty of those who inspected the purchased materials.

Dr. Dudley was upheld in his ideas, and began at once the long, painstaking and arduous development of what is now known as the "standard specification." The details of this development would be a story in itself, but I shall cut them short by saying that to Dr. Dudley more than to any other man belongs the credit of establishing the principle of purchase by specification, which is now the universal practice in this country. I verily believe that had he not been able to win the confidence of manufacturers in his sincerity and in his knowledge of his subjects, he would have failed entirely.

I am greatly embarrassed in trying to select for mention any of the many investigations that were made and the specifications that were prepared during Dr. Dudley's administration of the laboratory, for even a reference to each would unduly detain you.

The work of the chemical laboratory was begun at Altoona in a modest way, a fact which gave Dr. Dudley an opportunity to become acquainted with those with whom he was to be associated, and to familiarize himself with his surroundings, and I might add, very properly, to accustom himself to the formal character of a railroad organization. The laboratory staff consisted of himself and one or two untrained helpers, and from this beginning grew the present force of thirty-four chemists and other assistants.

During the first few months a number of relatively minor investigations were carried on. The first of these, if I remember rightly, was the study of the tallows used for locomotive cylinder lubrication. The great loss due to the rapid corrosion of the valves and other parts of locomotives had become very serious. Dr. Dudley found that by careful and proper rendering and the selection of fresh tallow the difficulty could be alleviated, and a specification was drawn that gave the promised relief. In later years the introduction of sight-feed lubricators has made the use of cylinder oil possible, but Dr. Dudley's investigation of tallows should not be forgotten, nor its importance overlooked.

It seems hardly necessary to speak to you of Dr. Dudley's great work in connection with the steel-rail problem, but it was a subject that he had very much at heart. Early in 1877 his investigations were started. Before entering upon them, however, his ever-present desire for thoroughness led him to ask permission to spend several weeks at the Sheffield Scientific School, under Dr. Allen, the better to perfect himself in steel analyses. His first paper on the properties of steel rails, read before the American Institute of Mining Engineers in 1878, was destined to attract world-wide attention. It was a very thoughtful and suggestive treatment of this most difficult subject, and was discussed with great vigor by engineers and chemists. This paper and the others that followed it have been published in several languages, and I would commend it to those of you who are engaged in research work, as a pattern of orderly arrangement and of clear deduction. Dr. Dudley's work upon this subject continued to the end. He was Chairman of the Research Committee of the Pennsylvania Railroad System's Rail Committee.

But this was only the beginning of Dr. Dudley's study of steel products. This material was being freely offered as a substitute for iron, and as one may easily imagine, the laboratory was obliged to give constant attention to the subject, for it was not easy to determine to what extent steel could be adapted advantageously to the many uses of the railroad.

One of the most far-reaching and important investigations made by Dr. Dudley was in connection with the purchase and use of burning oils. The vital question of safety in railroad operation was involved. Signal lights were apt to grow dim or to fail entirely, and a general feeling of disquietude prevailed among those responsible for the movement of trains. Dr. Dudley found that signal oils made from lard oil at the Company's own oil house gave no trouble whatever. The great difficulty was to discover why purchased lard oil should give different results. Methods for the examination of oils had not been fully developed, and those with special information were usually manufacturers, who were not quick to disclose it. But, almost accidentally, Dr. Dudley discovered in the course of his experiments that a reaction took place when acid was added to a mixture of cotton-seed oil and lard oil, and that the heat evolved was in almost exact proportion to the cotton-seed oil. The secret was out! Low-priced cotton-seed oil was being mixed with high-priced lard oil and sold for pure lard oil, so that the Company not only suffered in having unreliable signal lights, but in pecuniary loss as well. Of course, manufacturers were indignant and demanded proof. But the method of examination was not disclosed, lest it might be circumvented. The railroad company had absolute faith in Dr. Dudley's tests and determined to accept for purchase no lard oil that did not meet them. As a result it was soon possible to buy freely a pure product. There was probably no time in Dr. Dudley's official career when he was brought face to face with a more difficult situation, and I mention it now because it was a case involving not science alone but high moral courage as well.

As in the case of steel, the uses of oils for manifold other purposes received Dr. Dudley's attention. He devised a thin wick burner which could be used without a chimney for burning kerosene oil. He made a long and careful study of journal lubrication, and in connection therewith his exhaustive study of bearing metals has borne fruit a thousandfold.

I cannot let this opportunity pass without saying a word about Dr. Dudley's equally exhaustive investigations of paints and varnishes. The manufacturers were stimulated and encouraged to improve their product and methods by useful suggestions made to them by Dr. Dudley during the course of his inquiries, and the public at large has benefited greatly thereby.

I must pass rapidly over such important items as the analyses of coals and water, and the preparation of a formula for disinfectants, the manufacture of which was carried out under Dr. Dudley's personal supervision. The latter led naturally to a study of the sanitary conditions of passenger cars and their disinfection. The specifications for plushes required a long study of dyes and textures. Of course electrical matters found their way to the laboratory and specifications were issued for them. The lighting of passenger cars by the carburetor system was worked out under Dr. Dudley's direction, and, notwithstanding many prophecies to the contrary, it became a safe and useful means of lighting.

I must not fail to speak of the series of articles describing the methods used in the Pennsylvania Railroad laboratory for testing material, which were written by Dr. Dudley in collaboration with Mr. F. N. Pease, and published in the *American Engineer and Railroad Journal*, for the information of manufacturers and others interested. These articles began in 1889 and were continued through several years, and did much towards bringing about the standardization of chemical tests.

I will close this very meager reference to the activities and accomplishments of Dr. Dudley's life with the railroad, with mention of a subject that deeply engrossed his attention at the time of his death. Dr. Dudley had for many years studied the perplexing question of the transportation of high explosives by the Pennsylvania Railroad, but soon saw that it was a problem that must be treated by the concerted action of the railways, and a little later, that it must come under government supervision. Dr. Dudley individually did a prodigious amount of work in the development of a plan, which involved very delicate business and political judgment, as well as a thorough knowledge of the subject. The result was an agreement among the railways, and the adoption by the national government of laws for the regulation of this traffic, and the assignment of an eminent United States Army officer to assist in further perfecting the safeguards for the transportation of this very dangerous class of material.

And now, speaking for my official associates and for myself, I desire to pay this earnest and heartfelt tribute to Dr. Dudley's memory:

His service was of great and permanent value to the Pennsylvania Railroad Company. His activities extended beyond the bounds of the laboratory to the more general operations of the road in such full measure that in his death the Company will keenly feel the loss of his good counsel.

He has left behind him a noble heritage of honesty, fidelity, manliness and work well done. He won the friendship of every one in the service with whom he came in contact, from the highest official down and through the ranks to the man occupying the humblest position. He was a kind and generous friend to the young men and very solicitous for their advancement. A deep sense of personal grief pervades the service, and we shall ever mourn the loss of a valued friend and colleague, and an agreeable and stimulating companion.

CHARLES B. DUDLEY AS A CHEMIST.

By Edgar F. Smith.

Would that I were competent to speak adequately of Charles B. Dudley as a chemist! At the time your honorable Secretary assigned me this duty, I must confess I thought I could discharge the responsibility, for in a general way I felt myself familiar with the career of our departed friend. When, however, I began actually and seriously to study the life work of your late President, I promptly recognized my insufficiency, and realized that I could only be a pupil—a pupil, however, in perfect sympathy and accord with the thought and purpose of the master.

I recalled how, in the very earliest days of his connection with the Pennsylvania Railroad, Dr. Dudley meeting me in the University of Pennsylvania, where, at that time, he frequently visited, would often in his cheery, enthusiastic way propound question after question relative to methods of determination or analysis, or would suggest a wholly new course of procedure in the estimation of a compound or element which was then engaging his thought. To my mind, our friend was a true pioneer in his chosen field of research, as well as a shining, brilliant exponent of the idea of making his special science do service to his fellow men. That he was a pioneer is recognized in statements of his own made in 1875. Listen: "So little was the possible use of a chemist appreciated and so little work was known that he could do on a railroad, that permission to have a chemist was granted more as a concession and as an experiment than with any faith or belief that the scheme would prove to be permanent or valuable." Indeed, he wrote, "It is also fair to say that at that time the field for work was as much unknown to the chemist himself as to the railroad officers." Then, as a true pioneer and an inspired researcher he set about informing himself as to the problems which were before railroads and to discover in what ways chemistry might contribute to the solution of these same problems. The steps pursued were taken only after earnest thought and much tedious, trying experimentation; but as one follows this master mind in its workings, the mysteries are rapidly cleared away, and the unfolding and opening-up read like fairy tales. I fancy much of the vivacity and enthusiasm of our friend came from the consciousness that in his struggle with obscure and knotty questions he was surely letting in the light, gradually at first, but in the end with such brilliant illumination "that he who runs might read." He was winning out! And to him came "the joy and exultation of soul which comes from the discovery of a natural truth and the realization that the most happy and heart-filling thing in the world is to come face to face with something which no one but God ever saw before."

As a pioneer in his particular field of investigation he did not discover new bodies to which were assigned sesquipedalian names, nor did he promulgate fanciful, unstable theories. For these he seemed not to have any great fondness. He patiently tested out methods of analysis, improved or perfected them, discovered new methods, and applied old and new alike to the solution of the thousands of problems which came to him as he advanced further and further in his studies. He was a keen, exact and most intelligent analyst. In his own domain he was, indeed, the master.

To the student of the life work of Charles B. Dudley, there looms up bright and clear, upon every side, the earnest endeavor to make his science serve mankind. Witness his unceasing efforts to ascertain the proper nature of all materials in use by railroads, his efforts to eliminate every contaminating substance that would be harmful to the wholesomeness of the real substance, his care to exclude all that might, in any way, endanger the lives of those who traveled by rail, his prolonged study to contribute to their comfort and health, as well as his steady aim to associate with himself others who might aid in spreading and expanding the new ideas, bringing them into use wherever possible in the daily walks of life.

His deep, hearty interest in this Society is additional evidence of his ambition to make science and his contributions to it help you and me. His presidency of the International Association further demonstrates his purpose to have his philanthropy, for such his labors truly were, world-wide in its benefits.

When once the history of chemical science in America is written, there will be no brighter or more attractive page than that devoted to the story of the labors and achievements of Charles B. Dudley, pioneer and benefactor, of whom it may be truthfully said:

"So might I, toiling morn till eve,
Some purpose in my life fulfill,
And ere I pass some work achieve,
To live and move when I am still.

I ask not with this work combined
My name shall down the ages move,
But that my toil some end shall find
That man may bless and God approve."

CHARLES B. DUDLEY AS A METALLURGIST.

By Henry M. Howe.

He who is privileged to speak to you of Dudley the metallurgist must needs trench on the ground of the eloquent friend who is entitled to speak of Dudley the citizen, and on the ground well assigned to our fellow of the silver tongue who is to pay a personal tribute to our great leader. For Dudley was first and foremost a man, yes, a man and a prophet, and only secondarily a chemist and a metallurgist; and as a metallurgist he simply brought to bear on metallurgy those qualities which made him revered, loved, and followed as a man.

As the metallurgist of the Pennsylvania Railroad Company he had a broad field for the exercise of his powers, in studying the varied and important uses to which that vast organization puts the metals and their alloys, in adapting the material to its service and the service to the necessary limitations of the material. Among the objects and materials which he helped greatly to improve are cast-iron car wheels; cutting tools of cast iron; springs; axles; boilers; fireboxes; stay-bolts; rails; and bearing metals. Among these there are several as to any one of which taken singly his work entitles him to high rank as an adaptive metallurgist. Beyond this his studies of copper, lead, zinc, phosphor bronze, phosphor copper, and tin plate, were of great value, in leading to the improvements of specifications, and in other ways. His achievements in this one field form a life's work of uncommon value, apart from his faithful labors as a chemist, as a leader in the science and art of testing materials, and as a citizen.

But great as were the variety, labor, and ingenuity of his own direct experiments on these subjects, the wisdom, the sagacity, and the breadth of view with which he interpreted and applied his own results and those of others were of even greater value to his employers and through them to the community, the employer of his employers.

The number of excellent qualities with which every fellow metallurgist must credit him is at first almost bewildering. He was kind and more than kind; industrious, yes, indefatigable; keen; analytical; well informed; eminently fair and reasonable; receptive; clear as crystal in conception; lucid, graphic, and convincing in statement; absolutely faithful to his employers, yet just, honest, and even open to the opposing interests, to those with whom his employers bargained; original; independent; brave to the point of seeming unconscious of danger; stating his theses clearly and without shadow of equivocation, even when he stood alone and without an ally; yet so frank in acknowledging the limitations of his knowledge and the defects in his premises, that a change in his opinion because of new light rather brightened than dimmed his prestige. Withal he was so considerate of his opponents that his victories brought them no sting. With the fairness, gentleness, and chivalry of an Arthur went the strength and fearlessness of a Lancelot.

Is it possible to look on this list of admirable qualities, seeking vainly for offsetting defects, and yet to hold that these were separate and independent gifts? May we not more reasonably regard them as simply the various manifestations of a single great underlying principle, unselfishness or altruism? Was it not the direction of his vision, looking up, not down; out, not in; forward, not backward? For our own guidance I ask you now to consider this question earnestly with me.

To each of us the universe consists of two parts, first himself, second, all the rest. We naturally think of ourselves first, yes perhaps first, second, and even third, and only later and incidentally of the rest of the universe. But the prophet has the opposite point of view. In facing the problems which press on him every hour he has in mind rather the rest of the universe than his own personal interests. Whether he speaks with the trumpet of Moses, Elijah, or Confucius, in notes which echo distinguishably through all time to untold billions, or as

Dudley spoke to the men of his day and guild, it is in the same key, based on the diapason of the Almighty.

If I am right in holding that it is not the sonority but the key, not the quantity but the quality of his prophecy that makes the prophet, then he to whom our words to-night are tributary was a prophet.

From this point of view do not all of Dudley's varied qualities seem to be but necessary parts of a consistent whole, the several facets of a single symmetrical gem? Is there danger? What more natural than courage, which implies little more than that the object sought is bright in the foreground of our mental vision, and the danger to ourselves overlooked in the background? Have I to correct your error? What more natural than tact and chivalry, which after all only imply that my course is directed chiefly by the thought of the effect which it will have on you? Is a task severe? What more natural than devotion to it, zeal, industry, tirelessness, for do not all these mean simply the prominence of the task and the enshadowing of the fatigue in the mind's eye? And does not this lead necessarily first to mastery of detail, which after all calls but for labor in thought; and through this to clearness of vision and of speech, which after all call but for complete mastery of the subject; and through clear sight in turn to originality, which comes from such familiarity with the matter in hand that we see possibilities and explanations and consequences which are hidden from the superficial observer? Or, again, do your interests and wishes oppose those of another? What can ensue but fairness, which after all implies nothing but that you see willingly and weigh fairly the interests, rights, and feelings of that other; that your ear listens more willingly to your duties than to your rights? And so we could go on through the list of his merits. They are the natural results of a common cause, the generous, unselfish character.

He never preached in words: he did not need to. His whole life was a practical demonstration of that which is best worth preaching.

Even to-day men ask "Is the golden rule a workable scheme? Can we live by it in our everyday human conditions?" The question carries less of doubt, and far less of denial, than ever before; but there it stands. "Must not charity begin at home?" The life which we honor to-night has its great value in its clear and decisive answer to these questions. Who ever suspected that Dudley did as he would not be done by? Who ever questioned that his life was in the highest degree successful both for himself and his employers? He might indeed have exacted more money from the world. "Gold and iron are good to pay for iron and gold." But the happiness and elevation of such a life as his; the honor it unwittingly brought him; its guileless power, of which this meeting is but one speaking witness among a hundred which testify, eloquent in their silence —these things are no more to be weighed against money than is the life of wife or child.

We rejoice in having known him because he was what we would fain be; because he held up to us the best in ourselves, and showed us that we can live by that best: because he proved that practical worldly success of the highest kind, far from being hindered, was actually helped by loving obedience to those two great precepts on which "hang all the law and the prophets."

CHARLES B. DUDLEY AS A MENTOR.

By B. W. Dunn.

Mr. President; Ladies and Gentlemen:

My too short personal acquaintance with Dr. Dudley was limited to the last five years of his life, but during this time it was my fortunate privilege to meet him often and to discuss in affectionate intimacy subjects of mutual interest to us. My indebtedness to him, combined with the love and respect which I cherish for his memory, makes it more than difficult for me to speak of him analytically or dispassionately on this occasion.

If a mentor be defined as a mental guide, possessing a wider range of useful information and a personal magnetism strong enough to evoke with compelling force the admiration, confidence and affection of his associates, the term describes with peculiar aptness the relation of Dr. Dudley to many who now mourn his death.

We are here not simply to pay honor where honor is due, not merely to exalt the memory of a deceased comrade. It affords us some consolation to bear witness to the value of his loyal services to this Society, to the Pennsylvania Railroad, to the railway service of the United States, to the manufacturing industries that supply railway material, to the safe transportation of dangerous materials, to the legions of his friends and admirers. It is our duty to perpetuate for the benefit of ourselves, and of future generations, the uplifting force of his example. To this end it is appropriate to sketch, even though it be in skeleton form, his achievements in some one of his many activities. My personal knowledge of his work is confined almost exclusively to his efforts to promote safety in the transportation of dangerous articles.

When the statement is interpreted properly, I consider it a compliment to Dr. Dudley's memory to proclaim that, in the modern sense of the term, he was not an expert in any branch of science. He was too eager to absorb and assimilate the essential facts and principles of many professions to permit the devotion to one of that concentrated application so necessary to merit classification as an expert. An expert is necessarily narrow-minded and Dr. Dudley was anything but that.

Among the specialties in chemistry, we find the chemistry of explosives, in which a remarkable development of new facts, theories and principles, has taken place since Dr. Dudley, as a railway chemist, was asked nearly thirty years ago by the President of the Pennsylvania Railroad to investigate and define the risks that attend the transportation of explosives. He visited at that time the principal factories, witnessed tests and brought samples to his own laboratory for analysis and further investigation of their properties. He familiarized himself with foreign rules and practices and prepared a short but comprehensive set of regulations for the transportation of explosives. Previous to this time a special permit had been necessary to ship explosives by rail and it was characteristic of Dr. Dudley to recognize thus early the obligation of a common carrier to transport anything that is essential to commerce. He foresaw for explosives a rapidly expanding field of usefulness in all branches of development and construction work, and he had the courage to recommend that their transportation risks should be assumed as a public duty. The rules that he proposed in the early eighties to minimize these risks, and his subsequent revision of them, were adopted by many of the railroads in the United States, but no special provision was made for enforcing them.

By 1905 the amount of explosives offered for transportation had increased beyond even the Doctor's earlier estimates and the list of disastrous explosions during transit had attained alarming proportions. It was time for the next logical step, the cooperation of all railway lines to secure improved and uniform regulation of this dangerous traffic. A committee was appointed by the American Railway Association and Dr. Dudley was the most active member of it. He prepared for it an able technical report on the classification and characteristics of explosives and made another revision of his previous work which was recommended by the committee and approved by the Association as a set of rules for adoption by all of its members.

Another important step remained, and Dr. Dudley worked zealously to impress upon all the fact that "regulations do not enforce themselves." The committee of which he was such a prominent member secured in 1906 the approval of the Association for the organization of a "Bureau for the Safe Transportation of Explosives and Other Dangerous Articles" to be charged, in the interests of all of its members, with the inspection and the educational work necessary to enforce the regulations. This bureau was organized in November, 1906, and Dr. Dudley served as president of it from that time until his death. The bureau represented a novel experiment in railway administration. Its inspectors were not vested with any independent authority but they were given the right to inspect records and observe practices. They described the dangers, explained the rules and the reasons for them, and reported results. Any disciplinary action necessary to correct errors was taken by the officials of the line under inspection. The support given by these officials was in direct proportion to the confidence inspired in them by the inspectors.

Dr. Dudley was the solicitous mentor and the affectionate grandfather of the organization. No new step was taken without consulting him and it was seldom that any important action did not bear the impress of his wise counsel. It was evident to all that he worked for the success of this bureau as the crowning event in his extended career of usefulness. Long journeys, too fatiguing for a man of his years and state of health, were made frequently by him in its behalf and his last illness followed such a trip.

The regulations introduced by the bureau caused restrictions on both the shipper and the carrier; restrictions that increased the cost of preparing and transporting shipments. The difficulty in securing anything is proportional in some degree to the cost, and this applies especially to cooperation that is sought from naturally antagonistic elements. On more than one occasion the persuasive magnetism of Dr. Dudley's eloquence was felt in meetings of the American Railway Association, in conferences between representatives of the bureau and prominent shippers of dangerous articles, in hearings before committees of the national legislature and before the Interstate Commerce Commission. His was a disinterested plea for the promotion of public safety, the force of which was intensified by his personality.

We hear a great deal at the present time of federal regulations of interstate commerce and the subject will be of increasing interest and importance to railway officials. Whatever one's opinion may be of the wisdom of this regulation, the handwriting on the wall has been legible for some time to those willing to read it. Dr. Dudley was opposed in a general way to governmental control of railway operation, but he was quick to see the advantage of this control in the transportation of dangerous articles, and to him more than any other is due the passage by Congress in 1908 of the law that invested the Interstate Commerce Commission with authority to prescribe regulations for the interstate transportation of explosives. This advantage is not due to the possession by this commission of the technical information necessary to the framing of wise rules. On the contrary its members would be the first to acknowledge that they are lawyers as a rule and know little of the chemistry of explosives. It rests rather on the basic principle that we need some disinterested authority to adjudicate all disputes. An erroneous decision is better than none. The advocate of what is reasonable and right will secure justice from the commission sooner and with less expense than through a contest *à outrance* with his antagonist. We all know that public utilities differ materially from private enterprises and that the people, in whose hands the power rests, have decided to subject to governmental supervision the decisions of railway officials relating to rates and regulations. Those of us who are acquainted with these officials know also that their decisions are based upon their honest conceptions of equity and justice. My experience in working with Dr. Dudley to secure the cooperation of manufacturing shippers of dangerous articles to promote safe transportation has furnished abundant evidence of the willingness of shippers to submit to sacrifices when sound arguments are furnished to establish the necessity for these sacrifices. Experience has also demonstrated the wisdom, the honesty of purpose, and the unimpeachable integrity of the Interstate Commerce Commission. What better foundation can be furnished for the optimism that sees in the trend of modern events the dawn of a new era of peace and stability?

Having suffered in his younger days the disadvantages of poverty, Dr. Dudley kept a warm place in his heart for the railway laboring men. He lost no opportunity to extend his personal acquaintance with them and their problems. He attended and addressed, in the true spirit of a mentor, their various meetings, and he devoted many hours of his valuable time to the provision at Altoona of a suitable library for their use.

Speaking of the advantages of federal control suggests the unsatisfactory condition at present of the public utility labor problem. Labor organizations have done more than legislatures to curtail the authority of operating railway officials, and the day is not far distant when it will be necessary to invest a non-political and federal commission, or court, with the authority to adjudicate, and not simply to compromise, labor disputes. When this is done it should be made a criminal offense for any employee of an interstate public utility corporation to attempt to interfere with its efficient operation in public service by that collective act known in the railway service as a strike and in the military service as a mutiny. Without courts to decide on their merits the disputes of individuals relating to property rights, our land would be filled with strife and bloodshed; and yet we have made no such provision to prevent the waste of the country's energy in the struggles of railway labor and capital, struggles that necessarily involve more innocent than interested parties.

A general railway strike, that could be declared at any time by the leaders of labor organizations, would cost the country more and would disturb it more than would a first-class war of equal duration. It requires an act of Congress to declare war. Should it be possible for a greater disturbing power to be exercised for selfish purposes by a small number of our citizens? And yet who can blame the laboring man who honestly believes himself to be treated unjustly and who has no other recourse than to strike? This is an example of the class of problems that fascinated Dr. Dudley and it was an inspiration to good citizenship to note his efforts to form sound opinions. Knowledge, humility, honesty, unselfishness, perseverance, and "good will to all men" were interwoven in the fabric of his optimistic nature.

In conclusion, I cannot refrain from an illusion to his domestic life. A veritable reservoir of love and affection, fitted as few men are, to be an exemplary husband and father, it was his misfortune to live for years in domestic solitude. This added materially to his mental accomplishments, but the sacrifice to his humanity can be appreciated only by those who knew him intimately. Let us rejoice that he lived long enough not only to realize many of his ambitions, but also to enjoy for a few years at least the companionship of a wife who did all that an intelligent, sympathetic and loving woman could do to fill his last years with happiness. She is entitled to all the consolation that can come from the consciousness of a duty well done and from pride in the knowledge that at the altar of her affections the Doctor offered a pure heart and a mature mind.

CHARLES B. DUDLEY AS A CITIZEN.

By W. H. Schwartz.

The late Dr. Charles B. Dudley was related far more intimately to the municipal life of the city of Altoona than the average citizen of that town comprehends. For the greater part of his work was done so quietly and unobtrusively that few identified the man with the result. He never bothered himself about fame. By the hard work of laborious days and nights he sought results, not notoriety. Few men have done so much in so many different directions for their communities as Dr. Dudley did for Altoona. Few have been so anxious to bring things to pass and so indifferent about personal credit.

Dr. Dudley became a citizen of Altoona in 1875. He retained that citizenship until his lamented death. When he located there the city government had been in existence about seven years. The town was unkempt, the streets unpaved, the water supply insufficient, the street lighting inadequate, the annual receipts meager, the credit of the corporation poor, the pride of the people in their town practically non-existent, the school system primitive, the sidewalks made of planks, the people without the vision which must come to those who mean to win in the race for supremacy. In the generation that intervened Dr. Dudley was a part of Altoona's municipal life in a very vital sense. It would be difficult to name the promoters of the tremendous material, social, intellectual, spiritual advance that has come to the city with the passage of the years without including him as one of the number. He was always a busy man; he was charged with an arduous task; but he abounded in energy; more than to any other material thing one might compare him to a great dynamo, filled with splendid and exhaustless power, a power gladly devoted to the benefit of his fellow men, a power utterly devoid of the sordid or selfish element.

Many professional men decline to bother about the daily life of the community in which they do their work. They sniff at the practical politician and mourn over the perversity of the average voter, but neglect to do anything of practical value. Dr. Dudley was not that sort of a reformer. He knew what the city needed and he struck effective blows in the right direction at the proper time and in the wisest possible way. He sought to know every new editor, city editor or reporter who came to town. He had a habit of casually dropping into the newspaper offices or stopping newspaper men on the street, freely expressing his convictions concerning municipal or other problems. There was so much sincerity about the man, so much vitality, so much downright moral earnestness, that he became in some respects the most influential newspaper man the city possessed, although he seldom wrote a paragraph. He exerted his influence by proxy. Getting a good idea concerning some matter of local interest, he dropped it into the fertile soil of a responsive editorial or reportorial brain and lo! the work was in process of accomplishment. The power for usefulness of a busy professional man is increased manifold if he annex the people who make the local newspapers to his staff of workers. Men like Dr. Dudley not only enlarge their personal influence for good by getting into touch with their home editors, but also prove a veritable inspiration to those who make the newspapers from day to day.

The Altoona Mechanics' Library and Reading Room Association is one of the pioneer institutions of the "Mountain City." It was organized in the early 50's, some of its original officers and members having at a later period acquired international fame. Andrew Carnegie was one of the early secretaries. Dr. Dudley became interested in the association soon after taking up his work in Altoona and in 1880 was elected a director. It is not too much to say that during the rest of his life he devoted as much time and energy to the development of this institution as the ordinary man gives to his regular business. Loving books as he did with all the ardor of a scholar, and feeling that a community which keeps itself in touch with the best work of the great men and women of the ages is more likely to bring things to pass than one which seldom devotes a thought to things of the intellect, he labored unweariedly, but with great tact and wisdom, to bring the library into the conscious daily life of the people. The library was the object of his unceasing and affectionate solicitude. He spent much of his spare time in consultation with the librarian and others who were interested in the extension of its beneficent work and for years was an influential member of the committee that selected the books and periodicals annually purchased for the use of the members. During the thirty years of his identification with the library it changed its location thrice, each time occupying a larger and more commodious home; its membership increased from 98 persons to 1,445; the number of volumes on its shelves grew from 3,209 to 46,217; the methods of its administration were largely improved, so that when his connection with it ceased it was ministering not only to the intellectual pleasure of thousands of adult readers, including the aged and infirm pensioners of the Pennsylvania Railroad Company, but also to the instruction and profit of several hundred pupils of the public schools. Dr. Dudley would be the last person to claim credit for all the improvement that has taken place in the manner and methods of this great library and reading room, for he had some noble helpers who are still carrying forward the splendid work begun more than a half century ago, but it is the testimony of all who knew anything concerning his unceasing and unselfish labors in this particular section of his chosen life-work that he was the mainspring of most of the improvements undertaken during the period of his active connection with the institution. Officers and patrons will long cherish pleasant recollections of his practical labors for the enlargement of the library and the extension of its influence. For many a year to come it will enshrine his memory more completely than any other institution in the city of Altoona. The library for some years provided an annual entertainment course, consisting of lectures and concerts, each member having free admission for himself and one other. In later years this feature was discontinued and the Library Association, led by Dr. Dudley, threw the weight of its influence on behalf of University Extension, several valuable courses of lectures on instructive themes having been delivered. There was no phase of the intellectual life of the city in which Dr. Dudley failed to be a leader and an active and enthusiastic force for good. Many an ambitious boy or girl has just reason to bless his memory.

When the city of Altoona undertook to organize a local board of health nothing was more natural than the appointment of Dr. Dudley as a member. That was his first and last public office. He received no remuneration for his services, but it was entirely characteristic of the man that he gave himself utterly to the work of organizing the board, creating rules and regulations and working long hours to educate the people to protect themselves and their households by personal precautions. When an epidemic of small-pox visited the town he worked with all the energy of his body and mind to prevent its spread and end its ravages at the earliest possible moment. While he retained membership on the board he was its chief reliance. His knowledge and his wisdom were depended upon by his associates and they were freely and gladly given. Altoona to-day has one of the most efficient boards of health in the commonwealth. The influence of Dr. Dudley was a potent factor in producing this efficiency, and nobody more surely than the existing board realizes that "he being dead yet speaketh." What he did to decrease the annual rate of mortality or to promote the comfort and health of the inhabitants will never be fully known.

His services as a member of the board of health were supplemented by invaluable assistance to the friends of progress in the battle royal over the proposed enlargement of the city water supply in 1891. Situated directly under the shadow of the Alleghenies, the city of Altoona is so near the sources of the streams furnishing her water supply that the problem of securing an ample quantity had become a very urgent one. The rapid growth of the town, together with the wasteful methods employed, made it manifest that the small reservoir then existing at Kittanning Point would have to be supplemented by a much larger supply. The suggestion that a larger reservoir be constructed at Kittanning Point was taken up by the progressive citizens, of whom Dr. Dudley was a leader. Bitterly antagonized as the project was by a powerful interest, the timely services of the Doctor by way of collecting facts and putting arguments into the mouths of the newspaper men who favored the proposition, aided mightily in turning the tide of public sentiment in its favor.

Wisdom is justified of her children. Only those who passed through the bitter controversy which raged about the proposition to construct the great reservoir can realize the fierceness of the struggle. All the newspapers save one were arrayed against the plan; a powerful combination controlled the city councils for a time and succeeded in delaying action; plausible arguments were presented to the common people against the project. Ridiculous as they seem now, in the light of experience, they had influence then, and if the friends of the proposed method of increasing the water supply had been without the earnest and enlightened aid of men like Dr. Dudley the city would have been dwarfed in its physical progress and greatly harmed. A man of knowledge concerning the very problems involved in this urgent controversy, Dr. Dudley spared neither time nor labor in the preparation of an array of impregnable arguments which were duly presented to the people, both in the form of handbills and by newspaper articles, so that when the vote was taken upon the proposed loan, providing funds for the construction of the reservoir, the people voted "yes" by a very decisive majority. The reservoir has fulfilled the fondest expectations of its friends, so that the citizens of Altoona have on two separate occasions since voted sums of money aggregating $600,000 for the construction of a very much larger reservoir to be known as Lake Altoona and now in process of construction. So completely have the predictions of Dr. Dudley been realized concerning the practical utility of the impounding reservoir that not a whisper of opposition or criticism has been heard since, and the latest reservoir project has received pretty nearly unanimous support. The result of this controversy shows the immense value of such men as Dr. Dudley to the communities in which they live. He was always a busy man. He might have immersed himself in his special work and permitted municipal matters to drift. Many do. But he was not built that way. He possessed a peculiarly unselfish mind. The voice of duty was to him the command of God. He was not disobedient to the heavenly vision. He spoke out of an abundance of knowledge in a very practical manner and at the right moment. Speaking as one having authority, his speech had power, so that mighty results were accomplished.

A man like Dr. Dudley was inevitably interested in the public school system of his city. He never served as a school director, but he was always profoundly interested in the personality of school officers, whether directors or superintendents. He was a good friend to the aspiring teacher and was glad to do what he could to help that teacher gratify any laudable ambition. He was fertile in practical suggestions to superintendents and teachers concerning possible improvements in methods of instruction or administrative policy, and the boys and girls who really wanted to know never had a better friend than he. In this important field of endeavor, too, he found time at irregular intervals or in crisal hours to discuss the situation with newspaper people, displaying his customary breadth of view and comprehensiveness of vision. Here, too, he was as quiet and retiring as in other matters, pushing his ideas to the front but concealing his personality.

In the realms of practical progress the Doctor was a true helper of his city. He was one of the promoters of the City Passenger Railway enterprise which started as a horse line before the wonders of electric progress had begun to dawn upon the country. He was a director of that primitive enterprise and one of its most active friends until it was transferred to other hands. He had great faith in the future of Altoona and possessed property in the city and vicinity. In the city's social life he was by no means an unimportant factor, finding time in some marvelous manner for participation in more than one important social function and having been a member of the Altoona Tennis Club, the Altoona Cricket Club and of the Juniata Club, a strong social organization which flourished for some years. At the disbandment of the latter he was instrumental in having the surplus funds, about $1,000, given to the Altoona Hospital, another of the city's institutions in which he ever displayed a marked interest. In fact there does not seem to have been any important phase of the city's life in which he did not play an important part. In the lives of his fellow men he was also deeply interested, and scarcely a day passed that did not find him quietly doing a substantial service to a workman who at the moment needed just such help as he knew Dr. Dudley would gladly render to any who needed a friend.

Let me briefly sum up the relation of Dr. Dudley to the life of the city in which he resided for the greater part of his active life:

First: He was a very busy man, charged with the performance of important and intricate duties for a great corporation; and yet there was never a time when he was so busy that he could not spare a part of his time for the public good.

Second: The nature of his professional duties involved the expenditure of much time and thought; but the problems confronting the city were never so complex that he declined to consider them.

Third: As a director of the Altoona Mechanics' Library and Reading Room he constantly exercised a potent influence upon the intellectual life of the people. This was reinforced by his activity in University Extension work and his interest in the public schools.

Fourth: He constantly kept in touch with the newspaper men of the town. He never bored them, never stayed long enough to become a nuisance. His suggestions were put in an attractive way and bore fruit in stimulating articles which reached the people and caused them to think.

Fifth: In every crisal hour of the city's life he was ready to take off his coat, roll up his sleeves and go to work on behalf of the right. And because of this splendid trait he impressed his ideas upon his fellow citizens and brought things to pass.

Sixth: He was always interested in municipal politics, never as a partisan, always as a patriot. His influence was constantly exerted in the direction of better municipal government.

Under the circumstances the death of Dr. Dudley was a positive calamity to the city of Altoona. It was a far greater bereavement than the rank and file knew, for he accomplished results so unobtrusively and so largely through others that the real man was quite unknown to the generality of citizens. In most respects his life as a citizen of Altoona is one which can be commended unreservedly to the close imitation of his professional brethren. Too often they lack in that zeal, that devotion, that ardor for the city in which he excelled.

Because of the largeness of the theme and the time limit, no reference has been made to the activities and the splendid example of Dr. Dudley as a citizen of the commonwealth and the republic. Here also patriotic endeavor marked his career.

May his like increase!

CHARLES B. DUDLEY—A PERSONAL TRIBUTE.

By Robert W. Hunt.

The duty of closing this series of eloquent and affectionate tributes to the memory of our loved friend and fellow member falls to me. Others have spoken of him as railroad official, chemist, metallurgist, mentor, and citizen—my poor words are to be a personal tribute. I would that the gratifying task had been entrusted to some one better equipped than I, but, while my lips may lack power to express in fitting words the affection of the heart, I know that no one could feel more sincerely the high meed of praise and love which should constitute such a tribute.

Dr. Dudley's life was one of varied experience and many sides. His character was rugged, and yet he was so constituted that, while never losing sight of the desired goal, and never straying from the straight road leading to it, he could, at the same time, smooth the difficulties of the way by the sweetness of his persistency; which was ever present as evidence of his manifest honesty, and yet tempered by charity for, and magnanimity toward those who differed with him. His many years of experience in his official railroad capacity brought frequent opportunities for the exercise of such attributes, and that school prepared him for the duties incident to the Presidency of our Society. And it is undoubtedly true that without the exercise of such characteristics, and the great amount of time given to its affairs, its successful formation and subsequent useful life would have been impossible . When the Society was first formed, it was generally feared that it would become a manufacturers' organization, and therefore it was with hesitancy that others gave to its deliberations and recommendations unprejudiced consideration. I doubt if there was another man under whose leadership the Society could have so quickly been made successful. Dr. Dudley's whole business career had been as the representative of the consumer, yet he had always made manifest his endeavor to be fair to the maker. Hence the confidence which both sides had in him. There might be, and often were, differences of opinion, but never doubt of intelligence or honesty of purpose.

His country's call came to him while yet a boy at school, but the response was prompt, and he enlisted to play a man's part in the greatest and bloodiest drama of all time. He enlisted at the age of twenty as a private in the One Hundred and Fourteenth Regiment, New York Volunteers, and gave about three years of service, taking part in seven battles, and enduring many hardships. In the battle of Opequon Creek, fought on September 19, 1864, he fell severely wounded by a bullet.

He offered all he had upon the altar of his patriotism, and gave of his life's blood that the nation might live. His wound rendering further service impossible, he went back to his studies, and to bear to the grave the bullet and the lameness which was his greatest decoration of honor. That crippled youth did not return to enjoyment of petted adulation and ease—far from it; it was to take up a bitter fight against restricted means that he might complete his education, and in spite of every obstacle and the lost time, he with characteristic persistency could only be satisfied by a thorough education. He won, as he always did; and, instead of coming from the conflict soured and embittered, he emerged with a developed, mellowed, charitable, and most lovable character—"With malice toward none, with charity for all." Was he not worthy of all good things which could come to him?

There have been in the history of American technical societies but few such incidents as this to-night, and all of them have been held in the honor of not only intellectually great, but of also lovable men. They require response from deeper, warmer feelings than can emanate from the mere intellect. Love must call —and to-night our love answers.

Dr. Dudley was an honored and active member of over sixteen scientific societies of both this country and Europe.

His contributions to their papers and discussions were numerous and always of forcible value. He only spoke when he had something to say, and then said it well. How fortunate it was that his European trip of last year as our representative should have brought him the honor which he no doubt regarded as one of the greatest of the many which had come to him. Indeed "he died full of honors."

We cannot again in this life listen to his hearty greeting, feel that warm clasp of his firm hand while looking into those honest, kindly eyes. The knightly spirit has preceded us across the border into the great unknown; but we believe, we know, that the best of whatever is there, is now his. The parting came for us all too soon, and if so to us, his friends, what to that dear comrade of his, who made his later years so happy? Their life together was short, but oh, so happy, and what a blessed inheritance of respect and love he left to comfort her!

He was called while yet in the full power of his great abilities, with his whole being in sympathy with the duties of his life and love for his fellow men. After all, is not such the best time to go?

The sad parting came amid the shadows of the evening of the unknown, but, as certainly as there is a great and most just All-Powerful One, shall we in what will be to our lost one but a little while, be greeted by his bright and joyous spirit in the glorious morning of our everlasting day.

RESOLUTIONS, MINUTES AND ANNOUNCEMENTS
ON THE DEATH OF
CHARLES BENJAMIN DUDLEY

ANNOUNCEMENT IN THE PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

DECEMBER 28, 1909.

We have received from Philadelphia the painful news that our honored President, Mr. Charles B. Dudley, passed away on the twenty-first instant.

Scarcely three months have elapsed since the Congress, amidst general enthusiasm, elected this much esteemed researcher to the highest position of honor in the gift of the Association, and since Mr. Dudley undertook this difficult office, full of confidence and vigor for work. His whole life had been spent in testing, he said, in the simple words of thanks addressed by him to the meeting, and now as he was approaching the end of his work, the Association had conferred upon him the Presidency of their body, which he could not but regard as the greatest honor that had ever come to him.

It is a tragic stroke of fate that the old researcher, whose name will ever remain honorably inscribed in the annals of technical science, only enjoyed for so short a time the high distinction thus bestowed upon him by the fellow experts of his profession from all countries of the world.

For the Association itself it is indeed a most serious loss, that the work of the newly elected President should come suddenly to so abrupt a conclusion. From the moment when Mr. Dudley accepted the difficult office of President, he set to work with positively youthful ardor, to smooth all paths, so as to facilitate the future development of the Association, to make the attainment of its great aims possible, and to ensure the success of the coming Congress.

As a prominent researcher, as a clear-sighted and untiring worker, and at the same time as a man both of touching goodness and of that fine simplicity which recalls the great men of American tradition—as such, the late President will continue to live in the memories of all who had the happiness of knowing him.

The Association will always hold him in grateful remembrance.

RESOLUTIONS ADOPTED BY THE COUNCIL OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

FEBRUARY 5, 1910.

The Council at their meeting in Frankfort on Main give expression to their feelings of sorrow at the heavy loss suffered by the Association through the death of their revered President, Dr. Charles B. Dudley, who was recently elected amid general enthusiasm.

The Council mourn in the deceased an indefatigable and successful researcher in the domain of Testing Materials, and at the same time a man of the finest heart and noblest nature.

In order to show some open token of veneration and to keep alive the memory of Dr. Dudley as a researcher among the international circles of the Association's members, the Council have resolved to publish in their tri-lingual Proceedings, a Memoir, which besides a biographical sketch will also contain a critical appreciation of Dr. Dudley's works and writings.

FROM THE PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

February 10, 1910.

At the time the present papers were being printed, we received the very sad news that Dr. Charles B. Dudley, whose election as President had been so unanimously welcome, had died at Altoona, on December 21, after only a few days sickness.

Dr. Dudley was born on July 14, 1842, at Chenango County, New York. His first studies were conducted at the local school and academy. He volunteered for service in the American Civil War, and was dangerously wounded in one of the engagements. At the close of the war he went back to his studies, but was compelled to interrupt them for a time, in order to do journalistic and other editorial work, with the object of acquiring sufficient funds to follow the courses at Yale College. He devoted most of his time to the study of chemistry and graduated as Ph.D. in 1874.

After one year spent as assistant in the physical laboratory, University of Pennsylvania, Philadelphia, he entered the service of the Pennsylvania Railroad as chemist. In that position he worked for the last thirty-four years—a period of most fruitful activity—at testing materials embracing the whole of the requirements of the Pennsylvania Railroad. He was the pioneer in America in regard to the institution and regulation of testing methods; his work formed the basis on which were established the specifications for the supply of material of all classes and the improvements carried out in the manufacture of such material. He had become one of the most prominent technical experts in America, and his work received the approbation of the whole world; in this connection his researches on the relation existing between the physical and technical properties of rail steel and on the wear of steel rails, deserve a special reference, seeing that they are standard works which form a lasting record of considerable technical value.

The laboratory of the Pennsylvania Railroad offered to Dr. Dudley a wide field for research; his experiments played a most important part in the testing of materials throughout North America. For a long time he had been at the head of the powerful American Society for Testing Materials and had been deeply interested in working for the international unification of methods of testing. His appointment as President of our Association could therefore be considered as a crowning distinction, since the whole of his life had been devoted to testing. One of the results of his appointment would have been to allow him the most pleasing opportunity of extending his views and his great experience over an international field, to the great furthering of the cause of our Association for which he had always shown the greatest regard.

His death has destroyed all these hopes; it is a most severe loss to the International Association and to the problem of material testing.

Nor is it in technical circles, or on account of technical interest alone, that this is felt. Through the death of Dr. Dudley the world has grown poorer by the loss of one of its noblest, one of its greatest-hearted men.

MINUTE ADOPTED BY THE EXECUTIVE COMMITTEE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS.

JANUARY 17, 1910.

ADOPTED LATER BY A RISING VOTE AT THE ANNUAL MEETING OF THE SOCIETY.

Let us record at once our deep grief and our deeper gratitude, our grief indeed at the loss of a great leader and dear friend, but above all our gratitude that we have had the privilege of being led.

Such measure of usefulness as our Society has had it owes in very large part to that leadership. Here was a most rare combination of qualities, the sterling, the intellectual, the human, the judicial, each on a high level, all combining to form a character, a personality, whose like we shall not look upon again.

With a clear head to see the world's needs, to part the essential from the accidental and the merely concomitant, went the skillful and persuasive tongue to make clear to the rest of us what he had first made so clear to himself. With these went the perfect fearlessness, apparently even the unconsciousness of either danger or fear, which made him lead on where others would have flinched. With these again went his calm, clear, good judgment, which seemed to tell him spontaneously which among the good things that needed doing were the most worthy of being done, and what were the best and surest ways of doing them.

With all these admirable qualities went that which was necessary to the accomplishment of his high purposes, his kindness of heart, his sympathy, and his tact, which made us all his allies in what he undertook. Had he a proposal? Our affection and veneration for him made us almost its advocates before it was unfolded. Its intrinsic wisdom, and the clearness with which he expressed it, found an audience ready, almost anxious, and certainly expecting to be convinced.

Great as were his tangible works, his greatest was the imponderable. Standing on a high platform, his call raised us toward his level, all the more effectively because of his complete unconsciousness of his own height. We who have known and loved him are for that knowledge and that love the better and the higher—how much, ah, who shall say?

MINUTE ADOPTED BY THE BOARD OF DIRECTORS OF THE PENNSYLVANIA RAILROAD.

JANUARY 12, 1910.

In noting on its minutes the death of Dr. Charles B. Dudley, at his home in Altoona, on the evening of December 21, 1909, the Board desires to make record of the close of a brilliant career of over a third of a century in the service of the Company.

With Dr. Dudley's coming to Altoona, in November, 1875, was inaugurated a system of scientific tests of the materials used in railroad operation which has been productive of far-reaching results, both in the adaptation of manufactured products to the uses for which they are designed and in the establishment of standard working specifications, based upon accurate chemical analyses. These have gone far to secure the safety and efficiency of railway traffic, and have fortified the lessons of experience by such reliable data that they have aided largely in making the railroad profession one of the most vital of all in the development of industrial progress.

Dr. Dudley's life was devoted to the solution of the problems in which every man who travels on a railway has a personal interest—the construction of rails suited to resist hard wear, and, yet, not liable to fracture; the lighting, heating and ventilation of passenger cars; the construction of wheels and axles; the analysis of coals and oils and their comparative values for railway purposes; the examination of water supplies, both for boiler and drinking purposes, and many other kindred subjects. One of the last and most important questions which was satisfactorily developed by him was the transportation of explosives and other hazardous materials, and the adoption of safeguards in their manufacture which materially diminish the dangers that have heretofore been connected therewith; and to his intelligent and convincing statements and efforts to and with

Committees of Congress is largely due the enactment of the Federal law regulating the transportation of explosives.

His exceptional ability in connection with these and like subjects was acknowledged by institutions of learning all over the world. He was a member of many of the most important engineering and scientific associations, and the executive officer of several especially devoted to the matters in which he was such a recognized authority.

His personal traits won for him affection and regard. With all his ability he was unostentatious and simple in manner and speech. His friends were knit to him by the strongest ties, and among his associates he was universally beloved and honored.

His death came after a brief illness, but he leaves behind him a thoroughly established department of research and investigation, which will long show the touch of a master hand, in effective work for the Company, while those who knew him personally and officially will not cease to recall his kindly manner, helpful advice, and enduring devotion to the interests confided to his charge.

MINUTE ADOPTED BY THE COUNCIL OF THE AMERICAN CHEMICAL SOCIETY.

ADOPTED LATER BY A RISING VOTE AT A GENERAL MEETING OF THE SOCIETY.

In the death of Charles Benjamin Dudley, which occurred on December 21, 1909, the American Chemical Society has lost one of its most valued members, whether measured by the length of association with its affairs, by the wisdom and helpfulness of his counsel, or by his loyalty to its interests.

The Council of the Society desires to record its sense of deep appreciation of the services rendered to the Society by Dr. Dudley, both as a member from the time of its organization, as a long-time member of its Council and Board of Directors, and as its President.

By his professional accomplishments, especially in the field of applied chemistry, and in particular by his successful efforts to place the business relations between manufacturer and consumer upon an intelligent, accurate and equitable basis, Dr. Dudley had won an enviable renown, fully recognized by the Council. This success was largely made possible by his high integrity, his quiet sense of equity, his courage in maintaining a carefully formed opinion, and his uniformly lovable character—traits which also endeared him to all his associates, to whom his death brings a sense of personal loss.

The Council of the American Chemical Society votes, therefore, to spread this entry on its minutes and to extend its deep sympathy to the members of his family in their days of sadness.

ANNOUNCEMENT OF THE DEATH OF CHARLES B. DUDLEY AT A GENERAL MEETING OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

After the formal announcement of Dr. Dudley's death, the Secretary, Dr. Raymond, stated that a biographical notice would appear in the *Transactions* of the Institute, and continued as follows:

"I cannot make even this formal announcement without a word of witness to our love and admiration of one who was for more than thirty years a member of the Institute, whose presence at innumerable meetings was a delight and inspiration, and whose work contributed to its publications some of their most brilliant and profoundly important pages. In my more detailed notice of him, I shall emphasize, among other features:

"First: The demonstration which he was among the first to furnish in this country, of the value of scientific aid to business enterprises.

"Second: The method of that demonstration, which proceeded from his own versatile and sympathetic character, and consisted in that tactful combination of practical application with analytical research.

"Third: The fraternal spirit which put the results of his labor unreservedly at the disposal of his colleagues, and wasted no time in vindicating his own priority or originality. Dudley realized that he could discover two new things with the time and energy required to fight for recognition as the past discoverer of one.

"Fourth: The unfailing sweetness, cordiality and victorious joy of his temperament; he loved the world, he loved his work, he loved his fellow men, and we loved him.

"Finally, let me venture to depart, perhaps, from the tone of a professional memorial, and to say for those of us who knew him long and well that we rejoiced unspeakably when, late in life, he married a woman whom he loved. We saw how that experience renewed his youth, we saw upon his face the one last touch of charm—the signal of a heart fast anchored in a happy home. And we offer, with our praise of him, our sympathy and our congratulations to her whose affection added flowers to his laurels."

MINUTE ADOPTED BY THE TRUSTEES OF THE CHEMISTS' CLUB, NEW YORK.

In learning of the death of Dr. Charles B. Dudley, the officers and members of the Chemists' Club have realized that this was truly a personal loss to each one of them; that it meant the disappearance from their ranks of a figure long devoted to their cause, once prominent in their councils, and always sympathetic with their highest aspirations; that it signalized the end of a career which had been marked throughout by the highest love of country, the noblest devotion to truth and the most lovable traits of cheerfulness, helpfulness and thoughtfulness for others.

It is ordered that the Trustees of the Chemists' Club express to Mrs. Dudley their most sincere sympathies; and that these expressions of sympathy for her and unfailing esteem for Dr. Dudley's memory be entered upon the minutes of the Club.

MINUTE ADOPTED AT A MEETING OF THE BUREAU FOR THE SAFE TRANSPORTATION OF EXPLOSIVES AND OTHER DANGEROUS ARTICLES, OF THE AMERICAN RAILWAY ASSOCIATION.

In the death at Altoona, Pa., December 21, 1909, of its President, Dr. Charles B. Dudley, this Bureau has sustained an irreparable loss that is shared by all of the important organizations of scientific and professional men of which he was a member, and by the railway service of this country of which he was so distinguished an ornament and to which he contributed so liberally and unselfishly the fruits of his exceptional knowledge and experience.

A very prominent place, among the many activities of his busy life, should be assigned to his successful efforts to promote the safe transportation of dangerous articles, a work that engaged his attention for more than twenty years.

His activities in this line were extended to the entire continent when he became a member of the Committee on the Safe Transportation of Explosives and Other Dangerous Articles of the American Railway Association on its formation in April, 1905, and was of absorbing interest to him during the later years of his life. In the tentative work of the committee he was authorized to obtain authoritative data as to the classification and characteristics of explosives manufactured and offered for shipment, heading a sub-committee of experts of the highest reputation, which presented a most complete and able report. This report laid the foundation of the structure upon which the Regulations for the Safe Transportation of Explosives were formulated as approved by the Association in October, 1905, and this led to the formation of the Bureau organized to carry the rules into effect of which he became the President November 21, 1906. His thorough knowledge of the subject and his signal ability to use that knowledge were potent factors in overcoming whatever opposition existed in enlisting the hearty support of shippers of explosives in their enforcement and in securing the endorsement and cooperation of Congress and the Interstate Commerce Commission.

While we can no longer have the benefit of his clear judgment and wise counsel to guide our action in specific cases, those who have been associated intimately with him in the work of the Bureau will never cease to profit by his living example of loyalty, industry and integrity, nor will they forget the encouraging and elevating influence of an optimism that was a prominent characteristic of his nature and that paved the way to his most signal successes as a leader of men.

MINUTE ADOPTED BY THE EXECUTIVE COMMITTEE OF THE ENGINEERING CLUB OF ALTOONA.

In the death of Dr. Charles B. Dudley, the Engineering Club with the entire community mourns the loss of a true friend.

His interest in the welfare of this and kindred organizations was broad and a source of most helpful inspiration.

He was very courteous and approachable and ready to render every assistance to the Club and its members individually.

His place among us must forever remain vacant. His memory will always be most affectionately cherished.

ACTION TAKEN AT THE ANNUAL CONVENTION OF THE MASTER HOUSE PAINTERS' AND DECORATORS' ASSOCIATION OF PENNSYLVANIA.

REMARKS BY MR. JOHN DEWAR.

"Mr. President, I would ask that the delegates to this convention rise on their feet and with bowed heads remain standing for a period of time to give expression to their deep regret for the decease of Dr. Dudley and as an expression of sympathy and condolence for his widow. In Dr. Dudley the paint industry of the United States and Europe has lost one of its ablest exponents, a man who stood high in the estimation of the great company that employed him, a man who stood high in the esteem of all paint men whether manufacturer or master painter; a man whose wisdom and kindness was many times at the disposal of this association."

With tacit understanding of the situation and without the formality of a vote, at a signal of the gavel the convention rose in silent honor.

RESOLUTIONS ADOPTED BY THE FOREMEN'S ASSOCIATION OF ALTOONA SHOPS, PENNSYLVANIA RAILROAD.

Resolved, That in the death of CHARLES BENJAMIN DUDLEY this Association has lost a member noted at home and abroad as one of the greatest chemists of the country; and further

Resolved, That in his relation with his fellow members, his genial disposition and charming personality, he endeared himself to all who knew him and that the Association was honored by his membership and mourns his untimely death.

For a period of thirty-four years he was "chief chemist to the greatest railroad on earth;" was identified as a member or as presiding officer with numerous learned and scientific bodies in this country and in Europe; was so intimately connected with the Altoona Mechanics' Library that by his indefatigable zeal he made of it one of the best libraries in the State.

Therefore, It is fitting that we, his associates and fellow workers with the Pennsylvania Railroad, express our sense of loss and our sympathy with his bereaved widow, by placing this minute on the books of the Association and presenting her with a copy in engrossed form.

RESOLUTIONS ADOPTED BY THE BOARD OF DIRECTORS, ALTOONA MECHANICS' LIBRARY AND READING ROOM ASSOCIATION, ALTOONA, PA.

Whereas, Dr. Charles B. Dudley has been a Director of the Altoona Mechanics' Library and Reading Room Association for almost thirty years, and

Whereas, During almost all those years he has been Chairman of the Library Committee, whose duties were, in connection with the Librarians, to select all new books, arrange for subscriptions to periodicals, etc., and

Whereas, Dr. Dudley took an unusual interest in all the affairs of the Association, giving it a great deal of time and thought, and

Whereas, Through his efforts the Library has grown into an institution of considerable importance in the community and is recognized as a railroad technical library of very high standing, therefore be it

Resolved, That in the death of Dr. Dudley this Board has lost a sympathetic friend, an unflagging co-worker, an honorable associate and a wise counsellor. He always took the most intelligent interest in the work of the Association, having a clear and practical grasp of its aims and needs, and was at all times able and willing to carry out its purposes. Further be it

Resolved, That these preambles and resolutions be spread upon the minutes of the Association and that a copy be sent to Mrs. Dudley by the Secretary.

SELECTED EDITORIALS AND PRESS NOTICES
ON THE DEATH OF
CHARLES BENJAMIN DUDLEY.

FROM THE YALE ALUMNI WEEKLY.

EDITORIAL, DECEMBER 31, 1909.

AN IDEAL YALE LIFE

Forty-two years ago there entered Yale a Freshman much older than his mates of the Class. He had served in the Civil War and bore from it honorable scars. After furnishing roughly his North College room he had left cash resources of five dollars. With some College aid he earned his self-helpful way through the four years. He won undergraduate honors, literary and scholastic. After graduation, taking up chemistry as a profession, he rose to be the head of the chemical department of a great railroad corporation, discovered tests of certain obscure adulterants which saved his company—and others—untold thousands of dollars, and was honored by many learned societies. Not many years ago he sent back to the University Treasurer a sum representing with full interest the money received directly or indirectly from the College when he was an undergraduate. A few days since he passed the Great Divide to join on the other side the noble Yale host starred in the catalogue. Patriotism by its supremest test, self-reliant quest of learning, high service of his generation, and the final tribute of gratitude to his educational mother, unite to create an ideal type of man not less impressive because he is here unnamed.

EXTRACT FROM THE JOURNAL OF THE FRANKLIN INSTITUTE.

JANUARY, 1910.

The death of Dr. Dudley marks the completion of the life-work of an engineer whose services to the profession have been of the greatest value, both commercially and with respect to its scientific progress. The profession owes him a large debt for the thirty-four years during which he was chemist for the Pennsylvania Railroad, in which capacity he not only rendered invaluable service to that corporation but also to the profession at large by the publication of the results of many investigations. . . . .

His versatility and appreciation of the many sides of questions connected with railway practice are attested by the number and value of the papers he contributed to the technical press and presented to the various technical societies with which he was identified. . . . .

It is not alone as a technologist in the foremost rank of applied science that he will be recalled among his numerous friends; his admirable qualities of character will leave an even deeper impression in the minds of all who knew him than will his many professional attainments and achievements.

EXTRACT FROM THE CEMENT AGE.

JANUARY, 1910.

The announcement of Dr. Dudley's death was received with deepest sorrow by his many personal friends and members of the various technical and scientific bodies with which he was associated. . . . .

While a man of great determination and perseverance, Dr. Dudley had sincere respect and consideration for the views of others, and this good quality won for him the esteem and respect of all his fellow workers in the domain of science. His enthusiasm for experiment and research was controlled by a thoroughly practical temperament, which gave his work the highest value. He was the leading spirit in the formation of the American Society for Testing Materials, and took an intimate interest in all the details of its work. His recent election to the presidency of the International Association for Testing Materials was universally accepted as well-deserved recognition of his ability and worth.

EXTRACT FROM THE ENGINEERING RECORD.

DECEMBER 25, 1909.

In carrying on his researches and in making their results useful to his Company, Dr. Dudley built up a reputation of a most unusual kind. He was very careful about expressing definite opinions, but when he had reached such a point in his work that he was willing to say that probably such and such a thing would be found true, everybody else was convinced of its correctness. At a dinner in Atlantic City last summer he expressed his scientific creed clearly in the statement that he did not believe in doctoring the results of an analysis so they would add up 100 per cent., for in the study of the causes of minute errors would often be found lessons of deep value. He was a vigorous fighter for what he considered right; it took a man of the strongest moral courage, the keenest appreciation of public responsibility and the highest type of technical knowledge to fight as he did a few years ago for decent steel rails. At a time when neither the higher railroad officials nor steel mill directors appreciated how rails had deteriorated, he spent his last ounce of strength to protect the traveling public. The story of that long struggle will probably never be told; Dr. Dudley never revealed his part in it. But his friends who saw the sacrifice of strength he was making, in his old age, for a public that would never know of it, were able to appreciate all the better the stories they had heard of his gallantry on the battlefield.

The American Society for Testing Materials absorbed a large part of the time not devoted to his regular duties. He was its President for many years, and in this capacity prepared a series of valuable annual addresses on what may be called the ethics and practice of specifications and tests of materials. He also took an active part in the discussion of this and other societies, and was only recently elected President of the International Association for Testing Materials. This and other honors were deeply appreciated by him, but for the marks of distinction which appeal to the business man he had absolutely no regard whatever. Last winter he spent a great deal of time in Washington, calling on Congressmen and men of influence in public affairs, in aid of legislation reducing the hazard of transporting explosives. It was a severe strain on his strength, but he carried his point at last and went home happy in the knowledge that he had won one more victory for safety on railroads. Probably nobody would have ever heard of Dr. Dudley's work in this line had not Colonel Dunn insisted that it should be made public, for the result, and not the credit of producing the result, was all that Dr. Dudley cared for.

EXTRACT FROM THE ENGINEERING NEWS.

DECEMBER 23, 1909.

While Dr. Dudley was primarily a chemist, his work brought him in touch with a large range of engineering activities, and he became well known throughout engineering circles. In practical original research leading to industrial developments he bore a foremost part, and he received high honors from the scientific and engineering societies with which he was connected. . . . .

In personal qualities Dr. Dudley was a man of the most genial and sunny disposition. He went through life making friends at every turn, and even those whom he had to oppose in his professional work were compelled to respect and honor his fairness and friendliness. A few years ago the Pennsylvania Railroad Company, in view of Dr. Dudley's long and valuable services, relieved him of the official responsibilities he had so long carried, so that he has had liberty to carry on such work as he chose and enjoy foreign travel. In our issue of January 28, 1904, at the time of Dr. Dudley's election to the presidency of the American Society for Testing Materials, we published a portrait and full biography of Dr. Dudley. That biography closed with the sentence "Dr. Dudley has never married." It is pleasant for his friends who appreciate his sweet and lovable disposition to know that not long after that time Dr. Dudley was very happily married, so that the last years of his life were made pleasant in the comfort of his own home.

EXTRACT FROM THE IRON AGE.

DECEMBER 30, 1909.

Among Dr. Dudley's contributions to engineering progress, by no means least is his service as President of the American Society for Testing Materials in the past seven or eight years. His remarkable presidential addresses on the philosophical and scientific sides of the testing engineer's work are classics in testing literature. Attendants at the annual meetings of this society know well how Dr. Dudley's wide experience and his willingness to put it at the service of others proved the very life of many a discussion. His ability to draw out discussion was also marked. Without detracting in the least from the excellent work of others, it may properly be said that Dr. Dudley's personality has been a pillar of strength to this organization, and that his loss will be keenly felt in its councils.

EXTRACT FROM THE IRON TRADE REVIEW.

DECEMBER 23, 1909.

Dr. Charles B. Dudley, chief chemist of the Pennsylvania Railroad, died Tuesday, December 21, at his home in Altoona, Pa. As a testing engineer he won international fame, and through his skill and rare judgment Pennsylvania specifications have become noted throughout the railroad world, where they are to-day largely accepted as standards. To him a large measure of credit is due for the rapid advancement of the American Society for Testing Materials to a position among the foremost technical societies of the world. At the time of his death he was president of this organization, and had served in that capacity almost continuously since its formation. . . . .

It would be difficult to name an engineer who had a greater and more varied experience in the testing of materials than Dr. Dudley. He was called upon to test and pass judgment upon the quality of nearly all of the materials employed by one of the greatest, if not the greatest railroad in the world, involving an expenditure of millions of dollars annually. It was said of Dr. Dudley that he had no acquaintances—only friends, and to have known him was to have loved him.

EXTRACT FROM THE RAILWAY AND ENGINEERING REVIEW.

DECEMBER 25, 1909.

By the death of Dr. Charles B. Dudley, consulting chemist of the Pennsylvania Railroad, and president of both the American Society for Testing Materials and the International Association for Testing Materials, the railway world and that of science lose one of their most prominent and loved members.

The work of Dr. Dudley has been of inestimable value in promoting the scientific testing of materials. He has been the father of a movement which is of as much philanthropic as commercial importance. He was the leading spirit in the formation of the American Society for Testing Materials, and took an intimate interest in all of the details of its work. His recent election to the presidency of the International Association for Testing Materials was a well-deserved recognition, and his death will cast a pall over the next meeting of that organization, which is to be held in this country. The Review has frequently published his papers and addresses, which were always of an inspiring nature. To many thousands the news of his death will come as that of a personal friend—one whose memory will be revered hardly less for his amiable and forceful personality than for his work's sake.

FROM THE ALTOONA MORNING TRIBUNE.

EDITORIAL, DECEMBER 22, 1909.

The death of Dr. Charles B. Dudley, which occurred early last evening, deprives the city of Altoona of a citizen who possessed international fame. It robs the Pennsylvania Railroad Company of its chief chemist, a position which he held with constantly increasing honor for more than a generation. It takes from the State of Pennsylvania an adopted son who was ever jealous for her fair fame and ever eager to render unselfish service. It removes one who offered all that he had upon the altar of his country during the dark days of the Civil War and who during the subsequent years cherished the loftiest ideals and held that the unselfish practice of patriotism was the duty of every citizen. It leaves many humbler and less learned men very lonely this morning because they realize that they have lost a sincere friend who was never too busy to listen to their conversation or to offer them wise advice. It leaves a vacancy in the ranks of the friends of the Altoona Mechanics' Library that will never be filled.

Dr. Dudley was probably Altoona's most learned citizen. And yet he was as unassuming as a child. He mingled with the world's greatest minds upon terms of easy equality, but he was ever ready to converse with the common citizen and to do it in such a way as to avoid even the suspicion of patronage or superiority. It was not difficult for the most timid to gain his friendship and to feel quite comfortable in his presence. He was a man who lived in the midst of abstruse problems almost all his days and whose full mind overflowed into the scientific and class publications of the time. But he never showed his learning to the men who lacked his wisdom, and we suppose few who were not intimately associated with his work ever thought of him as one of the most celebrated chemists the world ever saw—in some vital particulars the ablest and most efficient of his time.

It is impossible for the *Tribune,* which knew him simply from the side of a prolonged and a most delightful and profitable (to its editor) friendship, to say here and now what ought to be said about his scientific acquirements and the permanent value of his work. This side of his life was best known and can be best spoken about by those who were associated with him in the same sort of work or who are familiar with the practical value of the results springing from his labors. He was an unquestioned authority in the solution of every question relating to the manufacture and development of the steel rail, his discoveries having gone far to revolutionize the theories of experts. The same is to be said concerning the distinguished value of his investigations concerning the use of steel in constructive work. He was an expert on the construction of car wheels, and the services he rendered in devising a rational and workable method of ventilating cars and providing a perfect sanitary system can never be properly estimated. As will be noticed by the narrative of his life, which will be found elsewhere, he was a member of many learned societies, at home and abroad, and had received many high honors because of the value of his services to the cause of human progress.

From whatever side it may be viewed, the life which changed the form of its activities last evening was a well-rounded and harmonious one. What he did for the great modern methods of transportation during the thirty-four years of his activity as the chemist of the great Pennsylvania Railroad Company, must be left to others to tell. The *Tribune* knew him as the untiring and vigilant overseer of the splendid library which is so largely a monument to his business sagacity and his literary insight. And it knew him best as a perfectly frank yet always earnest and helpful friend. It is almost impossible to conceive of that teeming brain as now inactive; only a little while ago it was so radiant with interest in every department of human endeavor. We believe it has already discovered fresh subjects for inquiry and received enlarged powers whereby to bring great things to pass. The brilliant mind has simply received a merited promotion.

PERSONAL TRIBUTES TO THE MEMORY OF CHARLES BENJAMIN DUDLEY.

TRIBUTE BY DR. HENRY M. HOWE.

In The Iron Trade Review, January 13, 1910.

The life of Dr. Charles B. Dudley was a very great object lesson to the great number of men who have had the privilege of either coming directly under the influence of his personality, or learning of his career.

That he was absolutely fearless, honest, and upright in all his relations was so evident, that it immediately impressed all those who met him. His character stood out at once on his face, and in all his actions. But the value of his example lay not in these qualities, admirable as they are, because these he shared with so many others. It lay rather in the combination of these sterling qualities with his kindness and gentleness of heart and unselfishness on one hand, and his good, hard, sound, common sense, and his power of execution on the other hand. It was this combination of these three sets of qualities that made his example so valuable. The degree of fearlessness and independence, which he showed, does not so often go hand in hand with such great kindness and generosity.

It must have been of the greatest value to an enormous number of young men, whose characters are forming, to have before them the object lesson that a man may be as absolutely independent and fearless as Dr. Dudley was, and at the same time rise to such eminence and be so absolutely beloved by everybody. Let us hope that they have taken to heart the lesson that the secret of his success, in spite of his fearlessness, was that very kindness of heart and that good sense and good judgment, which were so characteristic of him.

It is not easy to think of a life which has been a fuller inspiration to his fellows than Dr. Dudley's. If there is one respect in which it fell short of appealing most strongly to a very large number of young men, it was perhaps through his very highest virtue of all, his perfect unselfishness. Had he amassed a fortune, as he might have done, and as some who share his qualities in a very high degree have done, I am inclined to think that the immediate influence of his life on younger men, as a force tending to move and mould their careers, might have been greater. But I further believe that his not having amassed a fortune was after all only one of his greatest merits, in that it was a symptom and result of his great unselfishness. If such a degree of unselfishness lessens a man's immediate influence on his fellows, it is simply because he is on an ethical plane so high as to be somewhat out of their reach, that he is to that extent one calling in the wilderness. And yet this cannot be in vain. If that extreme unselfishness is above the heads of the great masses of men, there is also a very considerable number of men above whose heads it is not, and to that number of men this quality of unselfishness must have appealed in a very high degree. Thus he influenced the leaders. Through those men to whom this quality appealed then, I believe that he will indirectly and vicariously appeal with great effectiveness, not only to us of to-day, but to those who will succeed us.

None of us could ever come away from under his presidence at Atlantic City without feeling a certain ennobling and lifting influence which his personality had upon us. This we cannot have helped distributing to others, and they in turn to others, and so on. The ripple, which a stone cast into the ocean sets up, persists, though it cannot be traced, to the other shore of the Atlantic. The influence of Dr. Dudley's life and of all such lives will go on indefinitely. As Emerson says:

"The word unto the prophet spoken
Was writ on tablets yet unbroken."

TRIBUTE BY A CLASSMATE, LYNE STARLING (YALE, '71)

IN THE YALE ALUMNI WEEKLY, FEBRUARY 24, 1911.

A SELF-MADE MAN OF THE SEVENTIES.

Even Ralph Paine, the faithful portrayer of Yale in fiction, has, at least temporarily, deserted his happy plutocratic heroes for one working his way. Mr. Paine is always true in his pictures of life in college. Yet if called on for advice, I think I would give it in the words of Kipling's cockney soldier: "Stick to the bloomin' captains, Mulvaney. Commissary sergeants is low." In other words, I doubt if our excellent writer was as well acquainted with the man who works his way in college as with the type he usually describes, the extravagant, not over-useful, but very lovable, social idler, with a comfortable allowance, usually overdrawn, who sells his clothes to bet on the Yale team.

The man working his way through is the more inspiring example, even though we love him less—but do we? I think, as in other cases, though undoubtedly handicapped, it depends largely on the man himself. I have known many such who were both popular and respected.

There was one man who graduated nearly forty years ago, when classes were smaller and necessarily more drawn together than now, who might serve as an example for all time; a man who, to a large extent, paid his expenses by work, and I honestly believe exercised more influence in the Class than any other two men. A cheery, whole-souled fellow he was—rugged, hard-featured, badly dressed, but not conscious of it. I have never seen the crowd in which his battered straw hat, worn at rather a swagger angle, was not welcomed with cheers. He was older than most of the men, had seen hard service in the Civil War, was sophisticated but clean and moral. He early acquired the name of "Pater," and it so clung to him that if now I were to want to write his full name, I would have to look in an old catalogue to find what it was. He died less than a year ago in the prime of his usefulness, a Ph.D., and high in the Scientific Department of the Pennsylvania Railroad. I can still seem to hear his "Gol darn it, fellows!" when strenuously arguing for the right as he saw it.

Not all men can be what this one was. Not all have his absolute self-respect and freedom from suspicion. Many indeed have not his strong good sense and disregard for mere show. Few have the happy disposition and strong character, but what he was others can be in perhaps less degree. A poor man should not feel sensitive, but rather proud of what he is accomplishing under difficulties. He need not obtrude himself, yet neither should he hide. I do not suppose there are now, any more than in old times, snobs at Yale who do not recognize their classmates. The richer men will club together, and probably associate more closely with one another, but a poor fellow, who respects himself, and is not looking for slights, will not be cast out socially, especially and above all if he himself is a good Yale man.

TRIBUTE BY COL. B. W. DUNN, U. S. A.

IN THE RAILROAD AGE GAZETTE, DECEMBER 31, 1909.

My first impressions of Dr. Charles B. Dudley came from the frequency with which I found it useful to consult the Pennsylvania Railroad specifications, and these impressions were corroborated by the practice observed among technical men to accept the specifications as standards. Later, after having enjoyed for several years the pleasure and the advantage of an intimate association with the Doctor, I learned something of the difficulties that he overcame in the development of these specifications.

Close and continued application to work and to study; an inspiring and unselfish loyalty to the Pennsylvania Railroad; an ability to consider questions from different points of view and thereby to appreciate the difficulties of the manufacturer of materials while forcing him to make additional efforts to meet the necessities of the consumer; a disposition so genial, a patience so vast and an optimism so contagious, as to compel the willing cooperation of his associates; these were some of the traits that distinguished Dr. Dudley.

It is easy to understand why the members of the American Society for Testing Materials insisted year after year on making him their President, and why a handsome loving cup from them occupied such a conspicuous position in his home. Those who read the Proceedings of this Society will note the breadth and the soundness of view as well as the charm and the dignity of style with which his annual Presidential Addresses review modern progress in the testing and standardizing of materials for construction purposes. They will note also the frequent and valuable contributions by Dr. Dudley to discussions on a great variety of technical subjects.

At Copenhagen last summer he attended, as a delegate, the meeting of The International Association for Testing

Materials, and was elected President of that Association to serve until its next meeting in the United States in 1912. The honor was great, but no greater than the merit of its modest recipient.

I met him for the first time in 1905, shortly after the disastrous accident on the Pennsylvania Railroad at Harrisburg which involved the explosion of a carload of dynamite. From that time until his death, he devoted a large part of his time to promoting the safe transportation of dangerous articles. Only those closely associated with him during the last years of his life appreciate his many sacrifices to this work. Hurried journeys that called for the strength of a younger man, all day conferences with manufacturers and shippers in successful efforts to win their cooperation, patient reviews of technical laboratory reports followed by useful suggestions for the guidance of his subordinates, were some of the "extras" to a program already full.

His friends admired him much, but they loved him more. Who of them can ever forget his characteristic greeting, the contagious smile that banished, temporarily at least, all your troubles, the double hand grasp, the affectionate pat on your shoulder that accompanied his "How *are* you?"

STATISTICAL DATA

SCIENTIFIC, TECHNICAL, SOCIAL AND OTHER ORGANIZATIONS

In Which Dr. Dudley Held Membership at His Death, or With Which He Was at Some Time Connected.

International and Foreign Scientific and Technical Societies.

International Association for Testing Materials (President).
International Railway Congress.
Iron and Steel Institute.
Chemical Society, London (Elected Fellow, 1898).
Society of Chemical Industry, England.
Deutsche Chemische Gesellschaft.
Société Chimique de France.
Verein Deutscher Eisenhüttenleute.
Institution of Mechanical Engineers, England.

American National Scientific and Technical Societies.

American Philosophical Society.
Franklin Institute.
American Association for the Advancement of Science.
American Chemical Society (President).
American Electro-Chemical Society.
American Society for Testing Materials (President).
American Society of Civil Engineers.
American Institute of Mining Engineers (Vice-President).
American Society of Mechanical Engineers.
American Institute of Electrical Engineers.
American Railway Association.
American Railway Guild.
American Public Health Association.
American Forestry Association.
American Historical Association.
American Economic Association.
American Statistical Society.
Society for the Promotion of Engineering Education.
National Association for the Study and Prevention of Tuberculosis.

LOCAL SCIENTIFIC AND TECHNICAL SOCIETIES.

Washington Academy of Sciences, Washington, D. C.
The Engineers' Society of Western Pennsylvania.
Engineering Club, Altoona.
Engineers' Club of Central Pennsylvania.
Pennsylvania State Association of Master House Painters and Decorators (Honorary Member).

SOCIAL CLUBS.

Chemists' Club, New York.
Engineers' Club, New York.
Railroad Club, Altoona.
Union League, Philadelphia.
Cosmos Club, Washington.
Juniata Club, Altoona.

MISCELLANEOUS SOCIETIES.

American Civic Alliance.
Civil Reform Association.
Jewish Publication Society.
Palestine Exploration Fund.
Altoona Cricket Club.

COLLEGE SOCIETIES.

Phi Beta Kappa Society.
Alpha Delta Phi Fraternity.
Wolf's Head (Graduate Member)
Gamma Nu.
Linonia.

OFFICES AND HONORS HELD BY

CHARLES B. DUDLEY

President, International Association for Testing Materials, 1909- ——.
President, American Society for Testing Materials, 1902- ——.
President, American Chemical Society, 1896-1898.
Vice-President, American Society for Testing Materials, 1900-1902.
Vice-President, American Institute of Mining Engineers, 1880-1882.
Chairman, National Advisory Board on Fuels and Structural Materials.
President, Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, American Railway Association.
Chairman, Committee on Explosives, American Railway Association.
Member, United States Assay Commission, 1888 and 1897.
Member, Research Committee, American Society of Mechanical Engineers.
Delegate from the Pennsylvania Railroad Company, at the International Railway Congress, Paris, 1886 and 1900.
Honorary Member, Pennsylvania State Association of Master House Painters and Decorators.
Member, Board of Health, Altoona, Pa.
Medical Inspector, State Board of Health for Central District, Pennsylvania, including counties of Center, Clearfield, Clinton, Cambria and Blair.
Collaborator, Forest Service, United States Department of Agriculture.
Director, Mechanics' Library Association, Altoona, Pa., and Chairman of Library Committee.
Vice-President and Director, Second National Bank, Altoona, Pa.
Director and Auditor, Central Pennsylvania Trust Company, Altoona, Pa.
Fellow, Chemical Society, London, 1898.
Member, Phi Beta Kappa Society.

BIBLIOGRAPHY OF CHARLES B. DUDLEY, Ph.D.

On Lithium, and a Glass made with Lithium. *Proc. Am. Assoc. for the Advancement of Science, 1874.*

The Chemical Composition and Physical Properties of Steel Rails. *Trans. Am. Inst. Min. Engrs., Vol. VII, 1878.*

Does the Wearing Power of Steel Rails Increase with the Hardness of the Steel? *Trans. Am. Inst. Min. Engrs., Vol. VII, 1878.*

Wearing Capacity of Steel Rails in Relation to Their Chemical Composition and Physical Properties. *Trans. Am. Inst. Min. Engrs., Vol. IX, 1881.*

Notes on the Constitution of Cast Iron. (With F. N. Pease.) *Trans. Am. Inst. Min. Engrs., Vol. XIV, 1885.*

Fuel Oil. *Jour. Franklin Inst., Vol. 126, 1888.*

Chemistry Applied to Railroads. *The American Engineer and Railroad Journal, 1889-1902.* [The titles of this notable series of 55 articles are given in the appendix, pp. 118-119.]

The Wear of Metal as Influenced by Its Chemical and Physical Properties. *Trans. Am. Inst. Min. Engrs., Vol. XIX, 1890.*

The Making of Specifications for Structural Materials. *Trans. Am. Inst. Min. Engrs., Vol. XXI, 1892.*

Bearing Metal Alloys. *Jour. Franklin Inst., Vol. 133, 1892.*

Paints and Painting Materials. *Painting and Decorating, Vol. 7, 1892.*

Water Supply in Mountain Towns. *Annals of Hygiene, 1892.*

Discrepancy in Chemical Work by Different Workers. *Proc. Engrs.' Soc. West. Penna., Vol. 8, 1892.*

Standard Methods for the Analysis of Iron and Steel. *Proc. Engrs.' Soc. West. Penna., Vol. 9, 1893.*

The Need of Standard Methods for the Analysis of Iron and Steel, with Some Proposed Standard Methods. *Jour. Am. Chem. Soc., Vol. XV, 1893.*

An Attempt to Find the Amount of Phosphorus in Three Samples of Steel. Some Points in the Determination of Phosphorus in Steel by the Volumetric Method. (With F. N. Pease.) *Jour. Am. Chem. Soc., Vol. XVI, 1894.*

Circular to Iron and Steel Chemists on Method of Determining Phosphorus. *Jour. Am. Chem. Soc., Vol. XVI, 1894.*

International Standards for the Analysis of Iron and Steel. Reports of the Sub-Committee on Methods, Charles B. Dudley, Chairman. *Proc. Am. Soc. C. E., Vol. XX, 1894.*

Report of Committee on Analysis of Iron and Steel, American Society of Civil Engineers, June 23, 1894.

The Theory and Practical Use of Inert Pigments. *Drugs, Oils and Paints, October and November, 1896.*

Some Present Possibilities in the Analysis of Iron and Steel. Presidential Address. *Jour. Am. Chem. Soc., Vol. XIX, 1897.*

The Ventilation of Passenger Cars on Railroads. *Jour. Franklin Inst., Vol. 144, 1897.*

The Dignity of Analytical Work. Presidential Address. *Jour. Am. Chem. Soc., Vol. XX, 1898.*

Report of the Committee on Coal Analysis. (William A. Noyes, W. F. Hillebrand, and Charles B. Dudley.) *Jour. Am. Chem. Soc., Vol. XXI, 1899.*

The Making of Specifications for Materials. Presidential Address. *Proc. Am. Soc. Test. Mats., Vol. III, 1903.*

Standard Specifications for Cast-Iron Car Wheels. *Trans. Am. Inst. Min. Engrs., Vol. XXXV, 1904.*

A System of Passenger Car Ventilation. *Proc. Am. Philos. Soc., Vol. XLIII, 1904.*

Oils and Pigments. Lecture before the Master House Painters' and Decorators' Association of Pennsylvania, January, 1904.

The Passenger Car Ventilation System of the Pennsylvania Railroad Company. *The Pennsylvania Railroad Company, 1904.*

The Influence of Specifications on Commercial Products. Presidential Address. *Proc. Am. Soc. Test. Mats., Vol. IV, 1904.*

The Testing Engineer. Presidential Address. *Proc. Am. Soc. Test. Mats., Vol. V, 1905.*

The Dissemination of Tuberculosis as Affected by Railway Travel. Paper read before the American Public Health Association, September, 1905.

The Enforcement of Specifications. Presidential Address. *Proc. Am. Soc. Test. Mats., Vol. VII, 1907.*

Some Features of the Present Steel Rail Question. Presidential Address. *Proc. Am. Soc. Test. Mats., Vol. VIII, 1908.*

The Use of Some of the Natural Resources of the Country and Possible Economies in Their Use. Address at Conference of Governors, at Washington, D. C., 1908.

Engineering Responsibility. Presidential Address. *Proc. Am. Soc. Test. Mats., Vol. IX, 1909.*

NOTE: No attempt has been made to include in this list the extensive record of Dr Dudley's discussions of papers by himself and others, although these discussions are in large part of permanent interest and value. The list of titles presented has been gathered from many sources, but it is probably incomplete.—ED.

APPENDIX TO BIBLIOGRAPHY.

The following notable series of articles, prepared by Dr. Dudley and Mr. F. N. Pease, Assistant Chemist of the Pennsylvania Railroad Company, appeared in *The American Engineer and Railroad Journal* at irregular intervals from 1889 to 1902.

CHEMISTRY APPLIED TO RAILROADS.

FIRST SERIES.

1. Introductory: What the Chemist Does................December, 1889.
2. Tallow ....January, 1890.
3. Lard Oil ....February, 1890.
4. Lard Oil (Continued) ....March, 1890.
5. Petroleum Products ....April, 1890.
6. Petroleum Products (Continued)........................May, 1890.
7. Lubricants and Burning Oils ....June, 1890.
8. Method of Purchasing Oils ....July, 1890.
9. Hot Box and Lubricating Greases ....July, 1890.
10. Battery Materials ....August, 1890.
11. Paints ....September, 1890.
12. The Working Qualities of Paint ....October, 1890.
13. The Drying of Paint ....December, 1890.
14. The Covering Power of Pigments ....February, 1891.
15. How to Design a Paint ....April, 1891.
16. Paint Specifications ....May, 1891.
17. Paint Specifications (Continued) ....June, 1891.
18. How to Design a Paint ....July, 1891.
19. How to Design a Paint (Continued) ....August, 1891.
20. Disinfectants ....September, 1891.
21. Mineral Wool ....October, 1891.
22. Wood Preservative ....October, 1891.
23. Soap ....November, December, 1891.
24. Steel for Springs ....January, 1892.
25. Bearing Metals ....February, 1892.
26. How to Make Specifications ....April, 1892.
27. Sampling; and the Enforcement of Specifications.....May, June, 1892.

SECOND SERIES—CHEMICAL METHODS.

Introductory ....September, 1892.
1. Phosphorus in Steel ....December, 1892; January, 1893.
2. Method of Determining Free Caustic and Carbonated Alkali in Soaps ....April, May, 1893.
3. Method of Determining Carbon in Iron and Steel...July, August, 1893.
4. Method of Determining Sulphur in Steel............September, 1893.
5. Method of Determining Sulphur in Pig and Wrought Iron ....December, 1893.
6. Method of Determining Phosphorus in Phosphor-Bronze..March, 1894.
7. Method of Determining Manganese in Steel..............April, 1894.
8. Method of Determining Silicon in Steel..................July, 1894.
9. Method of Determining Tin in Phosphor-Bronze........August, 1894.
10. Method of Determining Copper and Lead in Phosphor-Bronze ....October, 1894.
11. Method of Determining Iron in Commercial Spelter..November, 1894.
12. Method of Determining Chlorine in Ammonium Chloride.January, 1895.
13. Method of Determining Ammonia in Ammonium Chloride ....February, 1895.
14. Method of Determining Flashing and Burning Points of Combustible Liquids ....May, 1895.
15. Method of Determining Tar and Tar Acids in Wood Preservative ....June, 1895.
16. Method of Taking Cold Test and Chilling Point of Oils and other Liquids ....July, 1895.
17. Method of Determining Specific Gravity of Oils and other Liquids ....October, 1895.
18. Method of Determining Proportions of Oil, Pigment and Moisture, or Deficiency of Hydration in Freight Car Color ....April, 1896.
19. Method of Determining the Fineness of Grinding of Freight Car Color and Passenger Car Color..................June, 1896.
20. Method of Determining the Shade of Paints.........September, 1896.
21. Method of Determining Proportions of Oil, Turpentine, Pigment and Moisture in Passenger Car Color.....September, 1897.
22. Method of Determining Sesquioxide of Iron in Freight Car and Passenger Car Color ....January, 1898.
23. Method of Testing Spirits of Turpentine.................April, 1898.
24. Maumené's Test for Oil ....June, 1898.
25. Method of Determining Tin in Phosphor-Bronze......December, 1898.
26. The Ventilation of Passenger Cars......................June, 1900.
27. The New Ventilating System for Passenger Cars.........June, 1901.
28.* Disinfection of Passenger Cars ....June, 1902.

*By Dr. Dudley and Mr. M. E. McDonnell, Bacteriologist of the Pennsylvania Railroad Company.

LIST OF PATENTS ISSUED TO CHARLES B. DUDLEY.

SUBJECT.	PATENT NO.	DATE GRANTED	RECORD VOL.	RECORD PAGE
Purifying natural waters for use in steam boilers	267,743	Nov. 21, 1882	22	1730
Making soda-lime	272,127	Feb. 13, 1883	23	570
Purifying water for boiler use	283,472	Aug. 21, 1883	24	731
Purifying feed water	285,591	Sep. 25, 1883	24	1229
Purifying water	291,167	Jan. 1, 1884	26	36
Purifying water for boiler use	291,168	Jan. 1, 1884	26	36
Apparatus for carbureting air or gas	342,863	Jan. 1, 1886	35	1029
Carbureter for air or gas	368,137	Aug. 9, 1887	40	678
Indicator for measuring flow of liquids in conduits	375,054	Dec. 20, 1887	41	1312
Carbureter	375,055	Dec. 20, 1887	41	1312
Check Valve (with J. D. Bowman).	405,250	1889	47	1494
Valve	422,924	Mar. 11, 1890	50	1308
Ventilating device for lamps (with A. S. Vogt).	665,513	Jan. 8, 1901	94	281

Presidential Addresses

of

Charles Benjamin Dudley

before the

American Society

for

Testing Materials

THE MAKING OF SPECIFICATIONS FOR MATERIALS.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY

DELIVERED BEFORE THE

AMERICAN SOCIETY FOR TESTING MATERIALS IN 1903.

It has occurred to us that in the present state of development of our Society, it might not be amiss to discuss some points in the making of specifications for materials. If we understand the matter correctly, there is more or less doubt and ambiguity in the mind of many; and while it is not hoped or expected that the present discussion will put the whole matter at rest, it is believed that it will serve some valuable purpose to have on record an attempt at a presentation of the case, as it looks to one who has spent over twenty years in daily contact with practical specifications for materials. It is not expected that all that is said will be agreed to, and it is more than probable that much of what follows will be found not applicable by others. Nevertheless, it is perhaps worth our time to go over the matter together.

The first point which we will discuss is the query: What has a society devoted to the testing of materials to do with the making of specifications? Should not methods of testing and the finding out of the various properties of materials which render them valuable and useful, be its legitimate field of study, rather than the assembling or combining of these various properties in the form of specifications? Should not the work of making specifications be undertaken by the engineers or the parties interested in any case? If we understand the matter rightly, this is the view taken by many of the leaders of the International Association, with which we are affiliated. The properties of materials and the methods of testing to discover those properties, seem to them to be the more legitimate field for the activity of the Society. In this country, on the contrary, we have taken what may be called the "broader view."

We regard as our legitimate field of study not only the valuable properties of materials, and the methods by which we are to determine those properties, but also the assembling, into concrete or useful form, of our knowledge in regard to any serviceable material. In our view, the more comprehensive field has much to recommend it. While it must be conceded that a society is doing good and valuable work which busies itself with the characteristics of the materials of construction and with the methods of testing, yet we cannot but feel that it must likewise be conceded that a society is doing better work which not only occupies the field of testing and study of materials, but also goes a step farther, and puts its accumulated information with its recommendations into definite and serviceable shape. Much may be said on both sides of the question, and its exhaustive treatment would absorb our whole time. We will therefore only add that we have failed to think of an argument in favor of making methods of testing the legitimate work of such a society as ours, which does not equally justify the making of specifications for materials a part of that legitimate work.

Coming now to the more definite discussion of our theme, it has occurred to us that it might be useful and valuable to give an exposé somewhat in detail of the methods practised at Altoona, in connection with the Laboratory of the Pennsylvania Railroad, in making specifications. It is of course recognized at the start that every specification is more or less affected by local conditions, and that much may be said which will not have universal application. Furthermore, the opinions which guide us in our work, and the results which we aim to accomplish, may reasonably not be accepted by others, and we have no disposition to think that what we shall say will be the last words on the subject. It may well happen, as time progresses, that much will be said by others which will modify our present views and present practice, both in this country and abroad.

The general plan which we have at Altoona is as follows: First, we try to find out what we want. Some difficulty arises in the service; some parts of constructions fail, or some material at present in use does not give satisfactory results, and an investigation is made to see if the cause of the difficulty can be located; or some product which is being largely used and which is being furnished by different makers, is believed not to be of equal quality from the different sources; or, indeed, it is desired to standardize a practice and make it uniform all over the road, and as an element in this problem the same quality of material must be furnished and used. These and other elements lead us to make investigations into the nature of the commercial products involved. These investigations lead to specifications. The specifications, after being made, are placed in the hands of the purchasing agent, and by him are made a part of the contract on which the materials are bought. Shipments of material in accordance with this contract being received, each shipment, or specified definite amount, is sampled, and the samples examined in accordance with the specifications. If the samples stand test, the material is accepted and paid for; if not, the material is rejected and returned to the makers. This plan has been in daily use at Altoona, in connection with the Pennsylvania Railroad, for something over twenty years. The present number of specifications, both physical and chemical, is forty-seven.

Now, how shall a specification be made? It is quite obvious from the nature of the case, that primarily in a specification two parties are interested, the producer of the material and the buyer or consumer, and in our first specifications only the relation of these two parties was considered. Indeed, we were accustomed to say for quite a period of time, that a specification was an attempt on the part of the consumer to tell the producer what he wanted. It necessarily followed from this limitation, that the first specifications did little more than define the qualities of the material, and it seems more than probable that general specifications, such as our Society can deal with, will necessarily be largely confined to this feature, namely, defining the quality of the material. It is true that methods of sampling, how much material one sample shall represent, and in some cases methods of testing, either in whole or in part, may wisely be embodied in a general specification, but it is obvious that all those features of a specification, which have to do with local conditions, cannot well be made a part of a general specification.

As has already been said, at first our specifications considered almost exclusively the two principal parties involved, namely, the producer and the consumer, but as time progressed it was found desirable and advantageous to consider several other parties, who were or might be involved in the matter. Questions began to arise as to how much material should be involved in one test. Then came the question: Would it not be advisable to buy in lots of the same size as the test involves? Then came the question of sampling. Then came the question: Shall part of the work of deciding whether shipments fill the requirements be done at the works where the material is made, or shall it all be done after the shipment is received? If the former, an inspector is involved, and he must have information which could perhaps best be embodied in the specification itself. Furthermore, those who actually applied the tests, the chemist and the engineer of tests, would frequently ask questions in regard to methods, or interpretation of various points, and finally it was found that those who ultimately receive the material, such as the storekeeper or shop foreman, could frequently make certain inspections, better perhaps and cheaper than any one else, and so information must be furnished for them. This necessity for information for the use of a number of different parties has made the modern fairly workable specification for certain materials to be a somewhat lengthy and at times a seemingly cumbrous affair. It is difficult to draw the line as to exactly what should be included and what excluded in a specification. The commercial interests of the manufacturer on one side, and the zeal, sometimes excessive it must be confessed, on the other side, on the part of the inspector or chemist or engineer of tests, lead to very close scrutiny of the wording of the specification, and it cannot be denied that many times conditions arise which make those who are deciding the fate of shipments wish that the specifications had been more minutely drawn. In drawing a specification, one is always between two fires, the fear of making a specification too cumbrous and unwieldy, and the fear of leaving out something which will be found desirable or even essential a little later. As far as we can be said to have reached a positive conclusion at Altoona, it may perhaps be embodied in this, that a good workable specification should contain such information as is needed by the purchasing agent, such information as is needed by the manufacturer, by the inspector, by the chemist, by the engineer of tests, and by the people who are to receive and use the material.

This view of the case will undoubtedly be conceded by all, but the exact amount of information covered by the word "needed" is where the difficulty arises. For example, should the specification cover the chemical method involved in the analysis of the material? Should it cover the methods of testing? Should it cover the complete instructions for the inspector, meeting every point, and so on? Upon this point our views are that the specification should not attempt so much. Where methods of analysis, or methods of testing, or points which the inspector must look out for, are well known, or can be covered in general language, it is sufficient to do this only. Where new methods are involved which are not well known and recognized, it is essential to either embody these in the specification, or to furnish this information in separate form, and refer to it in the specification. This is common practice, as is well known, in referring to drawings, blue prints, etc., and it may not be amiss at this point to state that in view of the difficulties connected with discrepancies in chemical analyses, we began, several years ago, to print and issue in separate form the methods used in our laboratory, making these methods a part of the specifications by reference only, and thus also a part of the contract. The same practice has prevailed elsewhere in regard to methods of physical testing, and it is our sincere hope that, sooner or later, our Society will issue in printed form what it recognizes as standard methods of testing. Such work, well and carefully done, will relieve specifications of much which they must now necessarily contain.

This, perhaps, is the place to discuss one or two faults characteristic of many specifications which we have seen. We will not attempt to deny that in our earlier work on this subject the same faults characterized our specifications. They are in print and may be read and known by all. The special fault which characterizes many specifications is the attempt on the part of the one who draws the specification to make it a place to show how much he knows. We have seen specifications which were apparently drawn with no other thought in mind than to embody all the knowledge the writer had on the subject. No discussion is needed on this point. The folly of it is apparent to all.

Another fault is in putting too many restrictions into the specifications. According to our views, the fewer possible restrictions that a specification can contain, and at the same time afford the necessary protection in regard to the quality of the material, the better the specification is. In some of our specifications we have only one test; in others, perhaps half a dozen; the effort, however, being always to have the minimum number which will yield the product that is required.

A third fault in specifications is in making the limits too severe. Some writers who draw specifications apparently put themselves in a position of absolute antagonism to those who are to make the material, and seem to have as a permanent thought in their minds to tie them down to the extreme limit. The maximum that a single test piece shows, the minimum of an objectionable constituent that may be obtained by analysis, the extreme point in elongation that by chance some good and exceptional sample gives, are made to represent the total output of the works. It is, perhaps, needless to say that such extreme figures are the worst possible mistake in making specifications. The success or failure of structures, or of material in service, does not depend on such extreme figures. It is infinitely better to specify a good average material, and get the necessary protection in structures by a more liberal factor of safety in the design, than to insist on such extreme limits, which can only lead to constant friction and demand for concessions at the penalty of delaying the work.

It may be interesting to know something of the routine leading to a complete specification in our work at Altoona. The first step in the process is the accumulation of information. This we obtain from any available sources. Sometimes we get samples from the service which have given both good results and bad results, a sufficient number being obtained to get a reasonable average, and make of these samples careful analyses and physical tests. If now the results obtained show a difference, either in physical properties or in chemical composition, between the good and the bad, the process is simple. The qualities of the material have actually been decided by the service. Again, in certain specifications the service does not give so much information, or it takes years for the service to develop what is good and what is bad. In such cases general knowledge is made use of, the resulting specifications being regarded as tentative, and after the material begins to be received it is carefully watched to see how it behaves. Again, direct, positive experiments are made, sometimes on a fairly large scale. The experiments leading up to the thermal test for cast-iron wheels involved the testing of some two hundred wheels, representing as many kinds of wheels as could be obtained. These wheels were all tested thermally, and a complete record made of their behavior. By far the largest portion of them were then likewise analyzed, to see whether chemistry would throw any light on the problem. In the work leading to the specifications for axles, some two or three years were involved in the accumulation of the information. Every broken axle that failed in service, for a long time, was carefully analyzed and physical tests made. Again, it is of course recognized that the possibilities of the material must be considered; nothing must be specified beyond what the material will reasonably give. Again, in the accumulation of our material leading to a specification, it is usually customary to pay a visit to the parties who make the materials involved, and learn from them, as far as possible, what their materials will give. A more or less intimate knowledge of the methods used in the manufacture of the constituents which enter into the finished product, and of the properties of each, we deem an essential pre-requisite to the drawing of a specification. Finally, the experience of practical men, as to the behavior and characteristics of materials which have been used for years, is made use of. Sometimes in writing, and sometimes in personal interview, these men are requested to state their experience, and it is not too much to say that from the practical men who know materials principally by their daily contact with them, extremely good and helpful suggestions have often been obtained. It should not be forgotten to mention, also, that other specifications, printed matter of all kinds, of which there is now such an abundance, proceedings of societies for testing, and other learned societies, investigations made and published by engineers, etc., are drawn upon whenever possible. It will be readily understood that this accumulation of information in the case of important specifications takes much time. Some materials have been under study for ten years or more, and no specification has yet resulted. Other subjects are simpler and the specifications can be made in a few weeks. Not a few of our specifications at Altoona represent two or three years' work in the accumulation of information, before it is ever put in shape.

The material, having been accumulated, is digested and some one of us puts it into the form of a specification, and here I may say what has been mentioned before, that it is rare that any attempt is made to put into the first draft of a specification all the knowledge that we have. In the thermal test of wheels already referred to, it was found that wheels under thermal test broke in nine different ways, and that they stood under thermal test without breaking from a few seconds to seven minutes. The specification as finally drawn rejected wheels only when they broke in two out of the nine different ways, and required that successful wheels must stand without breaking in those two ways for two minutes. It is a great temptation, and a common error, to put into the first draft of a specification too much. It must be remembered when making a specification for a material which has hitherto not been subjected to test, that the manufacturer is more or less uncertain as to his product, and that it may require on his part changes in methods, and possibly in materials entering into his product, in order to meet the requirements of the specifications. If now too much is put into the first draft, the inevitable result will be that undue difficulties will be introduced in the manufacture, and the consumer will not infrequently find himself without the possibility of supplying his wants in the market. It is infinitely better to make the first draft of a specification embody only a few essential points, and after such changes in the works have been made as enable the manufacturer to meet these requirements, to revise the specification, embodying more. A not inappropriate illustration of this point may be found in the drop test for car wheels. Although the car wheels made at Altoona many years ago would stand the drop test specified up to fifteen or twenty blows without breaking, the first specification for drop test of car wheels which was put out for public use was limited to three blows of the same drop, and it was with difficulty that wheels were obtained even under this test. In the course of a few months, however, the test was easily met, and was even made more rigid, and ultimately reached a limit of eight blows.

To return now to the specification. As previously stated, the material is put into shape by some one of us at Altoona. Then a conference is called, consisting of the mechanical engineer, the engineer of tests, the chemist, and the general superintendent of motive power, under whose supervision, according to the organization of the Pennsylvania Railroad Company, all tests and experiments are made. Others having special knowledge may be invited to this conference. The specification as drawn is carefully read over and criticised. As the result of this criticism it is redrawn, and then the material is put in print, copies of the print being sent to the purchasing agent and to each of the superintendents of motive power of the system. Along with the printed copy goes a request to each of the superintendents of motive power to criticise the specification on his own part, and submit it to his master mechanics or to those of his subordinates who may use the material and may be competent to criticise. To the purchasing agent the request is made that he shall submit the specification to all those manufacturers of the material involved from whom he desires to buy, with request for the freest possible criticism from their standpoints. The criticism from the service through the superintendents of motive power many times yields valuable suggestions. The criticisms from the manufacturers have been the result of some very peculiar and interesting episodes. Some of the manufacturers, apparently fearing that their criticisms may affect the placing of orders, content themselves by saying that they can meet the specifications as well as any one, and that they should be glad to have orders in accordance with them. Others take the occasion to bring forward characteristics of their own products. For example, in criticising a proposed specification for petroleum products at one time, one manufacturer desired a clause introduced that only Pennsylvania petroleum should be used. At one time in the criticism of a proposed specification for rails, information was developed seeming to indicate that the effect of certain constituents on steel was a question of geography, thus: The manufacturers east of the Susquehanna River brought forth the statement that sulphur and copper were not injurious to steel, but that phosphorus was its bane; while the manufacturers west of Pittsburg brought forth the equally remarkable statement that phosphorus did not do much damage to steel, but that sulphur and copper were most injurious to it. Those who were located between those two points practically said: We will give you whatever you pay for. Some manufacturers, however, in criticising specifications, apparently size up to the situation and give honest and valuable suggestions.

We regard this submission of a specification to the manufacturers, before it is issued, as a matter of the utmost importance. In the early days our idea was, as already stated, to tell the manufacturers what we wanted. We were the parties to define the material, and it was their part to simply give us what we asked for. At the present time our idea is that the specification should be the embodiment of the best that is known on the subject, no matter where the information comes from, and that it is simply the part of wisdom, and that we are not only foolish but shortsighted and unfair, if we attempt to make a specification without at least giving the manufacturer an opportunity to cooperate. We feel that the specification should be regarded as partly his creation, as well as ours, and that he should be able to see his own handiwork in it. We are free to put on record that to the cooperation and help of the manufacturers of materials quite a portion of the success, if any, that has attended the Pennsylvania Railroad specifications has been due.

The criticisms from all sources having been received, the specification is carefully gone over again in the light of these criticisms. As far as possible the valid and valuable suggestions of all are embodied. Conflicting criticisms, many times due to local conditions, are harmonized as well as may be, and the specification as redrawn and codified is then submitted to the proper officers for approval, and ultimately issued and made a part of the contract on which materials are furnished, as has already been described.

As already stated, it is not hoped or expected that the processes and methods made use of in the making of specifications by the Pennsylvania Railroad can be followed in minute detail by others in making specifications, and yet there is a single thought upon this phase of the case which seems to us worthy of some careful consideration; namely, the greater the care, the larger the amount of study, and the more well-directed time and effort that are put upon the specification before it is issued, the less will probably be the difficulty connected with it after it has once become a part of the contract. To our minds, the making of successful specifications demands more ability and a higher order of work than has heretofore been commonly given to it. The valuable specification represents the fruition of the studies of those who make investigation into the properties of useful materials, and of those who use them, and in reality it is the culmination of the work of our Society.

So much may be said on this subject, that it would be easy to weary you with it, but I trust you will bear with me while I touch upon one or two points farther. As we understand the matter, there is opposition on the part of the manufacturers of steel to having the consumer put out chemical specifications in detail. It is claimed that the consumer should only specify the physical properties of the metal, and exclude or limit by the chemistry only constituents which are objectionable, leaving the steel-maker free to vary those constituents upon which the most valuable properties of the steel depend, according to his own ideas. This feeling, if we are rightly informed, is much stronger abroad than it is with us, and we have been told that steel-makers abroad would not bid on a specification of which complete chemical requirements were a part. From what has preceded, it will not be difficult to understand how we feel about this matter, and it is hard for us to conceive where the method outlined above is followed, and especially where the manufacturer has a chance to criticise a specification before it is issued, why there should be any reasonable ground for antagonism to complete chemical specifications. The position which we hold in the matter is that a certain set of physical properties produced by, for example, high carbon and low manganese, may give a steel more valuable to the consumer than approximately the same physical properties, produced by lower carbon and higher manganese, or other interchange of the constituents commonly affecting the physical properties of steel. Moreover, we cannot help feeling that the chance to study the behavior of metal in service, and the relations between its chemical composition and that behavior, is a source of information which should not be ignored. No one can deny that this chance is more open to the consumer than to the producer, and we fail to see why the producer should shut himself out from this source of knowledge. As has already been stated two or three times, in our judgment a good specification is the result of the joint effort both of those who know steel from its behavior while it is being manufactured and of those who know steel from its behavior while in service.

Another point will, perhaps, bear a few words. We have found it difficult in our work to make any definite rule universally applicable, as to how much material should be represented by one sample. Where materials are made in batches or in heats, and the sample is selected at random, no serious difficulty has thus far arisen in making one's sample represent a heat or batch. Where a shipment, as in the manufacture of alloys, may be made up of material resulting from a number of like operations, without any certainty as to uniformity in the output of each complete operation, the question of sampling is more difficult. The same may be said of oils and paints, and other related materials. In such cases, it is usually customary with us to make an arbitrary sampling, and to follow this sampling by occasional more complete sampling, after the material has been received and passed upon. If such more complete sampling shows lack of uniformity in the shipment of material involved, it may not infrequently lead to a modification of the specification.

Closely related to the question of the amount represented by one sample, is how many individual parts shall make up the average sample. For example, shall one ingot represent twenty thousand pounds of an alloy, or shall more than one? In a shipment of oil, shall a sample from one barrel be used, or shall smaller samples from each barrel be mixed to form one average sample? Our practice has been to limit the number of subsamples entering into the average sample as much as possible, on the ground that the material should be uniform, and that the specification provides wide enough limits to make up for the ordinary variations, where the manufacturing or shop practices are reasonably good. If the material is uniform, or all of it within the limits of the specification, the multiplication of sub-samples really serves no useful purpose, and as we really buy and pay for a material described by the specification, it is not unfair to expect that any and every part of it should be in accordance with that specification.

Another closely related point is the question of retests. A shipment of material has been received, sampled in the regular way, and tested, and the material does not stand test. It not infrequently happens that the producer asks for another test, with the hope and expectation that this test will show that the material meets the requirements. No small amount of correspondence and personal interviews have been expended over this matter. Our general position upon this subject has been to decline retests, the theory being that the specification was not drawn for the purpose of making it easy for irregular, and we may say possibly carelessly made, material to be accepted. If a second test is made which does meet requirements, it is obvious that the consumer would naturally want to make a third test, and see which one the third test sustained, and we believe many specifications are drawn with such provisions. We cannot but think that this is bad practice, and that it is infinitely better to make the limits of the specification wide enough when they are first drawn, so that they will cover all the uncertainties in manufacture, except carelessness, bad judgment, or an attempt to sell an inferior product at the price of a good one. It is very gratifying to be able to state that with the large number of specifications enforced on the Pennsylvania Railroad, where each shipment is now examined and has been for quite a period of time, the number of rejected shipments which fail to meet the specifications varies from one and a half to two and a half per cent., possibly sometimes a little higher. Usually the rejections are characteristic of the new specifications, that is to say, when a specification has been out long enough so that manufacturers have had a chance to adapt themselves to its requirements, it is very rare that we have rejections.

Another point may be worth a few words, namely, is it possible to so draw a specification that material which has once been rejected will not be offered a second time? There is, perhaps, no point connected with the specifications which is more difficult to handle than this one. It is recognized that the putting of marks on rejected shipments, as is the custom in government work, deteriorates the quality of the rejected material, and of course adds a good deal to the cost, since the manufacturer must requite himself for the material so condemned. When materials bear serial numbers placed upon them for his own purpose by the manufacturer, the problem is less difficult, but for the mass of products which are made the subjects of specifications, such identifying marks are not available. It is perhaps fair to say that we have had shipments of rejected material returned to us, and have a second time rejected them on the second sample. Our feeling is that where there is a clause in the specification that the manufacturer must pay return freight, very few reputable people at least will run the risk of a second rejection, by returning material already once condemned. Moreover, it is not difficult to so mark rejected material with a private obscure identification mark, that it can be recognized if it is returned; and, as has been stated by one purchasing agent, it is easy to meet such cases, where the matter is free from doubt, by withholding orders from those who indulge in such practices. Our experience has been that the commercial world desires rather to do a straightforward, open, honest business, in a straightforward, honest way, and that where the specifications are reasonable, and the testing fair, there will be very little difficulty on this score.

Two points more and I have finished. First, how do specifications affect the business of producers? and second, what is the effect of specifications on the prices of materials? Upon the first of these points, let us say we are well aware that many producers object to specifications on the ground that they are annoying and harassing, and really serve no good purpose. On the other hand we are able to say, that some manufacturers have asked that specifications be prepared, and one larger producer, indeed, told us in conversation that the more difficult the specification, the better they liked it, on the ground that it limited the competition which they would have in producing the product. There is a point here which is perhaps worth a few words. Let us suppose that an honest manufacturer is making a good product. He understands his business, and has good facilities, and is turning out an excellent article. When he comes to sales, he is called upon to meet in competition, let us assume, those who are not equally well equipped, and who in order to secure a market must offer lower prices. In order to recoup for this diminution in prices, the latter of course must make an inferior product. So long, therefore, as the consumer buys on price alone and without any specification or examination of shipments, the honest, competent manufacturer is at a disadvantage. On the other hand, if there is a good, workable specification in force and each shipment is examined, the unfair competition of the inferior manufacturer is entirely eliminated. We have many times stated in conversation with manufacturers, that in our judgment those who are doing a legitimate, straightforward, honest business, should be the strongest friends that specifications have, and it is gratifying to be able to state that many manufacturers of commercial products look at the matter in this light.

Finally, in regard to the effect of specifications on prices. Many consumers fear that if they enforce specifications, the price of the product will seriously increase. This seems a legitimate fear, and it is a fair question, if the facts are as they seem to be, whether the value of the material according to the specifications is equal to the increased cost. It is gratifying to be able to state that experience indicates that after a specification has passed what may be called the "experimental stage," and is working smoothly, prices show a strong tendency to drop below the figures prevailing at the time the specification was issued. This seems to be due to two or three causes: First, the manufacturers are all bidding on the same quality of product, hence genuine competition prevails. Second, the specification describing what may be called a "staple commodity," for which there is a steady demand, slack time at the works may be employed in making this product in advance of orders, thus employing facilities to the best advantage. Third, the constituents entering into a specification material for which there is a steady demand, can without fear of loss be purchased in large lots, and at the best stage of the market, thus securing the lowest prices. Whatever the causes, the effects on not a few materials are as stated. Of course, supply and demand are important elements in prices, and there will undoubtedly be fluctuation, but it would not be difficult to give instances in which this general tendency of specifications to lower prices is clearly seen.

Other points may be discussed or touched upon more or less at length, but I fear that I have already taken too much of your time. In order that what has preceded may be put into fairly concrete form, I beg to submit the following conclusions, as in a sense summing up what has already been said, and as putting on record our ideas on various points in the making of specifications for various materials:

1. A specification for material should contain the fewest possible restrictions, consistent with obtaining the material desired.

2. The service which the material is to perform, in connection with reasonably feasible possibilities in its manufacture, should determine the limitations of a specification.

3. All parties whose interests are affected by a specification should have a voice in its preparation.

4. The one who finally puts the wording of the specification into shape should avoid making it a place to show how much he knows, as well as a mental attitude of favor or antagonism to any of the parties affected by it.

5. Excessively severe limitations in a specification are suicidal. They lead to constant demands for concessions, which must be made if work is to be kept going, or to more or less successful efforts at evasion. Better a few moderate requirements rigidly enforced, than a mass of excessive limitations which are difficult of enforcement, and which lead to constant friction and sometimes deception.

6. There is no real reason why a specification should not contain limitations derived from any source of knowledge. If the limitations shown by physical test are sufficient to define the necessary qualities of the material, and this test is simplest and easiest made, the specification may reasonably be confined to this. If a chemical analysis or a microscopic examination, or a statement of the method of manufacture, or information from all four, or even other sources, are found useful or valuable in defining limitations, or in deciding upon the quality of material furnished, there is no legitimate reason why such information should not appear in the specifications. Neither the producer nor the consumer has a right to arrogate to himself the exclusive right to use information from any source.

7. Proprietary articles and commercial products made by processes under the control of the manufacturer cannot, from the nature of the case, be made the subject of specifications. The very idea of a specification involves the existence of a mass of common knowledge in regard to any material, which knowledge is more or less available to both producer and consumer. If the manufacturer or producer have opportunities which are not available to the consumer, of knowing how the variation of certain constituents in his product will affect that product during manufacture, so also does the consumer, if he is philosophic and is a student, have opportunities not available to the producer, of knowing how the same variation of constituents in the product will affect that product in service, and it is only by the two working together, and combining the special knowledge which each has, that a really valuable specification can be made.

8. A complete workable specification should contain the information needed by all those who must necessarily use it in obtaining the material desired. On railroads this may involve the purchasing agent, the manufacturer, the inspector, the engineer of tests, the chemist, and those who use the material. A general specification may be limited to describing the properties of the material, the method of sampling, the amount covered by one sample, and such description of the tests as will prevent doubt or ambiguity.

9. Where methods of testing or analysis or inspection are well known and understood, it is sufficient if the specification simply refers to them. Where new or unusual tests are required, or where different well-known methods give different results, it is essential to embody in the specification sufficient description to prevent doubt or ambiguity.

10. The sample for test representing a shipment of material should always be taken at random by a representative of the consumer.

11. The amount of material represented by one sample can best be decided by the nature of the material, its importance, and its probable uniformity, as affected by its method of manufacture. No universal rule can be given.

12. The purchaser has a right to assume that every bit of the material making up a shipment meets the requirements of the specification, since this is what he contracted for and expects to pay for. It should make very little difference, therefore, what part of the shipment the sample comes from, or how it is taken. Average samples made up of a number of sub-samples are only excusable when the limits of the specification are so narrow that they do not cover the ordinary irregularities of good practice in manufacture.

13. Retests of material that has once failed should only be asked for under extraordinary conditions, and should be granted even more rarely than they are asked for, errors in the tests of course excepted.

14. Simple fairness requires that when it is desired that

material once fairly rejected should nevertheless be used, some concession in price should be made. On the other hand, where a consumer buys material on specifications, it is equally unfair that he should ask from the producer any guarantees covering the behavior of the material in service. Furthermore, it almost goes without saying that where materials are for use in places involving the safety of life and property, rejected material should never be used.

15. Where commercial transactions are between honorable people, there is no real necessity of marking rejected material to prevent its being offered a second time. If it has failed once, it will probably fail a second time, and if return freight is rigidly collected on return shipments, the risk of loss is greater than most shippers will care to incur. Moreover, it is so easy for the consumer to put an inconspicuous private mark on rejected material, that it is believed few will care to incur the probable loss of business that will result from the detection of an effort to dispose of a rejected shipment by offering it a second time. In this connection it may be said that those sub-employees of producers who pride themselves on working off rejected material on consumers, may in reality be doing their employers a very serious injury.

16. All specifications in actual practical daily use need revision from time to time, as new information is obtained, due to progress in knowledge, changes in methods of manufacture, and changes in the use of materials. A new specification, that is, one for a material which has hitherto been bought on the reputation of the makers and without any examination as to quality, will be fortunate if it does not require revision in from six to ten months after it is first issued.

17. In the enforcement of specifications it is undoubtedly a breach of contract, legitimately leading to rejection, if the specified tests give results not wholly within the limits, and this is especially true if the limits are reasonably wide. But it must be remembered that no tests give the absolute truth, and where the results are near, but just outside of the limit, the material

may actually be all right. It seems to us better, therefore, to allow a small margin from the actual published limit, equal to the probable limit of error in the method of testing employed, and allow for this margin in the original limits, when the specifications are drawn.

18. Many producers object to specifications on the ground that they are annoying and harassing, and really serve no good purpose. It is to be feared that the complaint is just in the cases of many unwisely drawn specifications. But it should be remembered that a good, reasonable specification, carefully worked out as the result of the combined effort of both producer and consumer, and which is rigidly enforced, is the best possible protection which the honest manufacturer can have against unfair competition.

19. Many consumers fear the effect of specifications on prices. Experience seems to indicate that after a specification has passed what may be called the experimental stage, and is working smoothly, prices show a strong tendency to drop below figures prevailing before the specification was issued.

20. A complete workable specification for material represents a very high order of work. It should combine within itself the harmonized antagonistic interests of both the producer and the consumer; it should have the fewest possible requirements consistent with securing satisfactory material; it should be so comprehensive as to leave no chance for ambiguity or doubt; and, above all, it should embody within itself the results of the latest and best studies of the properties of the material which it covers.

THE INFLUENCE OF SPECIFICATIONS ON COMMERCIAL PRODUCTS.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY

DELIVERED BEFORE THE

AMERICAN SOCIETY FOR TESTING MATERIALS IN 1904.

In the annual address a year ago, an attempt was made to describe somewhat in detail how a specification for a commercial product should be made. In view of the importance which specifications have thus far assumed in the work of our Society, it has occurred to us that we might perhaps not unwisely spend a few minutes together over another phase of specifications, namely, the influence which a carefully worked out and rigidly enforced specification has on the successful manufacture of commercial products.

It may perhaps be remembered that in our résumé last year of the parties involved in a specification, two were regarded as of prime importance: namely, the producer and the consumer; that both were recognized as having the right to a voice in the formation of the specification; and that in reality a properly drawn, carefully balanced specification covering any commercial product was a protection and an advantage to both the producer and the consumer. In the present paper we shall perhaps not go amiss if we consider a little more closely the side of the consumer; indeed, we might perhaps have wisely chosen for our theme, "The Influence of the Consumer as expressed in Specifications on Commercial Products."

We are frank to say that it is our firm belief that the influence of the consumer on commercial products is far greater than is commonly supposed. We are so accustomed to regard the great mass of commercial products as so completely in the hands of the producer, as something that the consumer is quite at liberty to take up or let alone as suits him, and as something in whose preparation he, the consumer, has had no voice, that the idea that the consumer does actually have an influence on, or exert some force in giving shape and form, or in deciding on the qualities which the article shall possess, does not seem evident at first sight. And yet we do not hesitate to reaffirm that the influence of the consumer appears in every successful commercial product, however great or however small, and that the consumer's power over the product, although perchance not appearing in formal and carefully prepared specifications, is nevertheless many times fully as great, or even greater, than that of the producer.

Let us see if this can be made evident by an illustration. The commercial product in question is so simple an article as a pair of shoes. The producer or manufacturer has decided seemingly almost everything about them. He has determined the style, the shape and the size, the materials in the uppers, the vamps and the soles, whether it should be button or lace, patent leather, French calf or cowhide, pegged or sewed, black or tan, and so on in infinite detail. And in each of these items he has not consulted the consumer, has had no specifications to work to, and apparently the consumer's voice in the matter has been nil. He can purchase the shoes or leave them, as suits him best. The manufacturer has gone ahead and filled his warehouses, and perchance in his mind has figured up the profits on his year's work. But in all this, has, as a matter of fact, the consumer no voice? I trow yes, as many a manufacturer has found to his sorrow and loss, who has too greatly ignored the power of the consumer in matters of this kind. If the shoemaker has used cowhide when the consumer wants French calf, his shoes are unsalable. If he has made a No. 6 size when the consumer's foot happens to be No. 9, there is a misfit and no business doing. If he has his whole product broad toes when pointed toes are the style and hence demanded by the consumer, his commercial product can hardly be said to be a successful one and he will undoubtedly have to dispose of it as best he can, ofttimes at a loss.

But it may be urged, it is true, in staple articles of almost universal use, the silent influence of the consumer on the product is granted. He would be a shortsighted producer who would attempt to ignore the demands expressed or understood, nay, even the foibles of the consumer, or, what amounts to the same thing, would not study his market. But there are cases, such as the making of a new product for which a demand has yet to be created, where the influence of the producer on the product covers the whole field. The consumer does not yet understand the new product, does not yet know what kind of a material it should be, and hence can have no voice in its production. Take for an illustration the new high-speed tool-steel. The manufacturer seemingly decides everything in regard to this new product, independent of the consumer. He first learns how to make the steel, decides what its composition should be, learns how to treat it, practically changes all our ideas as to what heat will do to a piece of steel, and develops a new art of hardening and tempering, and after his studies are finished, comes forth with his creation and teaches the consumer how to use it. Surely it may be urged, in such a case as this, the influence of the consumer on the product is not apparent. But those who so argue, we fear, can have had very little experience at the birth and death of new things, many of them good new things, which might have had perchance a long life of usefulness if their sponsors had not attempted to ignore the legitimate influence which the consumer has on even new commercial products, the fruit apparently of the brain energy of the producer alone.

The influence of the consumer on new commercial products is usually made manifest in the price he is willing to pay for it. If the new product is higher in price in proportion to results obtained than that which he is at present using, or if, even though economies are shown, he conceives the price is unreasonable, he will usually go on as he has been doing in the past, with the result that the new product fails to be successful. Makers of new things far too often make one or both of two serious mistakes. They either fail to sufficiently study the present condition of the field which their new product proposes to occupy, and as a consequence make the product cost so much to manufacture that it cannot successfully compete with what is already in the field; or, having studied the field carefully and thoroughly and having developed a new product which is a decided step forward over present practice and which produces notable economies, they place a price on their product, such that the ultimate economy to the consumer is so small that there is no real reason why he should change. Not once, but scores of times, have we seen new commercial products fail from one of these two causes. The man who fails to study his field and makes his product cost too much should have our pity for his shortsightedness. The man who, having devised and worked out something new, which may be actually useful and valuable, and who claims for himself all the financial advantage of the step forward, will find, if our observation and experience are worth anything, that he is killing the goose that may lay golden eggs for him, and that the disappointment which will inevitably follow his action is no more than a just punishment for his attempt to ignore the right of the consumer to a share in the advantage which comes from the progress of knowledge. This is hardly the time or the place to discuss this point to a conclusion, but we cannot help feeling that the legitimate sphere of the consumer is far too often almost completely ignored by those who are developing and exploiting new products. The point which we are trying to make is that always and everywhere, in every successful commercial product, the producer and the consumer each has a legitimate sphere, and that any attempt on the part of either to ignore the other will result in disappointment and failure. As we have tried to urge on other occasions, it is only by working together, by each respecting and honoring the rights and privileges of the other, that successful results can be obtained.

There is another view of this case, which will perhaps bear a few moments' consideration. A sound commercial transaction is one from which both sides secure advantage. A producer has something to sell, from which he hopes to reap the reward of the successful business man. How shall he best accomplish this?

Surely not, as is too often the case, by trying to give the buyer or consumer that which he may happen to have in stock, whether it is fit or not, and trying to persuade him that it will be found all right; but, on the other hand, by trying to understand what the consumer really needs, and devoting his energies to furnishing that thing and nothing else. Or again, a consumer has a want and goes to a producer for something to meet that want. Shall the producer, for the sake of the immediate transaction, supply that which he knows will not give ultimate satisfaction? The temptation is certainly great, and the loopholes and possible explanations of failure are so many that it is to be feared in too many cases the transaction is accomplished without due regard to its effect on subsequent business. But I stoutly maintain that such procedure is shortsighted business policy, and that far too soon those who habitually do not give satisfaction will find their customers slipping away from them. In business parlance, "they cannot hold their trade."

These business truisms would have no place in the theme which we are trying to discuss, except as they illustrate again the intimate relation between the interests of the producer and the consumer, and especially the influence which the consumer has on the successful commercial product.

Thus far we have considered the influence of the consumer, which is, so to speak, not expressed. It is a silent influence, an unwritten specification, one real and tangible in its effects, but which has never attained to the dignity of being expressed in words or print. But our real theme is the influence of carefully worked out, written or printed specifications, which are rigidly enforced, on commercial products. Perhaps we shall best bring out what we have in mind on this theme, by dipping into the history of some of the forty or more specifications which have been prepared at Altoona during the past twenty-five years.

The history of the Lard Oil Specifications is an instructive one. When they were first prepared, now over twenty years ago, two grades of lard oil were in common use by railroads, known as "Prime" or "Extra," and "No. 1 Lard Oil." The former, which was the best oil that could be made from the materials, was largely used as the principal constituent of what is commonly known as "signal oil," the oil which the conductors burn in their lanterns, and which at that time was used also in almost all signal lanterns everywhere. The function which this oil must perform is a very important one, since the safety of trains depends on the reliability of signals. The other grade, or "No. 1 Lard Oil," was and is principally used for lubrication. Both these oils, when pure and of good quality, gave excellent results in the places where they were used. The prices of both were high, the better grade often reaching a dollar a gallon, and the inferior grade from seventy to eighty cents per gallon. The better oil is light amber in color, while the poorer is inclined to red, and, as the quality diminishes, becomes more of a brown. The better oil is made from lard that is taken from freshly killed hogs, and is sweet and good enough to be used in cooking. The poorer oil is made from second or third grade lard, known in market as "No. 1 Grease" or "No. 2 Grease," and usually comes from hogs that have died in transit. All the animal fats, as is well known, are glycerides; that is, when they are in the animal, at least in good health, they are some characteristic fat acid, chemically combined with glycerine. But as soon as the animal dies from any cause, decomposition apparently sets in, one of the results of which is the separation of the fat acid from the glycerine. This separation is apparently also facilitated by the operation of rendering. Whatever the cause, the better grade of lard oil usually contains from one to four or five per cent. of free fat acid, and the poorer grade may contain from ten to twenty-five per cent. of the same. The influence of this free fat acid on the service of these two oils is deleterious. Careful experiments, many times repeated, show conclusively that a signal oil made from a prime lard oil containing the higher percentages of free fat acid given above will go out from crusting the wick much sooner, requires more frequent renewal of the wick and greater care, and is in every sense a less reliable signal oil than one made from a lard oil containing less free fat acid; while in the case of the poorer grade of lard oil, it is found that the more free acid it contains, the poorer it is as a lubricant, and the more rapidly the journals and bearings disappear by wear. All this detail is necessary in order that what follows may be understood.

About a year or perhaps two or three years before the Lard Oil Specification was made, a new product came forward, which has continued to the present day, which had added greatly to the wealth of the South, and which appears in more places in our modern civilization than many of us are aware of. The oil referred to is made from the seeds of the cotton plant, and is commonly known as cottonseed oil. This oil is a beautiful bright, clean, almost odorless material, containing very small amounts of free fat acid, but in its properties is unfortunately on the border ground between the drying and the non-drying oils, having some of the characteristics of both. It is not enough of a drying oil to be used successfully in paints, and on the other hand is too much of a drying oil to be used successfully either for burning or lubrication. It crusts the wicks, and the light goes out in four or five hours; and it gums so badly as to be almost useless for lubrication. The price at the time of which we are writing was fifty cents a gallon.. What now could be more natural than that this oil in some way should find its way into the lard oils which have been described above. It diminished the free fat acid of both grades, and especially improved the appearance and apparent salability of the poorer grade, to say nothing of the delicious rake-off of from twenty to fifty cents for every gallon of it used in the mixture. That it was being so used was suspected by consumers for some little time before the Lard Oil Specification was prepared, but it was only a suspicion; the chemistry of oils was at that time so poorly understood that no one could prove it. The use of the oils in service indicated it, but that was all. A couple of weeks' rather hard study in our laboratory developed a test which about a year later was independently developed by another observer and published, which made it possible to say with rather remarkable certainty whether a sample of lard oil was pure or not. It was not always possible to say what the admixture, if any, was; but if cottonseed oil was present, the amount could be told to within one per cent. Also a method of determining free fat acid in oils was developed.

Armed with these two tests, the oils of the market were questioned. At first, small samples were obtained and examined before orders were placed, it being required simply that shipments should be like the sample. The first month's samples numbered thirteen, and only three were found to be pure and of the proper quality. The next month's samples numbered seventeen, of which seven were satisfactory. In the course of a few months, or as soon as the trade became convinced that only those who furnished samples which were free from admixture of other oils, and were satisfactory in other respects, would get orders, all the monthly samples would pass the necessary tests, except that occasionally a new party would be asked for samples, in which case it usually took two or three months to convince him that nothing but straight goods would pass muster. But now a new difficulty arose. The samples would be all right, but the shipments or deliveries would be all wrong. Not a few contests were characteristic of those days, which contests were marked on the part of the producer by wordy assertions, by appeals to business reputation and standing, and by threats of litigation, and, on the part of those in charge of the purchase and use of the goods, by a quiet determination to defend to the death the interests committed to their care. Not yet in this particular industry had the producer learned that there were limits to his power over his own product, and that the consumer had rights which even he, the maker and owner, must not ignore. Fortunately, notwithstanding the bluster, the strife was confined largely to words; and after the affray, which lasted a year or more, was over, it was found that the conflict had resulted, so far as the producer was concerned, in some loss of business, in some financial loss due to paying return freight charges on rejected shipments and in traveling expenses to Altoona for the word combats above referred to, and also in a serious loss of business reputation. It is perhaps not too much to say that, as a matter of fact, within a year or a year and a half after this contest began, not a few of those who for years had furnished lard oil were stricken off the purchasing agents' lists, and to this day have not succeeded in reinstating themselves. On the part of the consumer, the results of the contest were gratifying. Improvement in the service immediately followed, and bills were paid with the knowledge that a full honest equivalent was furnished for the money spent. The information accumulated during these few months of contest was ultimately embodied in specifications, and for many years now, although hundreds, perhaps thousands of shipments have been tested, there has been scarcely a rejection for failure to meet requirements. Perhaps more important than all, a beginning had been made toward the establishment of a principle: namely, the influence and rights of the consumer in any commercial product, if it hopes to be successful, can never be ignored or lightly set aside. The special teaching which we would draw from this episode, as applicable to our theme, "The Influence of Specifications on Commercial Products," would be that enforced specifications protect the honest dealer from unfair competition. The concomitant protection against purchasing an inferior product at the price of a better one, and against using inferior materials in most important service which they give the consumer, will not escape notice.

Perhaps some additional side light on our theme may be thrown by the history of another Altoona specification. It is now perhaps twenty-five years ago that a certain special car happened to fall under the eye of one of the officers responsible for the maintenance of equipment, who observed that the varnish on the outside seemed to have perished almost completely, and that the integrity of the painting underneath was in consequence seriously threatened. The car was sent to the paint shop for special examination. The shop reported that the car had been varnished at so recent a date that ordinary wear would not warrant its present condition, and that the loss of varnish was probably due to excess of zeal on the part of the car-cleaners. The matter was referred to the foreman of the car-cleaners, who reported that they had given the car a pretty good treatment, but that really they could not be held responsible for any better results with the soap that was furnished to them. In order not to be set aside and diverted from his efforts to secure efficiency by the customary attempt on the part of subordinates who are called to account, to transfer the blame to some one else, the officer above referred to asked for a sample of the very soap used, and a partly used cake was furnished and sent to the laboratory. Now ordinary cleaning soap, as is well known, is a chemical compound of the various acids characteristic of vegetable or animal fats with either soda or potash or both. The combination is brought about by the aid of heat, the fats being mixed with the soda or potash in water solution, and the resulting product always containing more or less water as a necessary concomitant of the manufacture. Potash, being more expensive than soda, is less often used; also, potash soaps are softer than soda soaps. But, as is well known, the physical condition of a soap as to hardness is an important element in its successful use. Moreover, the nature of the fats used has a most important influence on the hardness of the soap. The soft animal fats whose characteristic fat acid is undoubtedly largely oleic, when saponified give a more or less soft mushy soap which is uneconomical to use, is less easy to handle both in manufacture and transportation, and is often unsalable in appearance. These objectionable characteristics are largely increased by the practice, so common among soapmakers, of adding a percentage of rosin to the fat. Tallow which contains a considerable percentage of stearic acid makes a much better soap. But tallow is more expensive than the soft fats and rosin. Accordingly soapmakers have sought for devices that would harden soaps made from the soft fats and rosin, and it has been found that an excess of alkali, and especially a percentage of carbonate of soda added toward the last, and thoroughly mixed with the soap before it cools and hardens, produces the result desired.

Returning now to the partially used cake of soap. A careful analysis of this sample showed that it contained, in addition to the alkali necessary to combine with the fat, about three and a half per cent. of free caustic soda, and over seven per cent. of carbonate of soda. It will thus be seen that the water solution of this soap which the men were using to clean the cars with, was in reality a weak lye containing quite an amount of sodium carbonate. But both lye and carbonate of soda in solution readily dissolve varnish; nay, even the combined alkali of a normal soap dissolves varnish to a certain extent, but very much more slowly than free caustic or carbonated alkali, even though the latter may be in very dilute solution. It is evident that the contention of the men in this case had a foundation of fact, and while it is recognized that the manipulation—that is, the method of using the soap solution—is a most important element in the problem, it is unquestioned that in the hands of the ordinary car-cleaner, such a soap as has been described will result in a much more rapid destruction of the varnish than if a normal soap were used. This incident led to the formation of specifications for soap in which the amounts of free caustic and carbonated alkali were limited, and no similar case of very rapid varnish deterioration has since been noticed.

Now this case has not been cited to show that the producer had any desire to ignore or set aside any of the rights or even desires of the consumer, or to obtain for himself any undue ulterior advantage at the expense of the consumer. In reality the producer was furnishing more detergent power per pound of soap than is characteristic of the normal article, since both free caustic and carbonated alkali are much stronger in detergent power per pound than the combined alkali of soaps. There is apparently no reasonable ground for an attempt to hold the soapmaker responsible for the injury to the varnish, and we cannot help regarding this episode as illustrating the influence of specifications on commercial products in this, that they tell the producer what the consumer wants. It is not to be supposed that the producer will know all the uses to which the consumer will apply his product, and without cooperation on the part of the latter, or as we have so many times urged, without the two working together, the producer may with perfect honesty make and furnish the wrong product.

Perhaps you will bear with me a few minutes longer. Our theme is so prolific that I fear I shall strain your patience. But I cannot deny myself one more illustration of the influence of specifications on commercial products, this time from the field of steel metallurgy. No individual specification, but rather a group of specifications, will be considered. For our purpose it will be sufficient to choose from the innumerable uses of steel three grades, soft, medium and hard. Let the boiler and firebox steel specifications represent the first, the axle and crankpin specifications represent the second, and spring steel specifications the third. Now it is well known that the grades of steel defined by these specifications differ from each other principally in the amount of carbon which they contain. The limiting amounts of the other constituents are of course not all alike, but the principal difference making the various steels applicable to their designed use is in the carbon, approximately 0.18 per cent. for boiler and firebox steel, 0.45 per cent. for axles and crank-pins, and one per cent. for spring steel. When these specifications were first drawn, some of them provided only for physical tests, some for chemical tests only, and some for both. Whatever the method of testing the shipments, however, when the specifications were first made, they provided only lower limits; that is to say, in firebox steel, a minimum tensile strength and a minimum elongation were specified. The manufacturer might furnish a product as much above these minimum limits as he chose. Exactly the same restrictions applied to the axle and crank-pin steel. In spring steel, a minimum content of carbon was given with no upper limit. Two or three reasons led to this procedure: First, there was the desire to leave the maker the widest possible freedom in the manufacture of the material; second, there was at that time no known reason why there should be any upper limit; and third, it was actually thought that a minimum limit in strength and elongation being secured, or a minimum amount of carbon, the product would really be better the more these minimum limits were exceeded. But as time progressed, and especially as the study of parts that had actually failed in service—that never-ending source of valuable information—became wider and wider, it began to appear that an upper limit likewise was a desideratum in specifications. The boiler plate, when there was no upper limit, occasionally gave difficulty in the shops in flanging and cracking at the bends; and an analysis and physical test of such plates demonstrated beyond question that the carbon and the tensile strength were too high for successful hand-flanging at such temperatures as are usually employed in this operation. Axles and crank pins which under the slow-moving strain of a tensile test, or under the drop test as then carried out, would quite fill the requirements, would not infrequently fail in service, either by breaking in detail, or as the analysis would frequently show, due to an improper proportioning of the chemical constituents. Spring steel with a lower limit of carbon only would occasionally fail in service, owing apparently to over-hardening with the very high carbons, or would give difficulty in the shops when working it, owing to the wide range of carbon in a shipment.

Moreover, as the knowledge of the influence of carbon, and especially of manganese and silicon, on the physical properties of steel increased,—and especially once again as the analysis of parts that had either broken or failed in some other way in service, or had given difficulty in the shops, began to increase and become an element in the making of specifications,—it became evident that the chemistry of steel was destined to play a continually more and more important part in obtaining a metal that would give best results. Accordingly, it was decided to revise existing specifications and introduce both an upper limit in tensile strength, and also as much chemistry with both lower and upper limits, especially in the carbon, as the information at hand seemed to indicate was necessary to secure the proper material. But upper and lower limits of carbon involve the idea of a range. How much shall the upper limit be above the lower limit? Obviously, if the range was too narrow, the steel maker would find it difficult, if not impossible, to make the metal. On the other hand, if the range was too wide, it would go far toward defeating the end to be accomplished by the introduction of upper and lower limits. In view of this dilemma it was with some misgivings that specifications embodying these features were prepared and issued. The limits finally decided on were from 0.15 to 0.25 per cent. of carbon, or a range of ten points, for soft steels such as firebox, from 0.35 to 0.50 per cent. or a range of fifteen points for medium steels, such as are used in axles and crank pins, and from 0.90 to 1.10 per cent. or a range of twenty points for hard steels such as are employed in making springs. It is gratifying to be able to state that the limits have not proved too narrow. With very few exceptions the steel makers have cheerfully and successfully worked within these limits. Is it too much to say that twenty years ago this would have been thought impossible? How many steel makers twenty or twenty-five years ago felt sure enough of their furnaces and their methods so that they would be willing to take orders and guarantee successful outputs on such limits as these? It of course is not claimed or even thought that this decided step forward in steel metallurgy is wholly due to specification, but is it too much to claim that the results now possible are in part, at least, due to the stimulus put upon the producer by the demands or desires of the consumer as embodied in specifications?

There is another phase of this stimulating influence of specifications on commercial products that will perhaps bear a word. In our experience, the first draft of a specification for any commercial product not heretofore bought on specifications is apt to contain not a few uncertainties. The consumer has been taking what the manufacturer gave him, without special study of its behavior in service, and the producer has been sending what the consumer would take, contenting himself in his study of his product usually to such problems as affected his successful output. Neither the producer nor the consumer rightly understand the material, the consumer because he has not yet carefully questioned the service as to what are its demands in the matter, and the producer because he knows his product principally at least only from the standpoint of a maker, and the consumer has not yet told him his side of the story. Accordingly, a first-draft specification, as already stated, is usually founded on more or less incomplete knowledge, and will be fortunate if it runs eight months or a year without revision. But when a material arrives at the dignity of being bought on specifications, and every shipment is examined, much more attention is paid to its behavior in the service, and indeed every characteristic of it is studied. This study not infrequently leads to the idea that modifications in the product are not only desirable, but ofttimes essential if the usefulness and adaptability of the material in the place where it is being used are to be maintained. Moreover, the growth in size of almost everything connected with railroads is not only demanding continually new designs to meet the increased strains, but also, in view of the limitations of space, constant changes in the nature of the materials employed in construction are likewise essential, if unwieldy not to say impossible designs are to be avoided. A few illustrations will perhaps make these points clear.

The mass of the first steel used in fireboxes contained from 0.10 to 0.13 per cent. of carbon. But a few years of service developed the fact that such soft lead-like steel was badly abraded by the coal, and failed to satisfactorily hold the thread on the stay bolts. Hence, in the specification at present in force, a harder metal, whose carbon has already been given, was asked for. This change introduced no serious difficulties in manufacture, and very large quantities of the harder product have been furnished, and more successfully used, for some years now.

The first steel passenger-car axles contained from 0.22 to 0.26 per cent. of carbon. But in the course of a year or two a number of these soft axles broke in detail, and a study of the case led to a demand for a stiffer steel for this purpose. Accordingly, when the present chemical specification for axles was prepared, the limits of the carbon were placed at from 0.35

to 0.50 per cent., as has already been stated. These proposed limits led to no small amount of discussion. At that time few if any axles had ever been made containing over 0.30 per cent. of carbon. It was feared that even though the proposed metal might be successfully made in the furnace, it could not be successfully forged. One steel maker told us in plain language we were making a most serious mistake, and that we would rue it. Another opposed the proposed specification in every reasonable way possible, and only took an order under it with the utmost misgiving. It is gratifying to be able to state that this latter maker of axles has within two years stated that the present axle specification was in every sense a most satisfactory one, and hoped it would never be changed. So great was the uncertainty and doubt about the ability to successfully make axles in accordance with this specification that the first deliveries were actually billed at 3½ cents a pound. Within four months the price dropped to 1¾ cents. Furthermore, a couple of years ago indications began to manifest themselves that even the present axle specification required modification in such a way as to require a stiffer metal still. Accordingly a number of steel works were visited and the matter talked over with the experts, as to whether they would be willing to try to make axles with from 0.50 to 0.65 per cent. of carbon. No one was found willing, but within six months word was sent by one of the works that they would gladly try it. Under the stimulus of the request, experiments had been made which promised a successful outcome, and although the question of stiffening the present axle has not yet been decided, there seems no good reason to fear that if higher carbon is decided on as the best solution of the problem, there will be any difficulty in obtaining it. Ten years ago we would have hardly dared to hope for it.

One more illustration of the stimulating effect of the consumer on commercial products, and I have finished. It was for a long time customary to use only crucible steel in making springs, either helical, elliptic or semi-elliptic, and in these springs the carbon employed was usually from 0.65 to 0.75 per cent. The service of these springs was very unsatisfactory. The breakage was something appalling, such that at some of the important repair shops a car-load of broken helical springs would accumulate in a few months. At that time the spring makers decided on both the kind of steel to use and the design. They were given the space that could be allowed for the spring, and the load it must carry, and they did the rest. In fairness it should be stated that the conditions were severe, and that apparently neither producer nor consumer understood the situation. Very few tests had ever been made, and apparently the strains in the metal had never been calculated. The matter was taken up with some vigor by the consumer's experts and an attempt made to get an understanding of the situation. It developed that when some of the helical springs then in use were brought down solid, the strain in the outside row of fibers was over 110,000 pounds per square inch. What wonder that the springs broke! As a result of the study of the matter, a specification was prepared covering both the design and the quality of steel to be used. In view of the small space available, and with the tendency toward increasing loads already mentioned, it was felt that every advantage must be taken, and accordingly a round bar was decided on as being best able to resist the strains, instead of the flat or oval, which had previously been used; the maximum fiber stress was placed at 80,000 pounds per square inch, instead of the indefinite 110,000 pounds or more which had been characteristic of previous practice; and also a one-per cent. carbon steel was specified instead of 0.70-per cent., as had previously been used. Still further, no mention was made of the process by which the steel should be made.

This proposed specification likewise met with some antagonism. It was urged, not without a good deal of show of reason, that crucible steel was the only fit material to use in making springs, and that so hard a steel as is given by one per cent. of carbon would be unreliable and probably cause more difficulty than had heretofore been experienced. It should perhaps be added for information that at this time the possibility of making a high-carbon steel in the open-hearth furnace had not been fully demonstrated, and that this proposed spring specification, leaving out the process by which the steel should be made, was a direct stimulus in the development of this method. The crucible steel people were therefore naturally a little anxious. It is undoubtedly well known that at the present time by far the largest portion of the steel used in springs is made in the open-hearth furnace. Notwithstanding the antagonism, the specification as drawn was sent out, and although there were some difficulties at the start—one spring maker at least refused to fill orders—it soon became evident that the specification was going to survive. The results in service were most gratifying. When thirty thousand helical springs according to specifications had been put in service, a count was made of those which had broken, and only two were found. After three or four years, when there were perhaps two or three hundred thousand of these springs in service, a request was sent to one of the principal repair shops to send twenty broken springs to the laboratory, in order that the relation between phosphorus and broken springs might be studied. At the end of three months, only twelve had been secured, and these were used as the basis of the investigation. The effect of the specification on the producer was equally satisfactory. Special and patented forms of bars absolutely disappeared; the open-hearth steel makers soon learned how to make with perfect success a high-carbon steel; and from being antagonistic the spring makers soon changed to the warmest friends of the specification, and recommended it everywhere to other railroads. It is perhaps not too much to say that ninety-five per cent. of all the freight cars built in the United States within the last twenty years are fitted with helical springs closely patterned or made in accordance with the specifications whose birth we have been trying to describe.

It would be easy to continue this discussion to almost any length, but I spare you. Nearly every one of our forty or more specifications at Altoona has a more or less interesting history, and some of them would illustrate points in our theme which we have not been able to bring out. But I fear this paper is already too long, and that I have wearied your patience. The conclusions from the episodes given and from the incidents recounted have perhaps been made sufficiently clear as we have gone along in our discourse.

But I am sure you will bear with me while I give you one general conclusion which to our minds sums up the whole matter: namely, the influence and voice of the consumer in the manufacture of commercial products have come to stay, and it is simply the part of wisdom for all concerned to recognize the situation. Also, since both the producer and consumer have each a direct interest in the product or thing made, the one in its production and sale, and the other in its use, there is no real reason why each should not study the product in most minute detail. If the producer knows better than the consumer, as he undoubtedly does, the effect of composition and details of manufacture on the thing made, so also does the consumer, if he studies as he should the behavior of materials in service, know better than the producer knows or can know the relation between the composition, the physical properties, or even minute characteristics of the thing made and its successful use. It is only by the combination of information from each of these two sources that perfectly successful commercial products can be obtained. Finally, if these views are accepted as correct, is it not evident that all energy spent in antagonizing each other is so much lost effort, and that the true policy is to work harmoniously together in our attempt to convert the crude materials of Nature into a shape to be useful in the service of man?

THE TESTING ENGINEER.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY

DELIVERED BEFORE THE

AMERICAN SOCIETY FOR TESTING MATERIALS IN 1905.

The gradual widening of the scope of the word "Engineer" is very interesting. Used apparently as long ago as the time of William the Conqueror, to designate men who had the ability to design and construct works of value, such as castles, or fortifications, or bridges, especially in connection with military affairs, it soon took on a wider meaning, and was properly applied to men having ability to design and construct works of practical utility in times of peace. The military men having simply been called "engineers," it became desirable to designate those who were doing similar work during peace times in some way to distinguish them, and accordingly, in contradistinction from the military engineers, they were called "Civil Engineers," a designation which remains up to the present and which characterizes some of the ablest men of the time. It would hardly be possible, or perhaps worth our while, to attempt to follow up historically the successive developments of this word "engineer." Suffice it to say that as time progressed, those who were able to design and construct something of value in the realm of mechanics, or other fields of human effort, were called "Mechanical Engineers," "Mining Engineers," "Naval Engineers," "Electrical Engineers," or, indeed, "Chemical Engineers." It is worth while to notice also, that as time has progressed, the meaning of the word, as well as its application, has broadened. Primarily applied apparently to one who had genius born in him, and therefore who had within himself the power to originate and to execute, in course of time we find the term applied to those also who simply direct, or carry to successful conclusion something they may have taken in hand. Indeed at the present time, the one who controls the machinery of a ship, as well as the one who handles the throttle of a locomotive, is called an "engineer." And, finally, it is apparently no abuse of words to say of a man who has guided any scheme in which he was interested with ingenuity and tact, or overcome obstacles by contrivances and effort, that he has successfully engineered his project through. In view of these thoughts, we are perhaps justified in regarding the man engaged in testing as an engineer, and not only in choosing "The Testing Engineer" for our title, but also in discussing in some of his relations that man who, if we read the signs of the times rightly, is becoming every day more and more prominent in the industrial world, and, as time progresses, is destined to play continually a more and more important part in the development of our civilization.

The field which the testing engineer occupies, and the cause to which his loyalty is due, may perhaps wisely claim a few moments' attention. It is plain that the testing engineer acts in a three-fold capacity: he is either an investigator, or a counsellor, or a judge. He is finding out new truths; he is protecting the interests of his client the producer; or he is determining by his tests that contracts are being fulfilled, or specifications lived up to, in the interests of his client the consumer. While all three forms of testing engineer may be and often are engaged in research, in investigating a knotty problem, or in devising means of demonstrating a point, it is perhaps more commonly the work of what may be called the "unattached testing engineer" to make investigations. The professors in colleges, especially those having a genius for experiment, and indeed independent investigators who, as the result of business shrewdness or by good fortune, are so situated that they are not compelled to struggle for an existence, are continually adding to the sum of human knowledge by their tests and experiments while laboring in this field. They have no clients to satisfy, no employer's interests to defend, and no antagonisms to overcome, except perchance the unwillingness of nature to yield up her secrets. Their loyalty is to the truth alone; their stimulus, their zeal for knowledge and their reward, the approbation of their fellows. These seem to be almost ideal conditions for securing the truth, and it would seem as though results obtained by such experimenters, or testing engineers, and under such conditions, ought to be accepted and acted on without question. But we venture to suggest that there is one desirable, not to say essential element, in the search for truth, that is lacking in the conditions outlined above. This is the element of human antagonism.

Perhaps an example will best make the point clear. The subject for investigation we will say is a method for determining phosphorus in steel. The professor or independent investigator makes his studies and experiments, and publishes his results. During the whole investigation he had been actuated by no desires, except to get at the truth. There has been no temptation, except perhaps the desire to finish the investigation, to stimulate him to neglect any essential point, to give any results or draw any conclusions that the most rigid interpretation of the facts would not warrant, and hence so far as accuracy is concerned, it would appear as though no questions should be raised. And yet, so great is our belief in the value of human antagonism where the truth is involved, that we cannot help saying that we would prefer a method which resulted from the contentions of two chemists, the one of whom was the employee of a consumer and who was trying to make out that the sample on which they were both working contained more phosphorus than the specifications allowed; and the other of whom was the employee of the producer and who was trying to show that the phosphorus in the sample was below the requirements of the specifications, there being a large commercial transaction involved in the result. We cannot help feeling that every point in the method would receive much more severe criticism, and consquently if it survived would be much more worthy of confidence under these conditions, than if it were brought out by a single experimenter making investigations for the sake of publishing them. So greatly does the legal fraternity rely on the element of human antagonism as an essential feature in the development of truth, that we are entirely safe in saying that the whole structure of legal procedure is based on this foundation. It may not be amiss here also to quote from one of our instructors in chemistry, who had reached the philosophic age, and who in a very dry way used to say that during his active work he had tested many published methods in analytical chemistry, which, for some reason, not necessary to explain, always apparently gave better results in the hands of those who devised them than he was ever able to get from them. We fancy it hardly needs saying that in this matter there is no intention of questioning the integrity or reliability of investigators who are studying the truth for the truth's own sake. The point we had in mind was to suggest the thought that perhaps those who are accustomed to glorify pure science may have overlooked one fairly important element in the development of truth.

Returning to the testing engineer: As already indicated, the field of work of this important element in the industrial world seems to be either to find out new things, or to protect the interests of the producer or consumer. And there are three kinds of testing engineers to occupy these two fields: namely, the unattached engineer, the consumer's engineer, and the producer's engineer. At first, there were apparently only two kinds of testing engineers: namely, the unattached and the consumer's. But it did not take long after consumers began to study and test materials and prepare specifications, before the producers found it necessary to protect their interests and defend their materials by means of testing engineers in their own employ.

It is perhaps hardly necessary to say that in this, our analysis of the scope and field of the testing engineer, we have not forgotten the various inspection bureaus and testing laboratories which are doing such excellent work in various parts of the country. As we understand the matter, these organizations, while perhaps not strictly covered by the definitions given, in that they do not derive their continuous sustenance in such a way as the unattached testing engineers, nor in the same way as those who defend the interests of the consumer or the producer, and in that they have an independent organization, and owe loyalty only where it is paid for; yet in a certain sense these independent organizations do perform exactly the same functions as the three classes of testing engineers which we have described. Any one of them will make investigations either in the interests of a client or for the sake of the truth alone; any one of them will temporarily, or continuously, if the retainer be sufficient, defend and care for the interests of a consumer, or will render a like service for a producer, provided, of course, that the interests of the two are not antagonistic at the same time. So that we cannot help feeling that the three kinds of testing engineers mentioned, the unattached, the producer's and the consumer's, fairly well cover the field.

What now shall be the cast of mind, and what the mental equipment of the testing engineer? Upon the first of these topics, it is difficult to say much that is positive. It is perhaps easier to say what kind of mind will not succeed in this branch of engineering, than to say what the positive requirements of a successful testing engineer are. We will perhaps all agree that he should be independent, self-reliant, gifted with the power of analysis of facts, as well as with the power of drawing conclusions from the data at hand. He should be ingenious in devising methods to demonstrate the points at issue, and a careful observer of data. He must keep himself free from bias or prejudice, and take especial pains that he does not deceive himself. He should be fond of experiment and have a genius for it. Many times during our nearly thirty years' attempt to do something in the line of the work of a testing engineer, we have had occasion to paraphrase the Latin apothegm and say, "experimenters are born, not made." He should keep constantly in mind the end to which his experiments tend, and understand clearly the effect of every step in the progress of his tests, and its influence on the final result. Above all, he should be a thinker. No man who, when a problem is presented to him, simply searches his memory for whatever he may have learned in the schools, or have perchance picked up in his reading, which bears on his problem, has any especial call to be a testing engineer. We are quite ready to allow that the power of seeing analogies between your own problem and one that some one else has had, and perchance successfully solved, is a legitimate and useful, not to say time-saving habit of mind; but the point we want to make is that the one who habitually and continuously approaches every problem through memory, or by studying up what others have done, is far less likely to succeed as a testing engineer, than one who habitually attacks a problem by an analysis of its elements.

But it may be urged, if experimenters are born, not made, and if so much depends on cast and habit of mind, what can the schools do in the way of training and furnishing mental equipment to produce successful testing engineers? We answer much, every way. While it is probably not possible for any school to make a thinker out of a dreamer, or a successful experimenter out of a numskull, we still claim that, given ordinary fair mental endowment, it is possible for the schools to make successful testing engineers, or to spoil the material they start with.

It hardly comes within the sphere of this paper, or coincides with our present purpose, to say anything about the curriculum of studies best calculated to fit a man to be a successful testing engineer. This is neither the time nor the place for such a paper, although we may possibly say something a little later about the self-education of the one who expects to spend his energy in this field of work. At this place we will, however, touch upon one or two points in connection with methods of teaching. Our observation of what the world wants to-day, not only in the field and work of testing engineers, but also in almost every other field, is men who can think; men with minds so trained and so fitted with mental equipment, that when unexpectedly and for the first time put in presence of a combination of circumstances, where action is necessary, they will know what to do and how to do it. This may look like a very severe dictum to apply to recent graduates, with their limited experience and small accumulation of facts, and yet we cannot help feeling that in some degree this dictum may legitimately be applied even to them, and that if they have been properly trained by the schools they will show in some measure a capacity for meeting unexpected and unforeseen emergencies. But it may be asked, what teaching and what training leads to the development of this capacity? We answer, that while it is undoubtedly true that the mental characteristics of the student himself are a most important factor, and that it is clearly impossible to make thinkers of every student in the class, yet as we understand the matter, that teaching which brings out and keeps prominent before the mind of the student the principles underlying the theme which is under consideration, be the subject of study whatever it may, rather than that teaching which fills the mind of the student with methods, with manipulation, and with accumulated information, embracing a taste of many subjects, will have a tendency to develop the kind of mind we are looking for. A somewhat extensive acquaintance with recent graduates from the chemical schools for a number of years past, has led us to fear that methods, manipulation and accumulated information were given undue prominence, and that principles and reasons why were not sufficiently insisted upon. We are clearly of the opinion that the schools truly desire to furnish what is wanted, and that the situation as we seem to find it, is due to the effort on the part of the schools to turn out their graduates, fitted to at once begin to earn a livelihood or perchance to take charge of independent work. We are compelled to say that, while the motive seems praiseworthy, and a legitimate yielding to the demands of the times, we cannot help feeling that many a graduate will, under such tutelage, fail to reach the success which, with a different method, would have been legitimately in his grasp.

Perhaps an illustration will make clear the difference in methods of teaching which we have in mind. Not long ago we separately asked three recent graduates, each one from a different, entirely reputable school, why nitric acid is used to dissolve steel, when one is going to determine the phosphorus. Why not use some other acid just as well? Two of the three replied that they supposed that nitric acid was a good solvent for steel, and they knew of no reason why any other acid that would dissolve the steel would not do as well. The third answered that in order to take the next step in the process, it was essential that the phosphorus should exist as ortho-phosphoric acid, and that nitric acid being an oxidizing agent would bring the phosphorus to that condition. Now each of these three recent graduates knew how to determine phosphorus in steel, and as a matter of fact each of them had done it in an entirely acceptable manner and under check for six months or more in my own laboratory. All three of them were familiar with the method and with the manipulation. But as we look at it, only one of them had been properly taught. He not only knew the method and the manipulation, but he also knew the reasons why, and the principles underlying the method. One of my assistants put the matter very forcibly. He said: "The chemist who knows methods and manipulation gets along swimmingly as long as everything goes well, and perhaps turns out more work in a day than a thinking chemist who understands the reason why for every step in his analysis; but let a difficulty arise, and your method chemist is absolutely lost."

There is another phase of this case which is perhaps worthy of a moment's notice. Given two young men of equal ability, and let both of them go through good technical schools, both graduating say as chemists, or as mining, mechanical, civil or electrical engineers. The one during his course of study has covered much ground, has stored his mind with facts, has learned carefully, and well, the methods and manipulation required in the branch chosen. The other has not covered so much ground, but every bit of information that he has, he thoroughly understands; he has acquired principles rather than a large array of facts, and he knows the reason why. Let now these two begin work after graduation in the same place, and we are ready to confess that the former will make the best showing, and progress the more rapidly for the first year or two; but if our observation is worth anything, the latter will distance his competitor at the end of ten years.

But we are perhaps spending too much time over this point. The mental equipment which the schools furnish is only a fraction of that needed by the testing engineer, especially if he happens to have it as his field of work, to defend the interests of a great consumer. It is legitimate and reasonably to be expected that the schools should teach a young man how to learn, and should start him in a number of subjects; but his real education comes later. We often say to our young men that the two things that a recent graduate needs most are experience and acquaintance. Under the head of experience, we comprehend the arranging of the information already acquired, so that each part will have its due, and only its due prominence, the accumulation of additional information, either by reading, by close and continuous study of his main theme or related branches—we fancy it almost goes without saying that the man who expects to reach even moderate success as a testing engineer, must study harder the first five or ten years after graduation, that he did at any time while in school—we say a man must accumulate experience by arranging the information already acquired, by reading, by study, and actual contact with industrial processes, and with the world's work, in every possible detail; and above all, a man must acquire experience by actual wrestling with problems that may be committed to his care. It is apparently not essential, in order to gain experience, that one should successfully solve his problems. Faraday was accustomed to say that he actually learned more by his failures than from his successes. We cannot, we think, too emphatically insist on the importance to the testing engineer of self-education, of the broadening of his field of knowledge and of the acquisition of facts. The testing engineer should be an omnivorous student; nothing too trivial to interest him, nothing too remote from his present line of work to make a legitimate demand on his attention should opportunity offer. The schools, if they have done their duty, have given you a more or less trained mind, and have taught you how to learn. It is your own fault if you do not broaden every day. You can never tell what moment you will need, and badly need, some out-of-the-way fact. Store them up against that time of need.

Perhaps you will forgive me an illustration or two on this point. We recently saw a broken steel car axle. The break occurred ten or twelve inches from the end of the axle. On examining both ends, there was some appearance of seams, not radial, but rather in a sense irregularly parallel to the circumference. These seams suggested that probably the axle was made from a billet coming from somewhere near the top of the ingot, and that the seams were in some way connected with the pipe. It was reasoned that if this were true, an analysis of the metal from the surface and from the center of the cross section of the axle would show segregation, and that if, for example, much higher phosphorus were found in the center than at the circumference, it would almost be a demonstration of the location of the billet. Of course the whole object of the study was to see if any information could be obtained that would prevent the acceptance of such bad axles in the future. It should be mentioned that the broken-off piece was sawed in two lengthwise, and that when this was done, from one of the halves a core amounting to about a third of the cross-sectional area actually fell out, showing that the seam indications at the end were genuine, and that the seam did actually exist. The analysis above referred to was made, and to our astonishment showed lower phosphorus in the center than in the circumference. This seemed to settle the question as to the relation between the seam and the pipe and, indeed, we regarded it as conclusive evidence that the billet from which this axle was made was not taken from too high up in the ingot; but it left unsettled the cause of the seam. Perhaps, however, a few words farther on certain well-known phenomena in steel metallurgy will help us in clearing up the point. It is obvious that if in a big ingot, a portion of it contains more than the normal amount of phosphorus, carbon or sulphur, as is actually the fact in the case of segregation, it must follow that there will be parts of the ingot which will contain less than the normal amounts of these constituents. It is generally assumed that the outside of a forging like an axle gives very close to the normal analysis of the steel, since from the method of manufacture this outer metal was near the surface of the ingot when the metal was cast, and consequently cooled too quickly to permit perceptible segregation. Also, if we are right, the analysis of borings taken from different parts of the inner face of an ingot sawed in two lengthwise for the purpose, shows that phosphorus, carbon and sulphur, near the middle of the lower third of the ingot, are usually below the normal. Now, since the phosphorus in the center of our axle was lower than in the circumference, it seems evident that the billet from which it was made must have been from somewhere in the lower third of the ingot. Apparently, therefore, we must look here for the cause of the seams. The steel makers present have undoubtedly sometime since foreseen the cause of the difficulty with this axle. For the benefit of the others we may say that seamy bottoms of ingots are now usually explained by wet or insufficiently dried bottoms of ingot molds. The steam or other volatile material generated by the heat of the molten metal, can apparently only escape up through the molten metal itself, forming a seam, which the subsequent treatment does not weld up.

Another brief illustration will perhaps emphasize the importance to the testing engineer of familiarity with the minute details of industrial processes. A couple of years ago, while the finishing cut was being taken on a steel driving axle in a lathe, the operator noticed in the freshly cut surface what appeared to be a small flaw. On testing this with a pin, the pin disappeared, and quite a length of fine wire followed it. On taking out a transverse slice of the axle at this point, a cavity was found in the metal, which would hold half a pint or more. The walls of the cavity were perfectly clean and bright, and but for the fact that the finishing cut just happened to open up the cavity a trifle, its presence would not have been suspected, and the axle would have gone into service. It is perhaps safe to say that one fourth or possibly one third of the cross-sectional area of the axle was embraced in the cavity. We have seen a number of such cases, and unfortunately the phenomenon is not too rare. Almost any practical steel maker, when asked for the cause of such a cavity in what is apparently a solid piece of metal, would probably laconically answer, "careless heater." In order to understand this statement, it is necessary to say that many driving axles, even when they are finished, are about eleven inches in diameter, and that the bloom from which they are forged is considerably larger. If now such a bloom when cold is put into a hot furnace, the outside layers get hot long before the inside has begun to raise much in temperature. A severe strain, due to the greater expansion of the outside layers, is accordingly set up, which strain is enough occasionally to actually rupture the inside. Subsequent forging opens out this rupture into a cavity. The rupture is usually accompanied by a noise like a pistol shot. The unfortunate part of the business is that there being a number of blooms in the furnace at one time, it is impossible to tell which one has yielded to the strain. As would be expected, the larger the axle the more common this defect, and we know of one large railroad that bores a two-inch hole through every axle over eight inches in diameter that is destined for passenger service. The boring of the hole enables the cavity to be discovered, either by the behavior of the drill, or by sight examinations after the hole is finished. It is interesting to know that something over two per cent. of all axles bored are defective in this way.

One or two points more, and we have finished. It may seem an idle question, but it is certainly an interesting one, as to which of the three kinds of testing engineers has the most attractive field of work. The unattached testing engineer certainly has the greatest freedom, but at the same time the least stimulus. The producer's testing engineer undoubtedly has the best financial reward, but at the same time the narrower field. He has, however, the advantage of concentration, and as almost every modern industry has scores of unsolved problems connected with it, there is no reason, if he will work, why he should not achieve a great success. On the other hand, the consumer's testing engineer has unquestionably the broader field, the greater chance for initiative, and perhaps more important than all, an opportunity to study the behavior of materials in actual service. This last item gives him a great advantage. The behavior in service is unquestionably the ultimate criterion by which every industrial product must be judged, and by whose decision, sooner or later, it must stand or fall. Undoubtedly, individual characteristics are a legitimate element in the choice, but our counsel would be to every ambitious testing engineer, to get as near to the service as possible, and to this end to make some sacrifices, if necessary, to secure a position with a consumer.

And this brings us to another point. We have many times heard complaints of the dullness and unsatisfactoriness of spending one's days and weeks in making routine tests. We are compelled to say that we do not understand this. It is one of our sincere regrets that we are no longer able to do routine work. To us there is genuine pleasure in seeing how the test comes out in each individual case, although we may have performed the same operation over and over again. Moreover, there is scarcely a method in use to-day, either in chemical or physical testing, that is not capable of improvement, either in accuracy or speed, or both; and what better opportunity for suggestions could be desired than is furnished while the hands are busy doing that which from long practice they do almost automatically, and with the attention necessarily directed to the subject in hand, leaving the mind almost free to dwell on possible changes leading to progress. Some of our very best thoughts have come to us while engaged in routine work. One is very near to Nature's heart when making tests, even routine tests, and if his mind at such times is alert and receptive she will not infrequently give him a hint or disclose a fraction of some of her secrets to his view.

There is one more phase of the work of the testing engineer which will perhaps bear a few words, and that is the relation between the testing engineer and those whose material he is testing. This is unquestionably a delicate subject, one that we would all gladly feel did not need discussion or comment, and yet one that is constantly thrusting itself into prominence, in some form. For the honor of human nature, it is gratifying to be able to put on record that during nearly thirty years of almost constant testing, only once have direct financial considerations been urged upon us to influence our verdict in regard to material. On the other hand, we have heard representatives of entirely reputable business organizations say openly, "It costs us something to sell our goods, and it is entirely immaterial to us whether this money goes to our selling agents, or to the representatives of the consumers." And this is not the worst phase of the matter. It is well known that the representatives of consumers who act in some sense in the capacity of testing engineers, in that their opinion or decision determines the placing of orders, not only accept substantial considerations from producers, but even demand them, if not openly, at least indirectly. The subject is one on which much might be said. An hour could readily be filled in narrating incidents and portraying the forms in which the hydra-headed monster, graft, manifests itself. We are confident that neither side is free from blame; we are equally confident that strict, open honesty is the only safe course. It may not be amiss to add that so insidious are the forms in which this evil manifests itself, that, in the words of the Scripture, they would at times deceive the very elect; and while it is not possible to discuss these matters without raising interminable questions of casuistry and metaphysics, it is possible to so act as to have the continuous approval of a good, clean conscience. No universal rule can be given. Each one in a sense must be a law unto himself. Perhaps the best every-day working rule for young testing engineers is, do nothing you would not be willing to talk over with your employer, even in the presence of the other party. It is sometimes a bit hard to resist and say "No!" but of one thing be sure—every departure from strict integrity will, sooner or later, return to plague you, and should your actions ultimately result in your downfall, from none will you get less sympathy than from those who may have contributed to your disaster.

THE ENFORCEMENT OF SPECIFICATIONS.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY

DELIVERED BEFORE THE

AMERICAN SOCIETY FOR TESTING MATERIALS IN 1907.

In the early days of specifications, they were little more than attempts on the part of the consumer to tell the producer what he wanted. Some specifications which we have seen consisted of only a few lines, and these either related almost entirely to a brief description of the material desired or embodied some simple tests. Indeed, in the preparation of such specifications there is reason to think that the consumer himself had meager information in regard to the material he was describing and perhaps only knew with certainty that the material he was receiving was unsatisfactory and that he wanted something different.

Later on, as knowledge of materials increased, as methods of testing became better understood and more completely worked out, as those who were making specifications learned by experience how difficult a matter it is to draw a satisfactory specification, and especially after it became the custom to consult the manufacturer in making the specification, it took on a new meaning. At first it was a demand; it now became an agreement. At first it was ofttimes perhaps promulgated with something of a feeling of superiority by its maker, and was received by the manufacturer or producer with a feeling of opposition and antagonism; it now became more of a compromise and was put forth and received with a much more conciliatory spirit on both sides. From being a species of legal instrument that had in it conditions and requirements that the one who held the purse strings felt that he had a right to insist on, it took on more the nature of a contract in which the stipulations had practically been agreed upon by both parties in interest.

Looking at the specifications in this light and assuming, as we must, that business to be successful must be conducted in accordance with the principles of honesty, integrity and fair dealing, it would almost seem that it would be a waste of time and effort to discuss the subject which we have chosen for this paper, "The Enforcement of Specifications." The specification is a contract and, as we have said again and again, in any properly drawn specifications both parties have had a voice, differences have been harmonized and the conditions and stipulations have been agreed upon. Now, if men are honorable and intend to do as they have agreed, as we are bound to assume that they are and do intend to do, what need is there for enforcement? Is it not safe for the consumer to receive and put into use the material which the producer furnishes, without the trouble and expense of maintaining a department or a corps of inspectors to protect his interests? Unfortunately the experience of the business world at the present time does not seem to warrant such a procedure. I doubt not there are consumers within the sound of my voice, who, if pressed for an answer to our question, would say with a somewhat sarcastic smile that the situation is utopian and that with human nature as it is, it is absurd to expect to get what you have contracted for, unless people are watched. On the other hand, no doubt an equal number of producers who hear me are entirely ready to assert that they are conducting their business in such a way and are making and delivering such a product, in their specification material, that any consumer would be absolutely safe in receiving and using it without inspection. For our own part, as the result of an almost daily experience for some thirty years with specification material, we are compelled to side with the consumers and to maintain the necessity for inspection and tests.

And lest by this statement we should seem to call in question the business integrity of the producers, among whom we are happy to number some of our best and most valued friends, let us hasten to say that there are so many conditions leading to the manufacture and delivery of unsatisfactory materials—that is, materials that do not fill the requirements of the specification on which they were bought—which conditions do not involve the business integrity or the honest intention on the part of producer to do as he has agreed, that we are sure no one need feel aggrieved at the establishment and maintenance by consumers of devices for the enforcement of their specifications. It would of course lead us too far to inject into this paper a discussion of business honesty on high moral grounds. Such a discussion is foreign to our present purpose. The basis of our discussion is the business truism, that a transaction is satisfactory when both parties get benefit from it and both parties are satisfied. No one believes more devoutly than we do, that with few exceptions, so few as to be almost ignorable, producers in general prefer to do an honest business at a fair price and profit, and that they always would do so, if it were not for certain conditions. What then are some of these conditions?

First, however, in order to avoid constant repetition of the words "materials according to specifications" and "materials not according to specifications," let us agree that the former may be properly designated as "satisfactory materials" and the latter as "unsatisfactory materials," the view point obviously being that of the consumer. This being granted, the first condition that we will consider which leads to the tender of unsatisfactory materials is improperly worded or unreasonable specifications. It is obvious that the view point of those having to do with either the making or carrying out of specifications being different and in a sense antagonistic, since their interests are naturally and legitimately opposed, the meaning which they attach to words will be different and both parties may be equally honest. We knew of a case once where a lumberman agreed to buy a large number of logs from the owner of a valuable timber tract on the simple specification that only two logs from a tree should be delivered. Imagine his surprise when the logs began to come in to find them small, tapering and full of knots. On remonstrating he was told that just exactly as the specification called for, only two logs per tree were being delivered, and he was invited to look at his contract. An inspection revealed the fact that although the lumberman undoubtedly had in mind when the specification was drawn that he should receive two logs from the butt of each tree, the important word "butt" had been left out; while on the other hand, the owner of the lumber tract had unquestionably read into the specification when it was presented, that under it he would be entitled to deliver two logs from the top of the tree, just as he was actually doing. It may not be unwise to add that a contract covering two butt logs from each tree was somewhat unusual, that the price was lower than would have been expected for such logs, and that as a matter of fact the case never came into court. In like manner an unreasonable requirement in a specification may lead to the same result. Our friends the steel manufacturers are constantly being presented with specifications containing stipulations which it is impossible or at best only occasionally possible to fill. Those who have made these specifications have, it is true, we fear neglected one of the prime requisites of a good specification: namely, to consult with, and on certain technical points be guided by, the best manufacturers. And it may be urged that a producer has no right to take a contract under a specification that contains a requirement that he knows he cannot fill. While this is true abstractly, it must be remembered that the producer is in a rather delicate situation. If he remonstrates against the unreasonable requirements, he probably loses a customer. If he refuses to take the contract with the unreasonable requirement, and as a matter of fact it is well known that this is done again and again, he not infrequently makes an enemy of the engineer or expert, who simply has a crotchet in his head, but is otherwise a very good fellow and who later may be valuable; so the contract is taken, even with the unreasonable requirement and with the thought in mind of getting along with the matter in the best way possible if any difficulty should arise. The producer we fancy knows that he is making good material and giving good value and with this thought condones himself for his seeming breach of contract. As far as our subject is concerned we cannot but feel that an improperly worded or an unreasonable specification is a most potent cause for the tender of unsatisfactory materials.

Again, the mistakes of subordinates are a frequent cause for the same difficulty. An illustration of what we mean by mistakes of subordinates will make the matter clear. Some years ago a railroad company placed an order with a most reputable firm for fifty barrels of the best grade of lard oil, known at the time as "Extra" or "Prime," the other well-known grades being Extra No. 1, No. 1, No. 2, and No. 3. The difference in the cost of the extreme grades was ten to fifteen cents per gallon. The order was what is technically known as a "rush" order,—that is, to be filled as soon as possible. In due time the material arrived at destination and was sampled and tested in the regular way. The test showed the material to be No. 3 oil, and the shipment was promptly rejected and returned to the shippers. They made a careful examination of the shipment barrel by barrel, and found that forty-five barrels contained oil of the proper grade and of unexceptional quality, while the five barrels were No. 3 grade, as the test had shown. On asking for an explanation, the foreman of the works said that when the order was received he only had forty-five barrels of the proper grade in stock and it being a rush order, he put in five barrels which he knew to be inferior, hoping that the matter would escape detection. It may be of interest to know that in this case the shippers actually felt themselves aggrieved and claimed that since they had to pay return freight on rejected material, the forty-five barrels of good oil should have been retained and only the five barrels of inferior oil should have been returned. The purchasing agent on the other hand very mildly, but very firmly, reminded the shippers that the order which he had placed with them did not call for any No. 3 oil, that there was a difference in price of at least five dollars a barrel between the two oils, and that if perchance the sample tested had come from one of the barrels of good oil, the shipment would have been accepted without question and it would have been a clear case of successful fraud by which they would have profited. But there was considerably more in this case than was brought out by the purchasing agent. Extra or prime lard oil is used by railroad companies almost exclusively in making what is technically known as "signal oil,"—that is, oil used in signal lights and in trainmen's lanterns; also, the safety of trains and even the lives of passengers depend on the reliability of the signal oil. And perhaps more important still, a signal oil made of No. 3 lard oil is utterly worthless and unreliable. The lanterns will commonly go out and fail completely within two hours after new trimming and filling with such oil. The bearing of all this on the necessity for the enforcement of specifications is too evident to require comment.

It would lead us wide of our proper field to raise and discuss the question whether such a mistake on the part of subordinates, as we have cited, is ever made with the knowledge and consent of the principals or not. We have heard it intimated that such transactions are fairly common and that when such a case comes to the knowledge of the office or the principals, one of two things is apt to result. If the shipment has gone through, the transaction is closed and no questions have been raised, the subordinate is usually not reprimanded, but on the contrary gets a smile of approval. On the other hand, if the fraud is detected and trouble and loss result, the subordinate not infrequently suffers.

Perhaps you will bear with me while I give another out of the many that might be cited of the conditions leading to the tender of unsatisfactory materials, even though those who are doing so have a sincere and honest intention of fully meeting the requirements. This condition is that commercial processes do not always yield what is expected of them. Something in the materials used, or in the processes employed, gives a product that is unsatisfactory, notwithstanding the producer supposed he had done everything that he could to secure a successful result. Let me give an illustration. Some years ago in our laboratory at Altoona, we examined in the regular way a sample representing a shipment of prosphor-bronze bearing-metal from a firm whose business reputation and character were simply above reproach. This material, as is well known, is an alloy of copper, tin, lead and phosphorus, the percentages of each constituent being fixed within narrow limits by the specification. The analysis showed copper, tin and lead within the limits, but no phosphorus, and the shipment was rejected. This was followed by a visit from one of the principals of the firm, who maintained that he had actually purchased in the market phosphor-tin at a high price and used it in making this very material, and that the fact that we found no phosphorus was a mystery to him. It was asked if he knew by analysis how much phosphorus there actually was in this so-called phosphor-tin, since our own analyses of the material in the market showed not over a third or at most half of what was claimed. He confessed that no analyses had been made, but stated that he bought the material on a guarantee that it contained ten per cent. He was then asked if he knew that there was a loss of phosphorus every time the alloy was melted and that with careless foundry manipulation this loss might readily amount to all the phosphorus he had actually added. His reply indicated haziness on the subject, coupled with a desire to learn. A few suggestions were eagerly noted and apparently well applied, since the same firm subsequently made and furnished to the road large quantities of entirely acceptable material.

And so we might go on quite at length, detailing condition after condition that leads to the tender of unsatisfactory materials, some of them perhaps not quite as free from suspicion as those already mentioned, but all of them emphasizing the necessity on the part of the consumer of apparatus and appliances for testing and a rigid enforcement of specifications. It will, perhaps, be sufficient if we enumerate without special illustration or comment, a few more of these conditions. A contract taken at too low a figure is a fertile cause of what we have agreed to call unsatisfactory materials. Under stress of competition agreements are made that if carried out strictly in accordance with the specifications, would result in loss, or lack of reasonable profit. Again, strange as it may seem, a very large number of manufacturers of commercial products as a matter of fact do not know the characteristics of their output. They have been making and selling their staple for a period of years, it may be, and as long as the consumers accepted the material and raised no questions, they themselves saw no need of making tests and experiments, except perchance such as would lead to diminution of cost in manufacture. Accordingly, very little or no knowledge was obtained of those qualities of the material which are of most interest to the consumer. It has been our custom for many years, as is well known, to send our proposed specifications to the manufacturers for criticism before they are officially issued, and we have again and again received from producers in reply to the question whether they could make a product that would stand the tests of the proposed specifications, the answer, that they could if anybody could. There was apparently absolute lack of even the most rudimentary knowledge of those qualities of their product which were of the most interest and importance to the consumer. And yet, without this knowledge, contracts are taken and shipments made. What more natural than that the material should be unsatisfactory in the technical sense of the word? Again, the tender of unsatisfactory material is often explained, after it has been tested and found wanting, by the statement that although it may not quite fill the requirements, it still is good material and will do the work. Of course it takes but a moment's reflection to lead any fair-minded person to the conclusion that this statement is not at all the question at issue and that if the consumer had been willing to use a material that is, in the language of the shops, "just as good," he would have specified such material and obtained the benefit of a corresponding variation in price.

Two more conditions leading to unsatisfactory materials may perhaps wisely be mentioned before we leave this phase of our subject. It not infrequently happens after a contract has been made, that unexpected and wholly unforeseen difficulties arise in securing raw materials from which the product in question is made. An unexpected demand has sprung up for that kind of raw material, making it scarce in the market, or the parties with whom the producer has a contract for his supply repudiates the contract, or there has been an accident or catastrophe affecting the supply. The producer, therefore, finds himself in the condition that either he is unable to make deliveries as he has agreed to do or he must, or thinks he must, make deliveries of his product containing such raw materials as he can get, with the accompaniment of that brood of troubles that arise when the tests show unsatisfactory materials. Not once, but many times, has this situation been prominent in the course of our work at Altoona; and there is one phase of the matter which we have found most difficult to understand. The producer goes ahead and makes up his product from inferior raw materials and makes shipments, knowing that there will be trouble; and then when the trouble arises, he explains and asks for leniency. The query in our minds has always been, why does he not explain and ask for leniency before he makes and ships the unsatisfactory material? If we may trust our experience, a frank statement of the situation beforehand would be far the wiser course. We fancy the reasons for the procedure actually followed will ever remain one of those business mysteries which are incomprehensible to the lay mind.

Finally, a most common and pestiferous cause of the tender of unsatisfactory material is the statement that delay must follow if these unsatisfactory materials are not received and used. We say pestiferous, because of all the causes leading up to the tender of unsatisfactory materials, this one seems to us to have the least foundation of equity to rest on and to be the one that smacks most strongly of a deliberate effort to force through an acceptance, regardless of quality. We are quite well aware that emergencies may arise in the case of those who are furnishing materials, which emergencies may fairly be regarded as legitimate causes for an unsatisfactory product.

We have already discussed a number of such. On the other hand we have so many times had occasion to feel that at the last minute, materials are tendered, which the parties had known for some time, or at least might have known, were inferior and not satisfactory, that the argument that "there will be delay if you do not accept this that we tender" is deprived in our minds of a very large percentage of its force. It would be infinitely better, it seems to us, not to make shipments, and either to put some of the energy now employed in trying to get unsatisfactory shipments accepted, into making and furnishing satisfactory material, or to make a frank statement of the situation to the consumer beforehand and abide his decision. Such a statement would do much toward smoothing down and removing some of the roughnesses and inequalities of the road which the producer and consumer are trying to travel together, toward the goal of a successful financial transaction.

Let us now turn to another phase of our subject. If we have succeeded in what has been said, it is evident that there is necessity for the enforcement of specifications and that too without assuming that men are dishonest or do not intend to do as they have agreed. Under present commercial conditions and with our present knowledge of the properties of materials, and of the processes by which they are made, it simply would not do for the consumer to leave his interests wholly in the hands of the producer. Each must look out for his own interests and be prepared to defend and maintain them. Perhaps we have said more than is necessary on this point, but the practice of buying and using materials on the reputation of the maker is so deep-seated and widespread, and has for so many years been the refuge of engineers in cases of failure, that perhaps the subject will safely bear elucidation at a little greater length than would otherwise have been admissible.

But how shall specifications be enforced? What are the essentials of successful enforcement? We reply, first, the examination and testing of the material tendered must be so planned as to be efficient and leave no loopholes for evasion or substitution of inferior materials. In the case of some substances every shipment must be tested. In the case of others, as for example, materials that are produced in heats or are stored in tanks or bins, the tests deciding their fate may be construed to cover the whole amount even though there may be a number of deliveries. The essential feature is that each test, or lot of tests, shall cover a definite amount of material and that nothing shall be left to the honesty and good intention of the producer or shipper. If we are going to trust the producer in one detail we may as well trust him in all. The strength of a chain is the strength of its weakest link. No universal rule can be given, but assuming that the specification is wisely drawn and provides only essential tests, these tests must be so applied as reasonably to cover all the material that is delivered.

Again, since it is clearly impossible, except perhaps in the case of proof strains, to apply tests to all the material in the shipment, it is obvious we must rely on tests of samples, and this brings up the question of sampling. Upon this point several rules are clearly applicable. First, a representative of the consumer must always take the sample. This is in accordance with the principle already enunciated that it is not reasonable or proper or safe to trust the producers in anything by which the validity of the tests might be affected. Not once but many hundred times have we been asked to allow the shippers or producers to send a sample and accept a shipment on its examination. The request was undoubtedly made in good faith and with no other desire than to facilitate the transaction. Perhaps it is needless to say that our belief in the facility with which unintentional mistakes would be made and a sample better than the average of the shipment be sent, has always led us to positively refuse such requests.

Second, the sample must be representative of the whole shipment, or lot under test. This point is usually provided for in the specifications and does not here require special comment. Nor is it essential perhaps to remark on the necessity that the sample should represent a definite amount of material, since this is also provided for in the specifications. We may, however, be permitted to say that some specifications that we have seen, seem to us to assume greater uniformity in the product made in successive similar operations, than actually exists in the material. If it were at all possible to avoid it, we would not like to accept articles of steel made by the Bessemer process, especially where strength and safety are involved, without a test of each blow.

A third point in regard to sampling has a more direct bearing on our theme, the enforcement of specifications; namely, the sample should be taken at random and not always from the same place. We have many times been surprised to find out how intimate the knowledge on the part of the shipper or producer soon gets to be of the practices of the consumer in sampling. Apparently the producer thinks it is just as fair that he should know all about the consumer's use of his material, as that the consumer should know all about his manufacture of it. This we are quite ready to concede. But now if in sampling a car load of oil the barrel next to the door is always chosen by the inspector, or if in sampling a pile of axles the one on top is always selected, or in picking out a spring for test from a lot assembled and offered if the one nearest at hand is habitually taken, it is perfectly evident that an opportunity is afforded for one of those unintentional mistakes of workmen or foremen that would result in the best material always being tested. It would take us too far away from our subject to discuss here the bearing upon these unintentional mistakes of the practice which is so common in many establishments of paying the subordinates, nay even the whole manufacturing organization perhaps, in proportion to the amount of successful output. We cannot but think, however, that ingenuity in sampling is a legitimate and reasonable offset to this practice and that it is as important that the inspector who takes the samples should be full of suspicion and scientific doubt, as that testing machines should be reliable, or that a chemical balance should give accurate weights.

As showing how failure to comprehend the whole shipment in the sampling may result in disaster and at the same time illustrate the unintentional mistakes of workmen about which we have already said so much, let us cite an incident. A lot of bronze castings were being furnished for use in locomotive construction. The order was a large one and shipments were made from time to time. The inspection force was pressed with work and, let it be confessed, not quite as much permeated with suspicion and scientific doubt as should have been the case. The bronze was bought on definite chemical specifications and from each delivery enough sprues were broken off from various castings by the inspector to properly sample the material. These samples were used for the analysis. Deliveries were made usually about three times a week and the inspector was sent for to inspect and sample the material whenever a delivery was ready. It was explained to the inspector that it would greatly facilitate the work of the foundry if he would allow, say, three fourths or more of the castings to have the sprues broken off and used over again, before the regular sampling was done. They would leave enough sprues attached, say to a quarter of the castings (nothing very definite as to the number of sprues to be left attached was promised) so that he would have abundant chance for selection. In the goodness of his heart the inspector allowed this to be done. A number of shipments were made, sampled, tested and accepted in this way. Some suspicion having arisen later in the minds of those higher up than the inspectors in the testing organization, some twenty full-size castings, all selected from a large number of those from which the sprues had been broken off before sampling, were sent for analysis. The analyses showed that in some manner not explained every one of the samples from the castings bereaved of their sprues by the foundry force were not only not according to the specifications, but showed unmistakable evidence of having in their composition large percentages of inferior scrap. It is perhaps needless to add that from this time forward, after the inspector had been changed, the sprues were all allowed to remain on all castings until the sampling was finished.

This brings us to the last requirement in sampling which we will discuss: namely, the sampled material should, as far as possible, not remain in the hands of the producers after it has been sampled. The equity of this practice will not, we fancy, be called in question; the actual carrying out of the rule is not always so easy. Materials that are sampled and tested after they arrive at destination, present no difficulties. We have known of refusals to ship until after the material had been tested and accepted, but when it was explained that it would be practically impossible to send inspectors to sample every shipment of every kind of material before it was started on its journey to the service for which it was intended, such refusals have usually vanished. Moreover, the refusal to ship has always seemed to us to argue, either a lack of knowledge of the characteristics of the material that the shipper is tendering, or a well-grounded fear that it would not stand test. Also, in the case of materials such as springs, alloys, etc., which can be inspected and sampled and then loaded at once, there is no difficulty; but in the case of materials which cannot be so treated or which must be stored, the matter is more serious. In such cases, marking in such a way that the marking cannot be defaced without showing it, must always be practiced. The chances for unintentional mistakes are too numerous and the fact that such mistakes do actually frequently occur is too common to permit of any uncertainty on this point.

Before leaving the subject of sampling, perhaps you will bear a word on the question whether a sample taken with all the known precautions does, as a matter of fact, actually represent the shipment. The sample is but a very small fragment of the shipment, and a doubt may fairly be felt as to whether the whole shipment is like the sample. It is obvious that if the specification is intelligently drawn, all the variations in the material due to uncertainties in the process of manufacture or unavoidable errors of manipulation, are provided for in the sampling which it directs. This leaves only intentional or unintentional variations, introduced by the producer, to be provided against. Our position in regard to these has always been that if the producer was willing to take the risk of our getting our sample from one of these intentionally inferior parts of the shipment, with the rejection which would inevitably follow, we were willing to take the chance of getting a sample from a better part of the shipment, with the consequent acceptance of some inferior material. Moreover, in cases of reasonable doubt we have a number of times sampled every part of a shipment, and are strong in our belief that very few commercial men would persistently offer material, portions of which they knew to be inferior.

But again let us discuss another phase of our theme. Let us assume that the specification has been wisely drawn, that a shipment has been properly sampled, and that the tests show that it does not fill the requirements. What is the next step? As a matter of fact in our own daily work, but one thing is ever done and that is the material is rejected. None of our specifications provide for a second or third sampling and corresponding tests. Our theory is that the material ought all to be of the grade called for by the specifications, since this is what the consumer has bargained for, and if this is the actual fact one sample is as good as fifty. We are quite well aware that there are many specifications in force which provide for second and, if need be, third tests, the fate of the shipment to be decided by the majority. But this has for a long time seemed to us to be a survival of the crude early days of testing, when neither producer nor consumer knew much about materials, and which it is high time should be banished forever. If a specification is so severe that only two-thirds of well-made material will stand test, the specification should be changed; and if a manufacturer can only make a product, two-thirds of which will stand test, he should either learn how to improve his product or go out of business. Testing was never intended to be a device to bring about the acceptance of inferior material;

but quite the contrary. Moreover, from three samplings and tests it is but a step to five or seven or nine, and perhaps if sampling and test is long enough indulged in a majority may ultimately be found which will always bring acceptance of the material. Surely the interests and responsibilities of the consumer cannot be trifled with in this manner.

But some one says, are you so sure that you are right in your single test that you feel that you are on firm ground in rejecting material and cutting off all chance for further tests? We reply, that is quite another matter. Retesting because the material fails, no question being raised in regard to the reliability of the tests, is entirely different from a retest because there is reason to think there is something wrong with the sampling or testing. In this case the burden of proof is on the producer and it is incumbent on him to show reasonable ground for reopening the case. On the other hand, it is equally essential that the consumer should welcome the investigations of the producer—should throw everything open to him, and give him every facility for satisfying himself that no injustice has been done. There is no room for a star chamber in the enforcement of specifications. In our own laboratory, we always keep the sample of every rejected shipment for a month and are always ready to give the producer half of our sample for verification purposes. Moreover, we have often said to shippers who were interviewing us over rejected material: "You may follow your material from your works to destination; you may see the sampling; you may follow the sample to the laboratory and either by yourself or your technical representative be present and watch the whole operation of the testing. And finally, here is half the sample on which we have worked; put it in the hands of any reputable chemist, and if he does not confirm our results, we will take up the question with him and find out who is in error." Our sincere desire is to get at the truth and we cannot put it too strongly: there should be nothing unfair or secret or arbitrary on the part of the consumer in rejecting material. On the other hand, the sampling and testing being fair and honest and reliable, there should be but one sampling and testing and no retests.

Closely related to the point we have just discussed is the question of the use of rejected materials. It is safe to say that hundreds of times during the past thirty years we have been asked, "Yes, it is true the material does not quite stand test, but cannot you accept and use it?" And only a little less frequently the same request has been made of those higher in authority in the organization. The arguments usually used are: "The material will give you good service; not quite as good as if it had stood test, but still on the whole fairly satisfactory." Also, "we are good friends of yours, and would do the same for you." And still further, "we are very large shippers over your line, and think some concession is due to us in view of this fact." There is apparently complete failure on the part of those using these arguments to comprehend the position in which they are placing the officer to whom these requests are made. Let us see if we can look at the matter from his point of view. It takes but a moment's reflection on the part of any fair-minded person to enable him to see that to grant the request means a complete breaking down of the specifications. The officer in question is usually responsible for the specification. He has made and issued it and that too after careful consultation with those who are to furnish the material. The requirements of the specification have been agreed to and a contract has been made with the purchasing agent or other officer, to furnish material that would stand test. If now the specification is to be waived in one case, why not in all, and what then becomes of the specification? Still further, a shipment of the kind in question once accepted becomes a precedent for the next case and so on *ad finitum.* Moreover, apparently also another and very important point is forgotten: namely, that it is simply unfair and unjust to those who are furnishing material which does fully meet the requirements, to accept shipments from others who fail in this respect. Much of the obloquy which is so rife at the present time, affecting those in authority in large organizations using large quantities of material, is legitimately and reasonably based on cases of this kind. It is claimed, and as it seems to us justly so, that certain parties have a pull and are able to do business with the organization in question, while others who are striving to be absolutely straightforward and honest and to do as they have agreed, are entirely unsuccessful. Moreover, there is another phase of the case. It may chance that the rejected material is of such a nature that the use of it would only involve a slight financial loss. This point we will refer to in a moment. But again, on the other hand, the rejected material may be of such a kind that the question of safety to passengers or risk to human life is involved in its use. In this last case it seems to us that there can be but one answer to the request to use unsatisfactory material and that is: "Nothing could induce us to accept and use this material." And in the case where only a money loss is involved, as has just been cited, we are clear that there is only one condition under which it is at all admissible to accept and use rejected material. It has been a puzzle to us how completely manufacturers and shippers lose sight of this condition. If among the arguments used to get the rejected material accepted the shippers would only urge "it is true the material is not quite what we have agreed to furnish and in view of this fact we will deduct a certain amount from the bill," their case would, as it seems to us, stand on firm ground and might have a reasonable expectation of success. Fairness and the ultimate satisfaction of both parties to a transaction is the only basis upon which successful business can be continuously carried on.

This whole matter of multiple tests, retests, and the disposal of unsatisfactory material can, as it seems to us, be summed up in a few words. Multiple tests are pernicious and should be abandoned. Retests, including the sampling, should never be made unless there is reasonable evidence to think there is an error somewhere in the first test, and to decide this point every reasonable facility should be furnished by the consumer to the producer to enable him to satisfy himself. Shipments or material once fairly rejected, should never be accepted and used if the material is of such a kind that safety or risk to human life is involved. And finally, it is suicidal, as it brings with it a train of almost unmanageable subsequent conditions, to accept rejected material in which only commercial considerations are involved, unless there is some abatement in price.

A number of other points involved in the enforcement of specifications might be discussed, but I fear I have already wearied you. Perhaps you will bear with me while I very briefly touch upon one or two more. It not infrequently happens that when the tests are applied to the sample, it is found that it almost but not quite fills the requirements. What should be the procedure in such a case? The answer is not quite so easy as might seem at first sight. It is well known that the ruling which prevails in many locations, especially abroad, is that the material fails and should be rejected. For example, suppose the specification requires not above 0.040 per cent. of phosphorus in the steel, and the analysis shows 0.043 or 0.045 per cent. Shall the material be rejected? It is plain that the accuracy of chemical work is involved. Now it should be confessed openly and plainly that no test gives absolutely accurate results. One of my old instructors used to say, "No chemist can make an absolutely accurate analysis. Even though the chemist himself was infallible, the methods will not give absolute results. There are chemists who can work near enough to accuracy so that their results are useful, and there are others who cannot." And the same is true of physical tests. Testing machines are not absolutely accurate, and strictly accurate measurements are very difficult to make. How then shall these inevitable inaccuracies be handled?

In our own laboratory no shipment is ever rejected until the test has been duplicated, and sometimes three or four tests are made. But this still leaves the unavoidable small inaccuracies unprovided for, and they must be provided for in some way, as not rarely acceptance or rejection turns upon them. Two ways of meeting the difficulty have been suggested. One is to have it a part of the specifications and to have the producers clearly understand it, that the limits of the specifications cover the inevitable and unavoidable errors of testing; that is, the manufacturer should work far enough within the limits of the specifications, so that the inevitable and unavoidable errors of testing would never lead to the rejection of a shipment. The other way is to make the limits of the specification sufficiently narrower or wider, as the case may be, to cover these unavoidable and inevitable errors of testing and then allow for them in deciding whether to accept or reject. The latter procedure is the one we have always followed in our laboratory. An illustration will make the whole matter clear. For certain purposes steel containing 0.04 per cent. of phosphorus will give us perfectly satisfactory results in service. But knowing as we do, that chemists will differ and that there are inevitable and unavoidable errors in the analysis, we make the upper limit of phosphorus in the specification 0.03 per cent., knowing that such steel can readily be obtained in the market without undue hardship to any one. It is evident we have by this procedure sufficient margin to cover inevitable and unavoidable errors in the determination, without raising questions which involve contention and hair splitting. It is infinitely better, it seems to us, to so draw the specifications that the service will be protected by a sufficient margin to afford good strong fighting ground, and then when a rejection is made stand by it to the bitter end. One of the most used rules of our laboratory is: never reject a shipment unless you know beforehand that, so far as the figures of the test are concerned, you will win in the contest which may follow the rejection.

Again, let us suppose that a shipment has been wrongly rejected and that the shipper has been put to expense in regard to it. Is any requital due him for his loss or must he regard it as one of the inevitable expenses of doing business? We answer unhesitatingly that in the case supposed there is only one thing to be done, and that is for the consumer to make good the loss due to the erroneous rejection. It is a poor rule that does not work both ways.

We should like to discuss several points further in connection with our theme, notably, what shall become of rejected material? How far has the consumer a right to protect himself against such material, and especially, has he a right and is it good policy for him to so mark rejected material that it cannot be offered again? Still further, we should like to bring before you the question as to who shall make good the annoyance and frequent money loss which are experienced by the consumer due to rejected materials. It is always annoying and often necessitates expensive delays and re-arrangements to reject a shipment. Also what penalty, if any, should the producer pay to requite the consumer for this annoyance and loss? Our subject is not nearly exhausted, but we have already taken too much time.

Bear with us while we conclude by presenting very briefly a problem which has had lodgment in our own brain for quite some time now and which recent events in regard to certain materials have seemed to force into prominence. It is plain that in using materials in those constructions which involve safety in the railroad sense, or risk of human life in the public sense, there is a question of responsibility involved. If rails are defective and break, if an accident with loss of life results from the use of poor material in car construction, if a bridge falls and produces a disaster due to inferior materials, or a building collapses from the same cause, it is clear that some one should be held responsible; and since there are but two parties involved in the materials, namely, those who make them and those who accept and use them, it is difficult to see how one or the other of them is going to escape the responsibility. Now our problem is, which of the two in equity should be held responsible? It is perhaps hardly wise at this time to attempt a definite answer. Much might be said on both sides, and probably no two persons, certainly neither of the two parties most interested, would give the same answer. But there is a phase of the case which we would like to present. It is well known that in the earlier structural work, when safety was involved, there was no testing worthy the name and materials were bought and used on the reputation of the maker. Fortunately the constructions in most cases had a high factor of safety. When disaster did come, if it was due to defective materials, it was explained that the materials used were from those of the highest reputation in the business, and that no one could really be held responsible. At the present time conditions have changed. The knowledge of the properties of materials of construction has increased, methods of testing and testing appliances have grown up in delightful profusion, and it is to-day entirely possible, we feel safe in saying, for an engineer to be reasonably sure that defective material does not go into his structures. We waive here the discussion of commercial considerations as affecting the use of materials. If it is shown that these have led to the use of defective materials, the moral responsibility for loss of life must certainly go to the one who has allowed commercial considerations to have such undue weight, be he either the maker of the material or the one high in authority who has allowed it to be used. But the point we want to make is, in view of present knowledge and present means and appliances for testing, are engineers or their principals any longer entitled to offer as an excuse for defective materials, that they were bought from the best makers? Can they equitably do so? Can they legally do so? Is not the time near at hand when engineers and their principals will be compelled, if not legally then by force of public opinion, to acquire by the establishment of laboratories and means of testing, by the making and enforcement of specifications, such knowledge in regard to the materials they are putting into structures, as will give the public greater security than it now has against disaster.

SOME FEATURES OF THE PRESENT STEEL RAIL QUESTION.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY

DELIVERED BEFORE THE

AMERICAN SOCIETY FOR TESTING MATERIALS IN 1908.

The Bessemer steel rail has a marvelous history. The outgrowth of an attempt to make wrought iron cheaply, it came in just at the time when the wrought-iron rail was beginning to demonstrate its unfitness to stand the pounding of the larger locomotives of the day. It perhaps is not too much to say that the Bessemer steel rail has made the modern railroad possible, and that without it, or its equivalent, the world's development would be half a century behind its present advanced position. And yet, notwithstanding all its merits, and its wonderful record in the past, no candid mind can view the present steel rail situation, and not be impressed with the thought, that the steel railroad rail, or, perhaps more comprehensively, the railroad track of to-day, is called upon to justify itself in the eyes of the public. No record of past success, however wonderful it may have been, will suffice to meet the present conditions. The changes in methods of transportation during the last quarter century, the increases in sizes of cars and locomotives, with the consequent increase in wheel loads and in the strains produced, have made new demands upon railroad tracks, and especially upon the rail, as the most important element in the track. It is plain, we think, that modifications at some point, and possibly at many points, are essential, in order that the new conditions may be successfully met. The startling record of rail breakages which has characterized the past two or three years, the rapid wear, and the almost appalling deterioration, due to crushing and flattening, of rails in track, have produced an outcry against the steel rail, which, seconded by the technical press, has culminated during the past two years, in a charge of criminal negligence on the part of those engaged in the manufacture of this great essential of railroad operation. No one at all conversant with the situation can successfully maintain that the subject is not a pressing one, and I am sure that all will agree that there is necessity for calm, cool, dispassionate consideration of the various elements involved in the problem. Perhaps you will bear with me while I attempt to discuss some features of this most important and most interesting situation.

And first let us briefly consider the changed conditions. It is surely not too much to say that in the past twenty-five years the changes in the conditions in which the rail is involved, have in three respects been most noteworthy: First, the average speed of trains has been largely increased; second, the average wheel loads of cars have been increased seventy-five per cent. and of locomotives over one hundred per cent.; and third, on some of the larger and more important railroads, the volume of traffic has increased at least three hundred per cent., and perhaps more.

The influence of increased speed on the life of the rail is not easy to estimate, nor indeed can much that is positive be said on this head. Undoubtedly some of the shocks which the rail must sustain are increased in severity by higher speed. This, we think, is clearly the case when a higher speed train passes over a loose joint. The end of the rail to which the wheel is approaching must have a more severe blow with a fast train than is given by a slower moving one. On the other hand there seems to be some evidence that for those strains whose severity is affected by the length of time the load is applied, the increase in speed may not be so injurious an element. We are all familiar with the fact that on thin ice, the boy who goes rapidly is less liable to break through and get a ducking, than the one who moves more slowly, and in exactly the same manner the quick stepper sinks less deeply into semi-plastic mud, than the one who goes with slower, measured tread.

The increase in wheel loads is a more important matter. Without going into the mathematics involved, and ignoring the apparently unsolved problem as to whether the rail under a moving load acts exactly like a beam supported at both ends and loaded in the middle, there is seemingly fairly good evidence that, all things else remaining the same, doubling the wheel load approximately doubles the strain in the metal. It follows, therefore, when wheel loads are doubled, either that the rail section and supports in use at the time must have sufficient margin in them to safely endure these doubled strains, or that some changes are essential.

The increase in traffic is also a very important matter. No point in the science of strength of materials, if we may use the expression, is apparently better established, than that repetition of stress has a direct bearing on the life of the part so strained. There is much indication, and the evidence is rapidly increasing, that the life of a rail, not only as regards wear, but also as regards its freedom from disintegration and breakage, is a function of the number of wheel loads that pass over it. We are strongly inclined to view, therefore, that we are on firm ground when we say that even though we grant that the rails made twenty to twenty-five years ago were good and gave satisfactory service, it is as clear as noon day, that the changed conditions of the present day, especially the heavier wheel loads, and the increase in traffic, demand changes in the practices that were prevalent at that time. No one, we are confident, will dispute this position, and I doubt not every railroad engineer within the sound of my voice will say to himself, "we do not expect the old rail to be satisfactory under the new conditions; many changes have been made, and yet the rails are unsatisfactory."

Let us examine this matter a little, and ask ourselves the question plainly, what have the railroads done to meet the changed conditions? First and foremost, the weight of the rail per yard has been increased. As a matter of record it may not be amiss to mention the successive steps of this increase on one large railroad. Within my own memory and study of this subject, the following weights of rail have been employed: 56 pounds per yard, 60, 67, 70, 75, 85 and 100. The increase is quite noticeable, the latest form being nearly double the weight of that first used. The battle of the sections, or the form in which the increase of weight has been disposed, will be referred to later on.

Yet it may be said: "It is granted that the weight of rail has been increased, but what evidence is there that the increase has been sufficient? Is not a rail weighing 110, 120 or even 130 pounds per yard, essential to meet the strains produced by the changed conditions above referred to?" Upon this point it is possible to say that most careful studies have been made, using the best obtainable data and making allowances for what is more or less unknown and uncertain, and that these studies indicate that the weight of rail to carry the increased wheel loads has been increased more rapidly than the wheel loads, and that the actual strain with the heavier wheel loads is no greater than was the case in the lighter rails under the lighter wheel loads formerly employed. It may be added that if 12,500 pounds per square inch is assumed as a safe working stress for such steel as rails are made of, the present 85 and 100-pound rails show stress well within this limit, even under a static wheel load of 30,000 pounds, with a dynamic augment of sixty per cent. of the static load. If these studies can be trusted, therefore, it would seem that so far as weight of rail is concerned, the railroads have done all that could reasonably be required to meet the changed conditions with which we are dealing.

But again it may fairly be asked, we think, whether increase in weight of rail is all that is required. No principle of structural construction is better established apparently, than that the support which material under strain receives is an essential element in its successful behavior. The rail alone cannot carry the load. It must be properly supported, and perhaps—mind you, I say "perhaps"—failure to properly support the rail may account for some of the rail failure of which we have heard so much during the past few years. Good railroad track involves a properly drained sub-grade, ballast, ties and rail fastenings, splice bars, and other joint material, and the proper maintenance of these, as well as rails. In other words, the rails are only one of the elements in the problem; I grant you, the most important one, but still not the only one. It would be manifestly unfair to blame the rail for failures which may be clearly due to defective support or fastenings. What then have the railroads done during the past fifteen to twenty years, in the way of supporting the rail, to enable it to successfully meet the changed conditions we are discussing?

First as to ties. It is well known that with the advent of the heavier rail, some railroads actually diminished the number of ties per rail. This may have been all right during the transition period, but it is manifest that the strain in the rail is increased by such practice. More recently, as the number of heavier cars and locomotives has increased, we believe the number of ties has been increased again, until now, in the best tracks, as many ties are used as can successfully be employed and leave room for tamping. It may not be amiss here to call attention to a characteristic of ties that bids fair to be of increased importance as time progresses. Owing to the continually diminishing supply of forest products, it seems fair to expect that the supporting face of the tie under the rail will gradually get less as the necessity for using smaller ties increases. This will clearly lead to an increase in strain in the rail, and may even now be an element in the problem. Perhaps the general use of a tie plate on wooden ties, or the development of an entirely successful steel tie, may obviate this difficulty before it becomes too serious.

The joint and the splice bar and fastenings have received an immense amount of study during the past twenty years, and while it would probably be too much to claim that the problem has been completely solved, no accusation that the railroads have been idle in this respect can be successfully maintained.

The ballast holds the ties in place, distributes the strain produced by the load to the sub-grade beneath, and undoubtedly performs some function in drainage. Taken in general, it is undoubted that there has been gradual increase in ballast, as the wheel loads and traffic have increased. That it has reached the proper thickness yet, even on those tracks which are best maintained, we fancy no one would be willing to affirm. We believe there are engineers who think that twice or even three times the present standard thickness of ballast is requisite, in order that the load may be properly distributed over the supporting surface beneath.

The sub-grade is the foundation and as such is unquestionably one of the most important elements in the problem. No amount of money spent on rails, ties, splices and ballast, will give successful results, on an inferior sub-grade. Our belief is that the importance of the sub-grade has not been sufficiently appreciated by engineers in the past. Indeed, there are indications that rail failures are a question of geography. The same rail, with the same locomotives and cars, and the same density of traffic, will have far less failures, if the sub-grade is sandy, porous, and well drained, than if the sub-grade is dense, heavy clay, which tenaciously holds water, and for quite a portion of the year may be called a more or less modified mud hole. The great enemy of the trackmen is water, and our firm belief is that if more study had been put on the problem of keeping water out of the sub-grade, fewer rail failures would have characterized the past.

The maintenance of track—that is, the amount of money and labor put upon the track to keep it up to its work, tamping ties, screwing up track bolts, keeping up renewals, giving heed to drainage, etc.—has necessarily increased as the wheel loads have become heavier and the density of traffic has increased. I know of no evidence that indicates that there has been a blameworthy falling off in any of these respects with the advent of the heavier rail. It is undoubtedly true that track expenses, even with the same maintenance of line and surface, show a tendency to diminish, the heavier the rail. It is easy to see why this should be so, since the heavier and stiffer the beam, the more the strains produced by the moving load are distributed, and consequently the less need that money should be spent to cause each minute part of the support to do its maximum duty.

And this brings us to an exceedingly interesting phase of the rail problem. During the past year or two, in discussions and committee meetings over rail specifications, the desire on the part of some railroad engineers has occasionally cropped out, to have a rail of minimum weight per yard, and yet so good that even though the track might not always in every detail be kept up to standard, there would still be no failures. According to their view, if the rails were what they should be, inferior track maintenance would be a very small matter. And, singularly enough, it seemed to be a little difficult for these engineers to see that this unloading of the whole problem upon the steel rail manufacturers was not entirely legitimate and praiseworthy. We hope to pay our respects to the steel rail manufacturers a little later, but we are compelled to say that this view of the case does not commend itself to us, and that we do not think responsibility can be so easily shifted to other shoulders. No one can be more desirous of good rails than we are, but failures in track maintenance cannot, we think, fairly be put upon the rail. On the other hand, we do think there is a legitimate question connected with this phase of our subject. This is, the requisite safety being always maintained, where does true economy lie in this contest between the rail and the track maintenance? There are three possibilities.

1. Would better rails with the same weights per yard as are now in use, even though obtained at increased cost, result in such diminution of track expenses, that economy would result?

2. Would the same so-called inferior grades of steel that are now being furnished, with increased weights per yard (it being conceded that increased weights per yard are not essential from the standpoint of strains), result in such diminution of track expenses, that economy would follow after paying for the increased weights?

3. Would better steel and increased weights per yard, at even still greater cost, be followed by such saving in other track expenses, that it would be true economy to obtain such rails?

We do not believe the data exist at the present time, that would enable a satisfactory answer to be given to any one of these three questions. And yet they seem to us to open up an extremely important field. It costs a certain amount each year to maintain a mile of track, including rail renewals, and we have never seen any figures that show that the distribution of the expense to each item is such that the sum total is a minimum. Perhaps better rails, perhaps heavier rails, perhaps the two combined, even at greater cost for rails, would bring about this desired result.

Returning now to our query as to what the railroads have done to meet the changed conditions produced during the last twenty years or more by heavier wheel loads and increase of traffic, it is difficult to see how any fair-minded person can think that the railroads, taken generally and as a whole, have not made a sincere effort to meet these changed conditions. It is granted that the action taken may not always have been the wisest action, that failures and mistakes have been made; and, indeed, it is undoubted that at times and places, more vigorous action should have been taken, and that too frequently there has been a disposition to lay the whole burden upon the steel maker. And yet, notwithstanding all this, it would, we think, be hard to maintain that there has not been much sincere, conscientious and faithful effort on the part of the railroads to meet the problems due to changed conditions, with which they have been confronted.

Let us turn now to the record of the steel rail manufacturer in this matter, and ask ourselves calmly and dispassionately, what has he done during the past fifteen or twenty years to assist in meeting the changed conditions, about which so much has already been said? Has he made better steel? Has he spent time and money and brain power in faithfully trying to improve his product? Has he heartily and earnestly cooperated with the railroad engineer, in his efforts to secure safe transportation of persons and property?

Before trying to answer these questions let us spend a moment with this problem of responsibility. It has already been hinted several times that there are railroad engineers who would be quite willing to put the whole burden of rail failures on the steel makers; and, on the other hand, it is quite as certain that the steel makers seem to have been not only willing, but as a matter of fact have again and again washed their own hands entirely of responsibility in this matter, and claimed that it was simply a question for the inspectors and engineers. We have heard them say in effect, not once, but many times, "Our mills are open to you. Here are the rails. Take them or leave them," thus practically putting the whole responsibility of accepting and using defective and inferior material upon those who from the nature of the case cannot know as well as the manufacturer, which are good and which are bad, and who many times have no alternative but to take what they can get. Not so do we understand the relation between the producer and consumer. From the nature of the case, the producer has essential information that the consumer does not have, and on the other hand, the consumer has essential information that the producer does not have, and it is only by working together conscientiously, honestly and harmoniously, that the best results can be obtained. We do not understand that the manufacturer of any material for the use of a public service corporation, where safety to human life is involved, can properly assume an air of indifference, can hold back essential information, which he as the maker of the material has, and the consumer has not, or can justly fail to cooperate in every reasonable way to the end that only safe material goes into the tracks. The making of steel rails for use under high-speed passenger trains, is something more than a mere commercial proposition. Both the producer and the consumer have great responsibilities in this matter, and neither can lay them aside or shift them upon the other.

Coming back now to our query as to the behavior of the steel rail manufacturers during the past fifteen or twenty years, we are frank to say that with the most sincere desire to be strictly fair in this matter, we cannot regard this behavior as eminently praiseworthy. There has been far too much antagonism, far too much holding back essential information, and far too great a failure to cooperate. Many within the sound of my voice will bear me witness that in conferences over steel rail specifications, it has many times been simply impossible to get such information from the representatives of the steel makers, as would enable critical points in the specifications to be wisely decided. And this is not the worst of the matter. Within two years past, entirely reputable engineers of railroad companies have said in my presence that they had been told by rail manufacturers, that if they did not take the rails offered, irrespective of specifications and tests, they would not get any. Still further, if I may judge from my own experience, it is only within the past year, or perhaps year and a half, that it has been possible to have what might fairly be called a consultation with the experts of the steel rail makers, over any point that involved the quality of the product, in any conciliatory, cooperating way. Far too much, we fear, the manufacture of steel rails has been studied in the past simply from the commerical standpoint.

And how about the steel itself? Is the steel that goes into rails to-day better or worse than that made fifteen or twenty years ago? It is well known that there is a general belief among railroad engineers, that the steel in the rails to-day is nothing like as good as it was twenty-five years ago. We are not quite able to follow these critics to the extent that they want to go on this point. Our judgment is that in two respects there is reason to think the steel in Bessemer rails is inferior to that made twenty-five years ago:

1. The larger ingots of the present day necessarily lead to increased segregation, and in so far as segregation is a serious element in the quality of steel, there is little room for doubt that the steel in the rails of to-day is inferior to that made some years ago. We think it fair to say that there is need for further study as to how far segregation, apart from internal physical defects with which it is so often associated, is a menace. We cannot help wishing that it was not in the rail to

anything like as serious an extent as many analyses show it to be, but at the same time, if the ingot was thoroughly sound throughout, we should like to study segregation farther before feeling willing to say the final word.

2. In so far as the more rapid working of the Bessemer process, which has seemed to characterize its full commercial development during the past twenty years or more, has led to incomplete action between the final additions and the blown metal, and to higher finishing temperatures in the finished rail, the metal must be inferior. The making of steel is a chemical process, and every chemist knows that all chemical reactions require time; and it is to be feared that Bessemer metal is, many times, cast in the ingot mold before the reactions are complete. The effect of this is certainly bad. Sound ingots cannot be obtained in this way, and if the ingot is unsound, good rails cannot be made. Again, we are quite well aware that high finishing temperatures are blamed on the rail section. Thin flanges, by getting cool too soon, seem to make it impossible to roll the head at the proper finishing temperature, and it is to be confessed, that in as far as the section is responsible for too high finishing temperature, the steel maker cannot fairly be blamed. But for all other causes leading to too high finishing temperatures, it is difficult to see how the responsibility is to be shifted.

Notwithstanding these, as we regard them, just criticisms of the later-made Bessemer steel, it is undoubted that a large percentage of the output of rails of the last twenty years has been approximately as good as that previously made. We are inclined to think that those who so vigorously denounce the later-made steel, forget the enormously increased traffic which these rails have carried. The lack of reliable figures showing comparative tonnage of the earlier and later-made steel is a very serious handicap in reaching a satisfactory conclusion in this matter.

But whether the earlier or later-made steel is better or not, it is certain that the need of to-day is for a steel even better than that earlier made. The speed is greater, the wheel loads are greater, and the tonnage is greater, and the steel, to successfully meet these changed conditions, should also be better. Do we find then that during the last twenty years, there has been real conscientious study on the part of the Bessemer steel maker, as to how to make better rails? Are the ingots any less unsound, and more free from shrinkage cavities, pipes, gas bubbles and blowholes? Have any of the suggested means of overcoming or minimizing segregation, and diminishing the pipe, been tried on Bessemer ingots? Have any of the Bessemer steel rail manufacturers or their experts contributed something toward the solution of the problem of how to secure safer and better rails? Have they welcomed and seemed willing to fairly try suggestions that might possibly lead to improvements in their products? Have they willingly accepted more frequent testing, to the end that inferior material might be kept out of the tracks? In so far as they have done honest conscientious work in any of these directions, let all honor be given them. In so far as they have failed, let us not add to their shame by discussing this phase of our subject farther.

Let us turn now to two or three other features of our subject. First, to the question of sections. It has already been hinted that the section has been blamed for some of the difficulties encountered in making good rails. The makers have urged, and we think with good show of reason, that the distribution of metal between the head, web and foot of the rail, in many of the sections, was such that it was practically impossible to finish the heads at the proper temperature. And since the sections were specified by the railroad engineers, the rail makers have felt, and we think justly so, that in so far as the section was an element in good rails, they could not be held responsible for poor rails. This criticism was felt to be so valid that within the past two years, two independent organizations have taken up the question of section *de novo*. One large railroad, through a committee of its own officers, reinforced by practical rail manufacturers, and the American Railway Association, through one of its own committees, assisted also by a number of practical rail makers, have both, but independently, devoted much study to the section.

The results of their deliberations have culminated in three types of sections. The one known as Section "A" of the American Railway Association is characterized by a shallower head, wider base, with thin flanges, and a greater height of section than either of the other two. Regarded as a beam or girder, this section is undoubtedly the strongest section of the three. It is apparently advocated by those who think that more of the duty of the track should be borne by the rail, and less by the other elements. It is obvious, as has already been stated, that the stronger the rail, as a beam or girder, the more the strains are distributed, and the less need, therefore, for exacting attention to the other features of track maintenance. Its advocates think that the distribution of metal between head, web and foot, is such that the rolling difficulties and especially the question of finishing temperatures, can be met with entire success. It would be a bold man who would be willing to affirm that this section will not ultimately prove to be the best of those under consideration, and especially that the transference of more of the duty to the rail will not result, as has already been indicated, in ultimate track economy. Those who oppose this section fear that the shallow head is an element of weakness. According to their view, with such steel as it is at present possible to get in rails, the pounding of the heavy traffic will lead to such crushing and splitting of the heads, owing to internal physical defects in the metal, that the section will prove a failure, especially on roads with heavy wheel loads and dense traffic.

The second type of section, known as Section "B" of the American Railway Association, is modified to meet this latter view. The head is practically the head of the American Society of Civil Engineers' section, thicker flanges, less height over all, and the same thickness of web. The distribution of metal is believed, as in the "A" section, to successfully meet the manufacturers' criticism, the head and foot having slightly over forty per cent. each of the metal, and the web the balance. This section is confessedly a compromise, but there goes with it the hope that it will ultimately prove itself worthy of being adopted as the standard recommended section of the Association. This section is weaker as a girder than the "A" section, but is believed to have sufficient factor of safety so that no difficulties will arise from this cause. These two sections have been proposed as "recommended practice" by the American Railway Association, and the question as to which is the better of the two, or indeed as to whether some other section is not still better than either, has been referred to the American Engineering and Maintenance of Way Association, an organization composed largely of railroad operating officers, to study and accumulate data, and make a report, after the sections have been tried in actual service.

The third section, known as the "P. S. Section" of the Pennsylvania System, is a step farther away from the "A" section. It has a still heavier head, a narrower base, thicker flanges, and the same thickness of web as the "B" section. The radius of the web is smaller, thus producing more of a buttress where the head and web join. The experience of the Pennsylvania System seems to be that with their heavy wheel loads and dense traffic, and with the grade of steel that it is now possible to get in rails, more rails fail from crushing and disintegration of the head, apparently due to the pounding of the traffic, than from any other cause; and accordingly in this section, the maximum effort has been made to strengthen the head in its weakest point. The distribution of the metal is satisfactory, and the strength of the rail as a girder or beam is practically the same as the "A" section, and is believed to be abundant for present conditions.

Which if any of these three sections will survive and become the standard section of the railway world in this country, it is of course impossible at the present moment to say. However, the issue is now clearly defined as never before, and the different ideas prevailing among expert engineers are clearly represented in the types presented. All the sections have been designed to meet the criticism of the steel makers, so that from this time forward, if these sections are used, there should be no excuse for improper finishing temperatures. It may happen that progress in steel metallurgy will so diminish physical defects in the steel, and so minimize the adverse effect of segregation, that all three sections will be found worthy of perpetuation. It is believed that a decided step forward has been taken by the preparation of these three sections, and much is expected from them in the next few years to come.

The question of the discard has occasioned many words during the discussions of the past two years, and we had almost said "bitter" words. There is material enough in this feature of our subject for a long paper. I fancy many of us had more positive ideas on discard three or four years ago, than we have at the present moment. The more the subject is studied the more difficult it becomes, seemingly, to express a final opinion that we are willing to stand by. If every ingot solidified in the typical way, and was like every other ingot, the question of discard would be easy. But it would almost seem as though every heat of steel was a law unto itself, and was different from every other heat of steel, and nearly the same might be said of every ingot. When we come to consider the conditions there seems to be much reason why this should be so. The differences in temperature at the time of casting, the more or less incompleteness of the chemical reactions, when the metal leaves the ladle, the differences in chemical composition of the different heats, the rate of pouring, the differences in the condition of the molds, the differences in rate of cooling dependent on surrounding conditions, the differences in practice at the different works, especially in the matter of covering and artificially cooling the top of the ingot, the length of time that elapses before the ingots are stripped, and the more or less fluid condition of the metal on the inside of the ingot when it reaches the first pass, to say nothing of accidents or mishaps that may occur in handling the semi-fluid ingots—all have an influence on the location of that part of the ingot which is supposed to contain the poorest of the metal, and which it is the object of the discard to prevent from getting into the rails.

In view of these uncertainties, we cannot but think that the position taken by the Pennsylvania System and the American Railway Association in their proposed specifications, is the most reasonable one: namely, to leave the discard to the manufacturers, and to safeguard the product by proper tests, especially by choosing the test piece from such a location, and making the rejections such, that it will be to the interest of the manufacturer to voluntarily discard the metal which will not stand test. This has been our practice at Altoona for many years. We have a number of specifications for different steel products, in which the word "discard" does not occur, and never has. An illustration will perhaps make this whole matter clear. When our axle specification was issued the whole question of discard was most carefully considered, and it was finally decided to select one axle at random for test from each heat of steel, after the axles from that heat had all been made up, stamped with the heat number, and put in a pile by themselves, and further, if the test axle stood all the tests, all the axles made from that heat were accepted, and if not all were rejected. After the specification had been in operation a short time, a manufacturer who had worked with us during the development of the specification, said to me, "There is steel enough in each one of our ingots to make thirteen axles of the size you are now using. As a matter of fact we only make and offer you for test nine, for if we should make the whole ingot into axles, and you should get for test one made from the steel which we now discard, you would condemn the whole heat, quite to our loss." We are firmly of the opinion that the matter of testing rails can be so handled as to give similar satisfactory results.

And this brings us to the question of tests and testing. During the past few years, much light has been thrown on this subject, and the truth compels us to say that a situation has been found that, in some respects, would be ludicrous if it was not so near the tragic. Let us see what the conditions have been.

1. The manufacturers have, in many cases at least, selected the rail-end as sample for test. The specifications being silent on the selection of the test piece, they naturally have urged that there was nothing to prevent their doing this, and they naturally again have, so far as information can be obtained, chosen the best steel in the ingot for test. It is not claimed that all specifications have been so loosely drawn as to permit such a suicidal practice, but it is certain that some of them have, and that the practice has been in vogue.

2. The "best two in three" principle has pervaded many specifications: that is to say, if the first rail-end stood test, the heat was accepted; but if it failed, a second was tested. If this likewise failed, the heat was condemned. If, on the other hand, it stood test, a third was tested, and the fate of the heat was decided by the majority. It would almost seem as though the specification had been drawn, not with the idea of being sure that only good rails should be accepted, but with the idea of being sure that as many heats as possible should be accepted.

3. Only one heat in five was tested; that is to say, as we understand the matter, if the rail-end stood test, and the heat was accepted, that acceptance carried four other heats with it. But singularly enough, if, on the other hand, the heat was rejected, that rejection only covered the heat from which the test rail-end came, and the four preceding or following heats, as the case might be, got another chance for their lives. The unsatisfactoriness of such a method of testing, it seems to us, must be evident to every candid mind that knows anything about the making of steel. As has already been stated, every heat of steel is a law unto itself, and there is no certainty, that because one heat or blow is good, the preceding or succeeding four are equally good, any more than there is a reasonable presumption that if one heat is bad, the preceding or succeeding four are likewise bad. And while it is agreed that when everything is working well, successive blows from the Bessemer converter may

be similar in many respects, it is not agreed that testing one blow in five gives any reasonable assurance that only good rails are accepted for use in the tracks.

We fancy the rather loose testing described in the three items above started in the earlier days, when the strain on the rail was far less than at present and the traffic far less dense, and has been perpetuated, partly owing to inertia on the part of railroad engineers, and partly owing to the resistance of the rail manufacturers. The wonder is, with such loose, log-rolling testing as has been in vogue, not that there have been so many rail failures, but that there have not been more.

But this is not the whole story. Until quite recently the specifications have been equally loose in regard to the drop-testing machine employed in making the tests. The weight of tup has been carefully stated, and the height from which it must fall has been given,—indeed, in some cases the foot pounds of the blow are carefully given for each weight of rail; but it has apparently been forgotten that the anvil or support on which the rail rests when it receives the blow is a most important element in the problem. It has recently developed that at one steel works the anvil was a couple of ingots laid down side by side, with appliances for holding them in place, and supporting the test rail, the whole resting on boards placed on the ground. At another steel works, the anvil weighed three thousand pounds, and rested on boards, stones and gravel. One rail manufacturer recently said in my hearing: "As long as the railroads did not object, why should we take measures to increase the severity of the test by putting in heavier or better supported anvils?" It is gratifying to be able to state that some of the more recent specifications, while according to our ideas still far from satisfactory in the matter of testing, do show marked improvement in some of the respects mentioned above, and still better, that the rail manufacturers are cooperating in and actually suggesting some of the improvements.

A few words now in regard to some of the details of testing rails; and first, in regard to the drop test. It is well known that many testing engineers do not favor the drop test for rails. To our minds, however, it is the only possible available one for the present, and the following considerations seem to us to have weight in confirming this view:

1. It tests the whole rail in the condition in which it goes into the track, instead of a small fraction of the rail, as is requisite in all cases of prepared test pieces.

2. It is sufficiently rapid, so that even though every blow is tested there is no fear of delaying the output of the mills while waiting for test pieces to be prepared, or for slower tests to be made. We have known of a case where, with sufficient force to handle the samples, fifty-five tests have been made in half an hour, on a modern drop-testing machine.

3. There seems little doubt but that some of the strains or shocks which the rail actually receives in track, are similar to those produced by the drop-testing machine. This is, we think, clearly the case with a loose joint and a rapidly moving train. In case the track bolts have become loosened, the end of the rail, when the approaching wheel mounts it, certainly gets a blow similar to that given by the drop-testing machine. We have known rails which have given long service in track to be broken in this way, and the fracture showed perfectly clean, sound metal.

4. Finally, if the specification requires that the deflection be taken, the drop test reveals a good deal in regard to the physical properties of the steel.

Second, in regard to the selection of the test piece. We fancy it goes almost without saying, that this should always be made by the inspector. In regard to location of test piece, it is of course understood that in shearing the ingot into rail blooms, it is necessary to make the bloom from which the test rail-end is to be taken a little longer than the others. It is therefore essential that the inspector or the specification should designate the bloom from which the test will be taken. Some recent specifications, wisely we think, designate the top bloom of the ingot for this purpose, it being generally understood that the so-called "pipe," if there be any, and the greatest segregation and physical defects, will be in this bloom. We may, perhaps wisely, call attention to the fact that if a cover and cooling devices are used on the top of the ingot when it is cast, the poorest steel in the ingot will not be near the top end of the top bloom, but more probably near the bottom end of the top bloom, so that if the inspector takes his test piece from the top end of the rail made from the top bloom, he will be more apt to deceive himself, than if he has the test piece cut from the bottom end of the top bloom. We have sometimes thought, when inspecting the practices of casting and cooling ingots in certain works, that it would be better to take the discard between the first and second blooms.

Third, in regard to height of drop. We have always opposed extreme severity of tests. Owing to the defects in the anvil previously referred to, if indeed they have been general, it is apparent that but little information that is of value, and that is safe to follow, can be obtained from previous tests. Our own view is that something a little more severe than the rail will receive in actual service, enough for a reasonable factor of safety, is all sufficient. The trouble is we do not know how severe the shocks in service are. Some recent tests of rails which had broken short off in track, made by the Research Committee of the Pennsylvania System, seem to indicate that a 15-foot drop with a 2,000-pound tup, and a 20,000-pound anvil, would have rejected two thirds of those which failed in service; also, that the 15-foot drop actually broke as many test pieces as the 19-foot drop, other conditions being the same. These tests should be much amplified before final conclusions can be reached, but as far as they go, they seem to indicate that we must look to other causes than defective or poor steel for a portion of the rail breakages, and that extremely severe testing is not necessary.

We have taken so much time with what precedes, that there is no opportunity to discuss a number of other features of the rail situation. The subject is far too large for a single paper.

It would be interesting to consider quite at length, how to manage the results of tests, in such a way as to be strictly fair to the manufacturers, and at the same time prevent the acceptance of inferior or defective rails. We would suggest that those especially interested study the specifications of the Pennsylvania System recently issued, and those of the American Railway Association, proposed at its recent meeting in New York City, April 22, 1908. Much might be written on the chemistry of the steel rail, and especially the phosphorus limit; also on open-hearth steel rails, but time and space forbid. The wear of rails has not been touched at all, and must be deferred to another occasion.

Summing up and putting in concrete form our views on the present situation, we are inclined to say:

1. The crying need of the hour is positive, definite information. Upon dozens of points, no positive data exist. During the discussions of the past two years or more, opinions have been as plentiful as leaves in autumn, but of positive, reliable, statistical information, or figures taken from properly kept records, there has been a dearth that was fairly oppressive. The steel makers have not been as deficient in this respect as the railroad engineers.

2. The time seems opportune for genuine progress to be made. The railroads through their organization, which in a sense speaks for them all, the American Railway Association, have taken hold of the matter with vigor, and have developed a large amount of valuable information; and for the first time in my twenty-five years' study of this subject, the steel rail manufacturers have shown a less antagonistic and more conciliatory and cooperative spirit than has usually characterized them.

3. The specifications proposed by the Pennsylvania Railroad System, and by the American Railway Association, seem to us to represent genuine progress, and to be worthy of most careful study and trial. While they may be said to represent perhaps the best that can be done, until more positive knowledge

is obtained, he would be a bold man that would claim that they will ultimately be satisfactory or final.

4. Whether the Bessemer process can be so modified and improved as to enable it to furnish rails that will be entirely satisfactory under the heavier wheel loads and denser traffic of to-day, and the near future, or whether the basic open hearth will soon be the source from which steel for these rails will be furnished, are questions worthy of serious attention. Our own feeling is that if a small fraction of the time and money that has been spent in the past over the commercial development of the Bessemer process, shall, in the next few years, be spent in getting sound ingots, free from blowholes, slag and manganese sulphide (if this shall be found to be as serious as it now looks), and in overcoming or minimizing segregation, it will last for many years to come.

5. The American Society for Testing Materials has a most important duty to perform at this juncture. By stimulating the development of information, by furnishing an arena for the presentation of such papers on the metallurgy of steel as are on its program for this meeting, by arousing interest in testing machines and methods of testing, by furnishing a forum where producer and consumer can meet on common ground and discuss their differences unhampered by commercial considerations or by artificial distinctions of professional ethics, and by keeping their own specifications up to date and utilizing new information as fast as it is obtained, it can so fill the field which it occupies, that when the ultimate record is made up, its contribution will be by no means among the least.

We beg not to be misunderstood in this matter. If we have called attention to loose practices; if we have indicated that as we look at the matter, rail manufacturers have in the past been a little too much actuated by commercial considerations, and have too vigorously antagonized the efforts made by inspectors and engineers to secure better and safer rails for the track; if we have pointed out that in some cases specifications have been loosely drawn, and that tests and inspection have too often been one-sided and inefficient—it has not been for the purpose of holding any one up to ridicule, or to make statements that would appeal to the popular fancy, but with a sincere desire to have the mistakes and shortcomings of the past so well understood, that they will not be perpetuated in the future. There is much indication, and it may well be, that what has been done in the past was sufficient for its day. But our sincere belief is that past practices are no longer applicable, and our plea is for more conciliatory and more conscientious action on the part of the rail manufacturers, and for more thorough and exhaustive study of all the elements of safe economical track on the part of railroad engineers, to the end that the changed conditions about which so much has been said may be successfully met, and the rail transportation interests of the country be put on a safer and better basis.

ENGINEERING RESPONSIBILITY.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY
DELIVERED BEFORE THE
AMERICAN SOCIETY FOR TESTING MATERIALS IN 1909.

Few fields of study are more fruitful of results and lead to more genuine progress than a study of the causes of failures. Such studies may be unpleasant and disagreeable, they may at times be even disheartening, but the man who would make substantial advances must heed the lessons which his failures teach. It is true that valuable information can be obtained likewise from a study of materials which have given successful service. And, ofttimes, when attacking a new problem, a comparison of the properties and characteristics of those parts of a structure which have behaved well in service, with the characteristics and properties of those which have failed in the same service, is a most satisfactory method of approach. And yet, it is doubtful whether the study of failures does not give the more positive information. Faraday, who spent his life in experiment, used to say that he learned more from his failures than he did from his successes. And it is not difficult to see why this should be so. When an experiment or a construction has proved successful, we are naturally most interested in the result, and do not usually spend time and thought and study over the details which have led to our success. On the other hand, if our experiment or construction is a failure, the cause of the failure is immediately sought for, every detail is questioned, and it is this study of the details which broadens our knowledge. Quite in line with Faraday's statement is the rather more homely phrase, with which you all are doubtless familiar, and which we remember to have seen somewhere in engineering literature, that "the scrap heap is the place to learn."

Closely connected with the query as to the cause of failure is the ofttimes more important question, who is responsible for the failure? If the matter in hand is an experiment which we are making for our own information, the question of responsibility is small and is practically swallowed up in the cognate question of the cause of the failure. But if, on the other hand, the failure involves the loss of human life or the destruction of valuable property, the question of responsibility may be very grave. And if we may trust our observation, the location of the responsibility for failure is not always an easy matter. I remember to have heard a former editor of *Harper's Magazine* say in a public lecture: "The general habit of humanity is to throw the teaching of the sermon over into the adjoining pew and keep practically none of it for ourselves." Much the same way is it with responsibility for failures. With each and all of us it is usually the other fellow and not ourselves that should be held accountable. In view of the situation, it has occurred to us that it might not be amiss on this occasion to spend a little time over the cause of, and responsibility for, failures in engineering constructions.

In our studies of failed and broken parts in connection with our work at Altoona for now some years, we have been gradually led to ascribe failures to one or more of the four following causes: namely, bad material, bad workmanship, bad or faulty design, or unfair treatment.

Let us spend a few moments with each of these possible causes of failure. First, bad material. This does not cover those cases where the wrong kind of material was used or material not adapted to the work. If cast iron is used when steel should have been employed, if the steel is brittle when the service requires tough, tenacious metal, this is no fault of the material. Failures due to the employment of material unfitted to the service come under another category. Nor can the material be blamed if the size of the part which fails is too small. This cause of failure also comes under another category. But material is bad, and may justly be charged with being the cause of failure, when it is different from what those who put it in service had a reasonable right to expect it to be. A rail with a bad pipe in the head, an axle made from a badly segregated bloom, a piece of concrete in which the materials are improperly mixed or contain not enough or inferior cement, are all examples of bad material, and if failure comes the failure may justly be charged to the material.

The query may naturally arise here, ought not the factor of safety employed to be sufficient to care for the uncertainties of material, so that the total output of a works could be made use of in service? We once knew an officer of a steel works who wanted to have one grade of steel used for all purposes, and who, when told that car axles made of that grade of steel would not be strong enough to hold up the load, replied: "Use more of it—that is, make the axles bigger." Undoubtedly there is a necessary relation between the factor of safety and some of the uncertainties of manufacture, but it can hardly be allowed that the producer should thus throw upon the consumer all the uncertainties of material. We cannot help thinking that our definition of bad material is sound: namely, material is bad when it is different from what those who put it in service had a reasonable right to expect it to be. If the material is bought on specifications, it is reasonable that it should be what the specifications call for. And even if it is bought on indefinite, verbal or written order, such material should be supplied as the buyer had a reasonable right to expect would be furnished.

But why is there ever any difficulty between the producer and consumer about material? The price is agreed upon when the order is taken and the quality of the material is either specified or understood. Why, then, does not the producer always furnish good material?

Our experience on this point has brought us face to face with several explanations of the difficulty we are considering. First and perhaps most important is the price. It is constantly urged that the consumer will not pay the price requisite to secure the materials desired. No information is usually given as to how far the wished-for price, requisite to secure such good materials as the producer would like to furnish, covers a desire for large profits, and consequently consumers have always been a little slow in attaching much weight to this excuse. Prices are largely determined by competition, and in the absence of something more than a verbal statement from the producer that better materials would be furnished at a higher price, he would be a bold purchasing agent that would pay the higher rate. On the other hand, it is undoubted that competition is the antagonist of quality, and where materials are bought without reasonable specifications rigidly enforced, there is unquestionably much weight in the contention of the producer.

Another reason or excuse for poor materials is that processes and methods of manufacture do not always and every time yield the desired first-quality product. Strive as the manufacturer may, the works always turn out some material that is inferior. Taking our illustration from the steel industry, it is well known that every heat is not equally as good as every other, and that a part of each ingot is inferior to the remainder of it. Of course, all of this inferior part that cannot be sold must necessarily remain as scrap, to be worked over again, with the result that the manufacturing cost of the marketable product is necessarily increased. Hence the tendency to crowd the limits and force upon the purchaser all the merchantable material possible, even though some of it may be inferior. It is fair to say that there is a good deal of human nature in this phase of our subject, and if only those of us who are without sin are entitled to cast stones we greatly fear very few stones will be thrown.

Another and most pernicious excuse for furnishing bad materials is the attempt, so common everywhere on the part of producers, to usurp the legitimate functions of both the consumer and his expert. This manifests itself in the statement, so commonly made by those furnishing material, that it is good enough for the purpose, thus arrogating to themselves the right to decide not only how the material shall be made, but also what kind of material the consumer and his engineer shall use. Pernicious though this custom may be, a good deal may be said in palliation of it. The practice is the outgrowth of an historical situation. In the earlier days, when the consumption of materials was only a fraction of what it is at present, the producer of any material was supposed to know not only how to manufacture it, but also its characteristics and how it would behave in service, and consequently consumers who in those days had scarcely begun to study for themselves the behavior of materials in service, naturally turned to the manufacturers for counsel as to what materials to use. This practice is still in vogue, and it is to be confessed that, where it is employed, no legitimate criticism of the producer can be made if he urges that the material is good enough for the purpose. On the other hand, as time progressed and large consumers began to study for themselves the behavior of materials in service, as they began to employ their own experts, as testing machines and laboratories began to increase, as, indeed, a society for testing materials came into existence and knowledge of the properties and characteristics of materials began to widen, it is evident that the situation has changed and that where materials are bought on definite specifications, the voice of the producer as to quality is no longer potent, and that the old excuse for inferior materials—that they are good enough for the purpose—is no longer entitled to consideration or weight. We are entirely ready to allow that the study of materials, during both the process of manufacture and their behavior while they are in service, is a legitimate field of activity for both producer and consumer, and, as is well known, we have persistently urged with all the force that we were capable of, that while specifications are being made there should be the heartiest cooperation on the part of both; but the specification having been decided on and the contract placed in accordance therewith, there really seems to be very little room left for excuse for furnishing materials that do not meet the requirements, because they are, in the judgment of the producer, good enough for the purpose.

We intentionally refrain from discussing that excuse for poor materials which has its foundation in an overweening desire to make money, since it is so clear that the producer who does not give a reasonable equivalent for the money that he receives must necessarily have a short business life. We are quite ready to acknowledge that no hard and fast line can be drawn between quality and continued business success, and yet we fancy few will deny that the man who sells inferior, worthless or adulterated materials which do not give satisfaction at the price of good ones, will have serious difficulty in securing a second or third order for the same kind of goods. In our own experience, and, let it be stated modestly, partly as the result of our own tests, a number of firms who formerly did quite large business with railroads, have either gone out of existence or have been forced to seek business in other fields than those which they formerly cultivated with such unfair profit to themselves.

Coming now to the second cause for failure in structures, bad workmanship. That bad workmanship is a far too frequent cause of failures, is common experience. The tendency to slight the job is almost universal. A rivet or a bolt is left out, with consequent increased strain on those which are actually put in; a forging does not fill out the pattern, or the metal is burned, or a weld is defective. We knew a case once where the construction on a passenger coach involved the safety of human life, and where the drawings required that there should be two nuts on a bolt and the end of the bolt riveted over. After the cars had been in service a few weeks and some minor repairs were being made, it was discovered that the bolts originally used in a number of the cars were too short, that the second nut only grasped one or two threads, and that the remaining space in the nut had been filled with putty, so manipulated and stained as to give the appearance of the riveted end which the drawings called for. We knew of another instance where two ends of a gas pipe in a small house were joined with putty instead of with the well-known sleeve or thimble. Fortunately the odor of the gas from a slight leak in the defective joint led to its discovery and repair before anything serious happened. There is little doubt that the experience of each of you will furnish quantities of cases of bad workmanship, and we have known engineers who did not hesitate to declare that bad workmanship was the principal cause of failures in service.

Those of you who have frequently been brought into contact with the results of bad workmanship, have no doubt, like myself, often wondered why work was so badly done. Not infrequently, in contemplating a failure in which bad workmanship played an important part, we have said to ourselves, "there was absolutely no excuse." And yet, since workmanship is so important an element in our theme, it may not be amiss to go a little deeper into the matter. Every one will recognize lack of skill, general inefficiency, and simple plain laziness, as important elements in bad workmanship. But since these are individual characteristics, it probably would not yield any valuable results to discuss them. It is true that the apprentice system, or lack of apprentice system, which is characteristic of many trades, might, perhaps, justly be blamed for lack of skill, but it would lead us too far to consider this point.

No doubt many will claim that inferior or insufficient compensation is the most fruitful cause of poor quality of work at the hands of those who, in our industrial system, play the part of hewers of wood and drawers of water. But if we are right, the experience of the last few years has not seemed to confirm this view. If this was the real explanation it would seem to necessarily follow that a voluntary increase in wages would bring an increase in efficiency. On the other hand, if we may trust the indications that we have been able to gather, the increase in efficiency following voluntary increases in wages has been most disappointing. We must apparently look further for the real reason for poor workmanship.

In our judgment, the method of compensation for work performed has a direct and most important influence on the quality of the service rendered. We refer especially to the piecework system in those places where it is applicable, and to the payment of all interested in proportion to the amount of successful output, which is so common in the steel industry. Both these methods of compensation stimulate output at the expense of quality, and it is not at all strange, perhaps, that after constructions have found their way into service, we should not infrequently find evidences of the haste, the slurring over, and the inferior workmanship which these methods have necessarily done so much to stimulate. We are not at all prepared to suggest any substitute for them, and we are, and have been for many years, an advocate of them from the standpoint of successful management; but it is folly for us to close our eyes to the fact that the piecework and successful output methods of compensation of workingmen are antagonistic to quality of work, and that, despite all our efforts to the contrary, they may justly be held responsible for some of our engineering failures.

One more phase of the workman problem. Close observers of the modern workman have noticed for some years a growing tendency on his part to manifest less and less interest in his work. *Esprit de corps,* pride in his work, and a genuine feeling of loyalty and devotion to the establishment of which he forms a part, are gradually becoming less and less. The allegiance of the workman, under the influence of the ferment and agitation which now prevades our whole industrial system, is gradually passing over, in a measure at least, to the labor organization. Instead of cooperation there is ofttimes antagonism. Instead of zeal and earnestness on the part of the workman to do his best, there is study how to make the organization stronger and secure greater benefits for himself. The effect of this transfer of allegiance on the quality of the work performed needs no elucidation.

It is not at all our purpose to discuss the labor problem, and this statement of the situation is cited only because it throws a valuable side light on the question we are considering. We may, however, be permitted a single statement: namely, "We are firmly convinced that if labor organizations would devote less time and energy to contention with employers and more effort toward making the organization stand for skill and plain, simple honesty in workmanship, and for fair dealing with, and reasonable devotion to, the interests of employers, all questions connected with the recognition of the union would fade into insignificance, and collective bargaining would be welcomed—nay, even sought for—by those who are managing the great industries of our modern civilization."

Third, it is evident that the engineer who makes or finally decides upon the design of any structure carries a heavy load of responsibility. He is first in the field and practically tells all who follow what is to be done. He must decide not only the kind of material that is to be used, but also the amount or sizes, and how it shall be disposed. His realm embraces every kind of structure, from the foundations of a bridge or building to the most minute detail of a locomotive or car. In railroad track he says or should say what weight of rail shall be used, the number of ties per rail, and the kind and depth of ballast. His knowledge of the properties of materials used in construction must necessarily be broad and comprehensive, and the field is so enormous that there are naturally numerous specialists, each being able to cover, and be an authority in, only his own little paddock.

The engineer who makes the design labors under two very serious difficulties. First, it is not possible, many times, to compute the strains to which the whole or parts of the structure will be subjected. Perhaps we can best make this point clear by considering the locomotive driving axle. The strains produced, when we regard the locomotive as a vehicle, are simple and easily determined. So likewise the bending moment produced by the action of the steam on the piston, as well as the torsion strain produced by the crank. But who can tell the bending moment produced by the lurch when the wheel strikes a curve at high speed? Who can even give a guess at the strain produced when the brake is applied, making an emergency stop at sixty miles an hour? Moreover, the tendency of the times is toward larger and larger structures. And as the parts increase in size, would any of us be willing to say that the strains in each part would increase directly proportional to the increase in size of the whole structure, or that a proportional increase in size of any given part would as successfully meet the increased strains as did the corresponding smaller parts of the original structure? The engineer who makes the design, perhaps more often than any of us, is at the end of his knowledge and, if failure comes due to defective or faulty design, deserves, in our opinion, more sympathy than any one else involved.

But the designer labors under another serious difficulty. He is often overruled and prevented from doing what his judgment prompts him to do, in the interests of safety, by those who control expenses. The construction he would like to use costs more, and the management, for economic reasons, demands something less expensive. Of course, under these conditions, much responsibility is taken off the designer. And while we are ready to allow that some check is desirable, since those who make the design are, after all, human and naturally will take care of themselves, we cannot but feel that this check should be sparingly applied in all places where safety to human life is involved.

Fourth, unfair treatment. As already indicated, there is a natural disposition on the part of each of us to relieve ourselves from blame and put the fault on some one else, and if our observation is worth anything, there is no field of parceling out deserts among those involved in failures and the responsibility therefor more fertile than this one of unfair treatment. This field is the especial paddock of the maker or producer of material. If a rail breaks or fails in service, there was, says the rail maker, something wrong with the track or with the locomotives or cars that run over it. If a car wheel breaks or fails to give a guaranteed mileage, the track was too rough, the use of the brakes too severe, or the lading too heavy, and so on. Far be it from us to say that unfair usage is not many times a legitimate explanation of failures. If a freight locomotive, designed to haul a heavy load at twenty miles an hour, is used at times on a passenger train at forty miles an hour, and in so doing shakes herself to pieces, the fault is certainly not in the materials nor in the workmanship, nor in the design, but in the unfair use. If, due to the growth in size of locomotives and cars, an old iron bridge, designed for not over two thirds of the live load which is actually put upon it, gives way and produces a disaster, the responsibility rests with the operating officer rather than with the bridge engineer. These examples might be multiplied to almost any extent, but perhaps enough has been said to make the point clear.

There is, however, another phase of this part of our subject. Unfair treatment is very much broader than the obvious misuse of a bridge or of a moving vehicle. The materials entering into a structure may be unfairly treated. If the calculated strains are too high, or, what amounts to the same thing, too low a factor of safety is employed, materials are unfairly used. Still further, where a structure is composite, it may, and undoubtedly does, often happen that the elements making up the composite are unfairly treated—as when, for economic reasons, not enough money is spent to properly install the structure. For example, a steel rail called upon to do its work supported by too few ties, insufficient ballast, and a badly drained subgrade, is unfairly treated. Moreover, the state of repair in which structures are maintained is clearly an element in their fair treatment. If not enough money is spent in repairs and parts become weakened by decay, corrosion, or wear, to such an extent that failure results, it is entirely obvious that the failure must be attributed to unfair treatment.

We have gone thus quite at length into detail in what has preceded in order that we might have definitely before us the elements entering into this problem and be able to see more clearly where truth and justice lie between the conflicting interests. If now our analysis of the causes of failure is accepted as correct, it is evident that freedom from failure in construction depends on the conscientious and intelligent action of four different contributors to the final result. The materials employed must be conscientiously and intelligently made, and must be what they are supposed to be. The workmen who use these materials must do their work conscientiously and under intelligent guidance. The engineer who designs the structure must have abundant knowledge of the properties of the materials he is using and must take as little as possible for granted in deciding on shapes, sizes and kind of materials to be employed. And finally, the one who installs and operates the structure, when it is completed, must keep it in proper repair and look well to it that no duty is required of it which subjects it to unfair strains.

It is likewise evident that, since the four parties involved in successful construction have different individualities and may have diverse and even antagonistic interests, there is abundant reason why there should be an attempt to shift responsibility for failure. And, indeed, we might perhaps safely go a step further and say that there is abundant reason why each of the four parties should try to limit the part which his own work plays in the final result, and say plainly, if the other three had done as they should there would have been no failure. The man who furnishes the material is tempted to say: "If the designer had allowed a proper factor of safety everywhere, if the workmen had done their duty, and if the structure had received only proper fair treatment, almost any material would have been good enough." The engineer who makes the design is tempted to say: "If the material had been what I had a right to expect it to be, if the workmen had done good work and there had been no abuse of the structure in service, there would have been no failure." And so on, for the others. It is plain that the problem of obtaining successful constructions is a complicated one, and that the chances for divided responsibility which are involved are no small element in this problem.

Within the last few months two episodes have occurred which so clearly illustrate two phases of our theme, that we cannot forbear to quote them. The two phases are unfair treatment and the inference that the blame for failure rests on some one else. It will be remembered that within the past two or three years there has been much outcry in regard to broken steel rails, and the steel rail manufacturers have, in the technical press, been quite severely called to account for their shortcomings. Indeed, from this platform, in the last annual address, some statements were made indicating that it was believed that the maximum fiber stress in the 100-pound rail under present conditions of wheel loads and speed was not over 12,500 pounds per square inch. Some two months ago we received a letter from one of the ablest metallurgical engineers connected with steel rail manufacture in this country, in which this statement was very seriously called in question. The writer of the letter figured that under many conditions the fiber stress might be double the figure given, and that under extreme, but still possible, conditions the fiber stress might reach nearly four times this figure. The obvious conclusion was, although this was not stated in the letter, that it was these extreme fiber stresses, this unfair treatment, which caused the rails to break. We have tried in vain thus far to get some one much more competent than ourselves to prepare a paper on this subject for this meeting, and one object we have in mind in citing it now is to stimulate study and attention to it. Will not some one take hold of this problem and give it exhaustive treatment, allowing the maximum effect to wheel loads, counter-balance, effect of the steam, want of rotundity, flat spots, nosing, and speed? A theoretical treatment, even though we are not all satisfied that the rail acts like a continuous girder supported at the centers of the ties, cannot fail to be valuable.

The other episode is the experience of the Atchison, Topeka and Sante Fé Railroad with broken rails on different sub-grades. This road had some two hundred and twenty-seven miles of roadbed which were sandy, porous and well drained, and ninety-one miles which were largely clay of a kind that holds water. The traffic was the same over both portions and the rail all 85-pound rail. The rail breakages in one year were two and a half times greater per mile of track on the clay sub-grade than they were on the sandy sub-grade. Mr. Wells, the general manager of the road, was kind enough to say, in communicating this information, that these facts seemed to confirm the statement made in the last year's annual address that "there are indications that rail failures are a question of geography." More to the point for our present discussion is the obvious conclusion that the use of rails on clay sub-grade full of water without sufficient porous ballast is unfair treatment, and that breakages, under such conditions, cannot justly be said to be the fault of the rail.

But perhaps we have said enough in analysis of the causes of failure. Let us now devote a few moments to precautions that may be taken with material and workmanship in the interests of safety; and to a consideration of what should be our mental attitude toward design and unfair treatment. And first as to workmanship. Under present conditions the necessity for close supervision is evident. Managing men everywhere recognize this necessity and are employing all means at hand to secure it. We knew an officer of a large corporation some years ago who said to his board of directors: "If you will allow me to spend $50,000 a month more in salaries, so that I may give your work better supervision, I will give it back to you four-fold." Moreover, with the growth of modern industry, and especially with the development of machinery as an element in this growth, the individuality of the workingmen has necessarily diminished, and the present industrial ferment of strikes and lock-outs, with their accompanying riots and violence, is, as we interpret it, the revolt against this debasement of individuality. That the revolt should at times go too far, that unreasonable demands should be made, that demagogues and agitators for their own advancement should get into positions of prominence, is perhaps to be expected. As time progresses these will pass. It takes time to bring a change of views in both employed and employers. Already there are signs of something better and our belief is that in the not far distant future, as the result of wiser management on the part of labor organizations and reasonable concessions on the part of employers, there will be a return by the workingmen to the old-fashioned virtues of interest and pride in their work, and unswerving loyalty to the organizations which they serve. The effect of this change on the quality of workmanship needs no comment.

Second, with regard to material. It is difficult for us to see how any one who is responsible for safety in structure dare at the present time put material into these structures which has not been bought on carefully prepared specifications, and which, before acceptance, has not been rigidly inspected and tested. In time past, before consumers understood the demands which the service makes on materials, the reputation of the maker was perhaps the best safeguard known for good materials and was accepted as reasonable defense in the investigations following disaster. But in these days, when the service has been so frequently questioned, when so much accumulated information is available, when experts and facilities for testing are so largely multiplied, we cannot help feeling that the management that puts materials into service, especially where safety is involved, without careful and conscientious inspection and testing, is taking a risk that it is no longer entitled to assume. It is gratifying to be able to see that, as the years go by, there is constant and steady growth in this field. And while the ground is still far from being covered and the number of standard specifications still far too small, each year brings some progress, some steps forward. This society has a most important mission to fulfill, and the publications of no organization that we know of anywhere are doing more to elevate the standard of quality of materials of construction than the annual volume giving the results of the deliberations of this body.

Third, bad workmanship and bad materials can apparently be so controlled as to secure safety by sufficient supervision and by having proper specifications, with rigid inspection and test. But how about the unfair treatment of materials, or the structure made from them? Here no supervision beyond some meager legislative enactments and the condemnation of public opinion in case of disaster, is possible. It is, of course, true that those in charge of the construction and operation of utilities in which the public safety is involved are constantly face to face with the possibilities of heavy losses in the way of damages for accidents, and no doubt this is a most powerful check against unfair treatment. But it has seemed to us for a long time that the producers of material have far too much neglected their opportunities. Surely it is as legitimate that the producer should study the treatment his material gets in service, as that the consumer should study the methods by which that material is made. It may take the consumer a few years to become familiar with the idea of being told that he has not treated material fairly, since he is undoubtedly accustomed now to thinking that he can do what he wishes with what he has bought and paid for; but we are confident there would have been fewer complaints of material in the past if the method we have suggested had been in vogue. It is, of course, not to be understood that we are recommending howls about unfair treatment as excuses for inferior materials. What we have in mind is that careful studies and investigations should be made by the producer, leading up to demonstrations if possible. It is common experience that the truth is reached with much greater certainty and speed if a problem is attacked by two parties who approach it from different standpoints and are actuated by antagonistic interests. Our whole Anglo-Saxon jurisprudence is founded on this method of procedure.

Fourth, what shall we say of the engineer who makes the design? We have already described his difficulties, pointed out his limitations, and expressed our sympathy with him in his chance failures. It remains to put on record a few thoughts which have forced themselves on us, not once but many times, while preparing this paper, as especially when contemplating the difficulties of the engineer who makes the design. The truth is we are using materials in construction without sufficient knowledge. There is crying need for experiment. Testing machines, adequate to cope with some of the problems which now confront engineers, do not exist. We are increasing sizes and constantly building larger structures. If the test of service gives a failure, it simply proves that our guess as to the increase needed was wrong; and if the test of service shows freedom from failure, we still do not know that we have used material wisely and economically. The factor of safety everywhere is largely a guess. The late A. L. Holly, one of the brightest mechanical engineers in this country twenty-five years ago, used to speak of "the ridiculous factor of safety, one-half of which is a factor of ignorance." We cannot help feeling that no better use could be made of some small fraction of the millions that have been accumulated by individuals in connection with our great industries during the past half a century, than in the establishment of a Bureau of Engineering Research. Who will avail himself of this magnificent opportunity?

Just a word in conclusion. No one, I am sure, can contemplate the situation which we have been trying to discuss, without being impressed with the diverse and ofttimes antagonistic interests involved. The producer of material is anxious to secure the largest amount of successful output and the greatest possible amount of reward therefor. The consumer wants to limit this by restrictions as to quality and to obtain the material at the lowest possible figure. The workman's interest is to secure the maximum of pay for the minimum of effort, and in this struggle it may perchance happen that the quality of work suffers. The employer's interests are clearly the reverse of the workman's, and so on. The foundations of these diverse interests are of course very deep, and with the present organization of society it is not easy to see how they are to be obliterated or their antagonism neutralized. But we beg to make one suggestion. Would not an infusion of genuine conscientiousness into our industrial life bring an amelioration? If a little less energy was expended in the mad race for wealth and a little more zeal manifested in maintaining the rugged virtues of honesty, integrity and fair dealing, would not some of the friction and contention of our present commercial life disappear? We must all live together, and surely harmony is better than contention. There are some things in life of more value than money.

Selected Addresses

of

Charles Benjamin Dudley

THE DIGNITY OF ANALYTICAL WORK.

PRESIDENTIAL ADDRESS BY DR. CHARLES B. DUDLEY
DELIVERED BEFORE THE
AMERICAN CHEMICAL SOCIETY IN 1897.

It will doubtless be conceded by all, that in the choice of the field to which one proposes to devote his life-work, a number of things should be consulted. Among these may be mentioned not only mental capacity and the opportunities for training by courses of study which may be available to him, but also what may be termed natural inclination or love for the work. Just how much weight should be given to each of these elements is a query not easily answered, but few will deny that genuine interest in or real love for the field of work chosen, should be allowed as great sway as possible. Those of us who have gotten far enough along in our life-work to be able to look back somewhat, and to see and differentiate the causes that have shaped our line of effort, know full well that circumstances beyond our control, rather than our inclinations and desires, have in many cases determined our course; but the fact nevertheless remains, that for the best results, for the attainment of even moderate success, one's efforts must be in a field agreeable to him, and his heart must be in his work. Fortunate is the man for whom circumstances so shape themselves, that he is able to pass his years in the field of his choice, and spend and be spent in work that is congenial to him.

Assuming now that for most of us, circumstances and conditions have been such that we are spending our lives in the field of our choice, let us consider for a moment a tendency that seems to be a concomitant of those thus fortunately situated. Do we not occasionally find in ourselves a disposition to magnify the importance of the field in which we happen to be engaged? Are we not somewhat inclined, quite naturally perhaps, to think that our field of work is more important than that in which others are occupied? Does not the theoretical chemist, whose inclinations lead him to spend his time in writing reactions, and building structural formulas of wondrous architecture, often feel within himself that his work is on a higher and nobler plane than that of the patient analyst, who has furnished the data which he uses? Does not the organic chemist, who delights in the study of the carbon compounds, who can repeat for you series after series of chemical bodies, differing from each other by the constant addition of an element or group of elements, in whose vocabulary "types," "substitutions," "replacements," "condensations" and "isomers," are familiar words, and who, when a new organic compound is discovered, cannot rest until he has found to what series, and what place in the series, it belongs, or what its relations are to other bodies in that marvelous structure, based on the element carbon, which the studies of the last half century have reared before our eyes,—I say does not this organic chemist oftentimes feel that he is engaged in a field far more worthy of study, and to which is due much more consideration, than to that of his inorganic brother, who devotes days and perhaps weeks to unraveling the constitution of some obstinate silicate, whose crystalline form gives little help, and whose oxygen ratio is hidden or obscure? Or again, does not the physical chemist oftentimes think, that with the tools of his more especial field, with his specific heats, his vapor-densities, his heats of chemical combination, and his ions, he is quite competent to solve all problems worth solving in the realm of chemistry, and that those who are engaged in other lines are far below his standard, and can be looked down upon quite with pitying sympathy? Still once more, do we not often see the pure chemist whose battle cry is "original work for the work's own sake," claim for himself the highest seat in the synagogue, and refuse to join his efforts with those of others whom he regards as his humbler brethren, namely, those working in the field of applied chemistry, in securing the benefits of organization to extend and widen the borders of our science? Finally, not to make distinctions, do we not frequently see the analyst, who knows so well how necessary it is to have the trained and skillful hand, and the acute and watchful brain, both working together and at the same time, in order to secure the accuracy without which his work is worthless, claiming for his field, that it is the foundation upon which our science rests, and that those who spend their time in locating the position of an atom in its molecule, or in finding the relations of an organic compound to other members of its series, or perchance in inventing long names for new compounds in which all the resources of the ancient Greek and Latin are brought to bear, to reveal in one word the constitution of the compound,—I say does not the analytical chemist often regard these workers as shallow, empty-headed, and unworthy to be called chemists?

Now far be it from me to say that this partiality of each for his own field is blameworthy. We can, indeed, conceive of cases in which this partiality may be carried a little too far; but within proper limits, not only is it not blameworthy, but even as it seems to us, it may be praiseworthy for one to magnify the importance of the work in which he is engaged. A just and proper estimate of the value of his own work, a reasonable pride in his chosen science, or in that paddock of his science which it has fallen to the share of each to care for and cultivate, and indeed a moderate, though necessarily a somewhat partial, comparison of himself and his field of labor, with others, even though that comparison is somewhat to the detriment of the others, are not always necessarily bad. On the other hand, such pride and such comparisons tend to stimulate to renewed activity, tend to sustain in the perplexities and discouragements of work, and tend to keep one's effort concentrated on the work which he can do best. Looked at in this light, the generous rivalry of one branch of our science with another, or the pardonable pride of each in his own chosen field, and even in his own work, may be a distinct advantage; and I know you will bear with me a few minutes, while I, with proper modesty, and in the true spirit, I hope, try to magnify a little the field of analytical work.

To my mind, then, it is just and proper to take pride in analytical chemistry, because of the power which a properly conceived and executed analysis has of explaining difficulties. A few illustrations will, perhaps, make this point clear, and I am sure I will be pardoned for giving illustrations from my own experience, rather than historical ones.

Some years ago, after a passenger coach on the Pennsylvania Railroad had been through the hands of the car cleaners, it was noticed by some of the officers that the paint on the outside looked very bad, and had apparently been injured by the cleaning. A careful examination by the paint experts revealed the fact that the varnish was nearly all gone, and in some places the paint itself partially removed. As a matter of discipline, the car-cleaners were called to account, and requested to explain why the paint and varnish had been so badly injured. Their reply was that with the soap that was furnished for car cleaning no better results could be obtained. This statement was, of course, received with a grain of allowance, it being well known to railroad operating officers that almost universally when anything goes wrong, and the men are called to an account, the materials are blamed. However, in order to give the men the benefit of the doubt, a sample of the soap was obtained, and submitted to analysis, when it was found that this soap actually contained over three per cent. of free caustic soda, and about seven per cent. of sodium carbonate. It is evident that this soap had been very carelessly made from cheap materials, and since it is well known that water solutions of both caustic and carbonated alkalies are fairly good solvents for dried linseed oil and other constituents of paint and varnish, it is clear that the defence of the men, in this case at least, was legitimate, and that the soap was really at fault. It may be added for information that the circumstances above described led to the preparation of a specification for common soap, in which the amount of free and carbonated alkali was limited to very low figures, and that no similar difficulty of destruction of paint and varnish has since occurred.

Another illustration from a different field will emphasize the power of an analysis to explain difficulties. A lot of boiler plate was at one time received at Altoona shops, from one of the best makers. In this lot of forty or fifty sheets, two were found which gave difficulty in flanging, this operation consisting, as is well known, in bending over the edges of the sheets while hot, nearly at right angles to the balance of the sheet, in order to enable it to be joined to other sheets in the boiler. The two sheets referred to cracked in the bend, although the remainder of the lot gave no difficulty from this cause. The workmen being thoroughly experienced, and the practices of the shop being excellent, the cause of the failure in the case of these two sheets was not apparent. An analysis of samples from each of these sheets, however, showed 0.35 per cent. and 0.36 per cent. of carbon respectively, while analyses of samples from other sheets in the same lot showed in no case above 0.12 to 0.15 per cent. of carbon. The explanation of the difficulty seemed now quite clear. The shops had been supplied for a long time with the softer grade of steel, and the methods and practices in use were those applicable to that kind of steel. No wonder then that with the harder grade, difficulty should arise, as actually happened, and but for the analysis this might have passed into shop traditions as one of those unexplained and unexplainable crotchets of steel, which both the makers and practical users of this metal delight in constantly bringing forward.

A single illustration further will, perhaps, suffice on this head. A few years ago, a shipment of some three hundred freight axles was received at two different shops on the Pennsylvania Railroad, from an entirely reputable maker. Some of these axles were used for repairs, and some went under new cars. Scarcely had they gotten into service, however, before difficulty began to arise. The axles began to break. Indeed, one of them broke before the car had been turned out of the shop yard, one broke into three pieces before the car had made 150 miles, and in less than three months eight had broken. Each of the broken axles was sent to the laboratory, and a careful study of the case made, with the hope of discovering the cause of the failure. An examination of the freshly fractured ends of several of the broken axles showed that for a little distance in from the circumference, the fractured steel presented an appearance quite different from that given by the remainder of the fracture. Moreover, a line of demarcation between these two apparently different kinds of steel in the same axle, could be clearly traced. Accordingly, it was decided to make analyses of borings from near the circumference and near the center, and see whether this would reveal anything. It may be stated that the axles were known to have been made from Bessemer steel, and should normally have contained not more than 0.10 per cent. of phosphorus. The analysis of the borings from near the circumference of the axles in no case gave figures up to this limit, while the borings from the center of the axles in no case showed less than 0.16 per cent. phosphorus, and in some cases the amount was as high as 0.24 per cent. Those who are familiar with the methods in daily use in modern steel works, will from these figures at once understand the cause of breakage of these axles. For the benefit of those who are not, it may be well to explain that in most modern steel works, large ingots are now the rule, and that in large ingots which take considerable time to solidify from the molten condition, analyses show that some of the constituents of the steel are not uniformly disseminated throughout the mass. This separation of the constituents during cooling, technically known as "segregation," is characteristic of the carbon, the phosphorus, and the sulphur. Furthermore, the segregation appears to be worst in the upper third of the ingot, so much so that many specifications now require the upper third of the ingot to be removed, and not used at all in making the articles the specifications call for. This much being stated, it is clear why our axles broke. They were made from badly segregated steel, perhaps from the rejected upper thirds of a lot of ingots, the balance of which were used for other purposes. Subsequent correspondence with the parties furnishing the axles gave good grounds for belief that such was the case.

For the comfort of those who ride on railroads, it may be added, the three hundred axles were at once withdrawn from service, and that since that time, a chemical and physical specification for both passenger and freight axles has been prepared, which is believed to preclude the possibility of such axles as are described above being received by the Pennsylvania Railroad.

These illustrations of the power of an analysis to explain difficulties could be prolonged to almost any extent, but I spare you. Furthermore, I should not like to be understood as claiming that every puzzle, every difficulty, or every state of affairs in nature, where the reasons for the phenomena which we find are not apparent at sight, can be explained by a chemical analysis. Our knowledge is far too limited for this. Moreover, many cases could be cited in which an analysis throws no light whatever on the situation, but notwithstanding this, an experience of some twenty years in seeking out the causes of things, as a necessary preliminary to the intelligent modification of practices and methods, in connection with a great corporation, has continually impressed me more and more with the very great help which a properly conceived and executed analysis can give in cases of difficulty.

But again I take pride in the field of analytical work, because of the opportunity which thoughtful analytical work affords for finding new things. The careful, thoughtful, observant analyst is constantly on the verge of either being able to add to his own knowledge, or of being able to contribute something to the general progress of our science. And here again I must be pardoned for using, as illustrations, cases which have arisen in the laboratory of the Pennsylvania Railroad Company.

A few years ago, in our laboratory, we began to get ready to make our analyses of the samples of steel which were designed ultimately to be the international standards for the analysis of iron and steel. Before starting in on these samples, however, it was deemed prudent to do a little preliminary work on some other samples with the idea in mind of seeing whether apparatus and method were satisfactory. Accordingly four separate and distinct determinations on the same sample were made for carbon, using the double chloride of copper and ammonium to release the carbon, and burning in oxygen gas. The four determinations agreed with each other within one or two hundredths of a per cent., and were regarded as fairly satisfactory. But as the work was important, and as some parts of the apparatus had not worked quite satisfactorily, it was decided to repeat the four determinations. Meanwhile a new stock bottle of solution of the double chloride had been made exactly in the manner that had been our custom for some time previous. When the second four determinations were obtained they differed from the first by more than a tenth of a per cent. I need not weary you with the details of our hunt for the cause of this discrepancy; how every point in the apparatus was tested up one after another; how various modifications were tried; how combustions were made on crystallized sugar to check ourselves; and how finally we located the difficulty in the double chloride of copper and ammonium solution. These details have all been published. Suffice it to say that as the result of this work, together with subsequent work by other chemists, it is, we believe, now generally accepted that the commercial ammonium double salt contains carbon in some form, probably pyridine, that its use as a solvent to release the carbon from iron and steel is unreliable, and that the substitution of the potassium for the ammonium double salt overcomes these difficulties. The point which I especially want to emphasize is that in trying to do a little careful analytical work, we struck a new and apparently hitherto unsuspected source of error in one of the oldest and best established methods of iron and steel analysis.

Another illustration will perhaps make this point still more clear. In the regular course of work at one time, a silicon determination was made in a piece of tire steel, which had been sent by an officer of another railroad for information. The figures found by our analysis were 0.14 per cent., these figures being sent to the officer above referred to. A little later word was received that an analysis of a sample from the same tire made by another chemist gave 0.28 per cent. as the content of silicon. This, of course, led us to look over our work, with the idea of finding where the cause of the discrepancy lay. A careful examination of our weights and figures showed that it was not an error of calculation. Accordingly we decided to duplicate our work, need I say, with the expectation of finding that the other chemist had made a mistake? Judge of our surprise when we found that our second analysis confirmed his figures exactly. Our first and second analyses had been made by the same method, and by the same operator, working on borings from the same bottle, and the cause of the discrepancy between the two was not, therefore, at first sight apparent. On carefully questioning the operator, however, as to exactly what he did at each step of the method, a clew was obtained, which when followed out, cleared up the whole difficulty, and ultimately led to a modification of the method. The silicon in these samples was determined by what is known as Drown's method, consisting in dissolving the steel in nitric acid, adding sulphuric, heating until white fumes of the latter acid appear, to render the silica insoluble, dilution with water, filtration, washing and weighing. The difference between our two analyses consisted simply in this: that in the first case, after the dilution with water, there being considerable work in hand, the vessel was allowed to stand over night before filtration, while in the second case filtration immediately followed dilution. Subsequent work on this point showed that in this method silica is not completely dehydrated by heating in concentrated sulphuric acid, in presence of iron salts, but is apparently rendered collodial and sufficiently dehydrated so that if filtration follows soon after dilution, fairly accurate results will be obtained. On standing after dilution, however, this colloidal, undehydrated silica, apparently goes into solution again. Indeed we were able to get on this same sample, anywhere from one-eighth up to the full amount of silicon present, by varing the time of standing after dilution, the longest time covered by our experiments being about four days.

Perhaps I may venture to give you still one more illustration of how, in the course of analytical work, new and apparently hitherto unnoticed reactions may be hit upon, and modifications of methods result. Every chemist who has done much mork in determining phosphorus in iron or steel, by the reduction of the molybdic acid of the yellow ammonium phosphomolybdate, and subsequent titration of the reduced solution, cannot fail to have been annoyed by the occasional failure of duplicates to agree. Apparently in the two analyses everything has been done exactly alike, and yet the results do not agree. Every thoughtful chemist cannot fail to have felt at such times, that somewhere in the method there were conditions affecting the result, that were not fully controlled. During the last six or eight months in our laboratory we have apparently struck one of these hitherto uncontrolled conditions, whose influence is not large, and yet enough to at times cause annoying discrepancies in duplicates, or between different chemists working on the same sample.

In order to make clear what follows, it should be stated that in the ordinary working of this method, the yellow precipitate, after careful washing, is dissolved in ammonia, and this solution then treated with sulphuric acid largely in excess, and diluted to a definite volume, in which condition it is passed through the reductor, and subsequently titrated with standard potassium permanganate. The reductor in common use consists, as is well known, of a tube of heavy glass, about five-eighths of an inch internal diameter, and about a foot long, filled with powdered zinc, the top being fitted with a funnel, and the bottom with a stop-cock. Below the stop-cock, a smaller tube carries the rubber cork, by means of which the reductor is fitted to the flask which receives the reduced solution. This smaller tube usually projects into the flask an inch or two, and it is customary to use the pump to draw the liquid through the reductor. This much being premised, we may say that in a communication from Mr.

Porter W. Shimer, one of the members of the Sub-Committee on Methods of the Committee on International Standards for the Analysis of Iron and Steel, he, among other things, called attention to the fact that when making a number of determinations on the same sample, all other things being the same, he got a reduced solution that required more permanganate if he prolonged the small tube below the stop-cock in the reductor nearly to the bottom of the flask, than if this small tube projected only an inch or two into the flask. This statement brought afresh to our minds a thought that every one who has worked much with molybdic acid must have had: namely, that reduced molybdic acid is very easily reoxidized. We accordingly determined to find out, if possible, whether this was actually the case, and, if so, how much this difficulty might amount to. Accordingly, a stock solution of ammonium molybdate dissolved in water was prepared, and a number of aliquot parts of this solution measured out. Now, obviously, there are two chances for the reduced solution to become oxidized by exposure to the air. One of these is from the air in the flask during the reduction, and on the other from the outside air during the titration. Without going into minute detail, it is perhaps sufficient to say that when we reduced an aliquot part of our stock solution, using the short tube of the reductor, and adding the permanganate drop by drop, with continual agitation during the whole titrations, we used 22.7 cubic centimeters of our standard permanganate, all figures given being a mean of a number of closely agreeing determinations. When now we made the reduction the same as before, that is, with the short tube of the reductor, but titrated by allowing about ninety-five per cent. of the permanganate required to run into the flask before agitation at all, and finishing the titration drop by drop, we used 23.1 cubic centimeters of permanganate; in other words, so sensitive is a reduced solution of molybdic acid, that it is easy by varying the mode of titration to introduce considerable error. Prolonging now the tube at the bottom of the reductor as suggested by Shimer, which would result, as is apparent, in a diminished exposure of the reduced solution to the air in the flask before titration, we found our aliquot part to use up 23.6 cubic centimeters of permanganate. But even with the prolonged tube, there is some exposure of the reduced solution to the air during the reduction. Accordingly, on the suggestion of my principal assistant, Mr. F. N. Pease, we put a measured amount of standard permanganate solution into the flask which was to receive the reduced solution, more than sufficient to react with it, and then prolonged the tube from the reductor, to dip below the surface of this permanganate. Obviously with this arrangement the reduced solution is entirely prevented from air exposure. On making the reduction and titrating the excess of permanganate with standard solution of ferrous sulphate, it was found that the aliquot part had now used up 24.1 cubic centimeters of permanganate, an extreme difference in amount of permanganate used under the varying conditions described of nearly six per cent. Obviously, if two chemists were working on the same sample of molybdic acid, one employing the manipulation first described, and the other that last described, the discrepancy between them would be serious. The discrepancy on phosphorus in steel, while the same in percentage, is very much smaller in actual figures, but still enough to be annoying. The work above referred to is not yet quite finished, but enough has already been done to demonstrate that the ordinary method of determining phosphorus in steel can be advantageously modified in the interests of greater accuracy; and also, although not yet rigorously demonstrated, there are strong indications that molybdic acid (MoO_2), is always reduced by zinc to Mo_2O_3, and that the more complex formulas, $Mo_{12}O_{19}$, $Mo_{24}O_{37}$, etc., so commonly given as representing this reduction, simply mean that the conditions under which these formulas were obtained, permitted the reoxidation of the reduced solution to the extent indicated.

There is another phase of this question we are discussing, "The Dignity of Analytical Work," which will perhaps bear a few words. It seems to be universally conceded that the brain that plans and guides is worthy of more honor than the hand that executes; the general deserves more than the private soldier; the architect, than the builder ;the investigator who plans the work, than the chemist who makes the analyses. Few will object to such a distribution of rewards as this, and certainly no one will claim that a chemist who, machine-like, simply follows directions, without thought or interest in the matter, can fairly claim recognition for anything more, perhaps, than manipulative skill and honesty. But, on the other hand, is it fair to say that such analysts can truly be called analytical chemists? Does not the genuine analytical chemist embody within himself, not only the capacity of brain to wisely plan his method of attack, to conceive which one of the possible reactions in the case it will be best to employ, but also the requisite manipulative skill, to carry out the line of action decided upon? To my mind, these two things, namely, the brain power necessary to plan the work, together with the continual activity of the brain while the work is going on, and the skilled and trained hand requisite to do the work, are necessarily coexistent at the same time in the good analytical chemist, and woe to that chemist who tries to put them asunder. The analyst whom chance or the exigencies of earning his livelihood have thrown into a situation, where day after day he must, for a time at least, do the same thing over and over again, and who does not, even in this situation, use his brain constantly, does not each time he adds a reagent think what is going on in the beaker, does not each time he washes a precipitate think what he is washing out, does not every time he makes a weight take a genuine interest in the result, and even the hundredth time that he makes the same determination, is not on the lookout for some flaw in the method he is using, or some possible new reaction in connection with it,—such an analyst, I say, will stand a good chance to remain a routine chemist all his life.

On the other hand, what shall we say of those chemists who plan out a line of investigation, and are content not to make the necessary analyses themselves? We are quite well aware that at the present time this is a very common method of making investigations, and we can, of course, understand that pressure of other duties may make it impossible to pursue investigations in any other way. But we cannot regard this state of affairs as, to say the least, anything less than unfortunate. If we may trust our own experience, the time spent in making the analyses required by one line of attack on a stubborn problem is most valuable, in the opportunity which it affords for carrying the problem in mind, and planning out other lines, in case the one in hand does not succeed. Moreover, still more valuable is it to make the analyses yourself, in that while doing so, you so frequently get suggestions from the work that are the very ones upon which final success depends. I wish there was time to illustrate this point as its importance deserves, but the history of chemistry and your own experience will have to furnish them to you. To our minds it is hard to overestimate the importance, especially to a young investigator, of his doing his own analytical work for himself. If we read rightly, this was the almost universal habit of the old masters of our science, and we greatly fear that those chemists, who from choice delegate their analytical work, will find after years of such delegation that their reward of successful investigations is very small.

A single thought farther. At the present time so much applied chemistry is either based on analytical work, or has analytical work as an almost essential constituent of its existence, that in a paper discussing analytical work, a few words may not be amiss on the relations between pure and applied chemistry. Without wishing to touch in the slightest degree on mooted or disputed questions, it may not be unfair to say, that while the applied chemist does truly, as the name indicates, in the mass of his work, utilize or apply the discoveries of others to useful effect, it does not at all follow that in the field of applied chemistry no discoveries yet remain to be made. It is certainly not too much to say that no thoughtful chemist has ever worked for any length of time in any field of applied chemistry without finding himself surrounded with problems involving new and unknown reactions, with problems, am I not safe in saying, requiring for their solution, as good appliances, as deep study, and as keen thought, as any that occupy the minds of the pure chemists. These problems continually force themselves upon him, and his only regret in the matter is that the time at his disposal does not permit him to solve them as fast as they arise. A prominent feature of these applied chemistry problems remains to be mentioned: namely, they generally have immediate useful applications, as soon as they are solved. The applied chemist usually makes an excursion into the unknown, because some difficulty has arisen in the course of his regular work, or because some new, more rapid, or more economical method of accomplishing results is desired. He may succeed in finding a new reaction, or in utilizing an old one, as the basis of a successful commercial process, or in modifying a manufacturing method in the interests of both economy and speed. But whatever his work, the immediate useful application of the information he secures is both his stimulus and guide. He may not be able from lack of time to follow his work up, and find the complete relations of the facts ascertained to the other branches of chemistry, but this is his misfortune rather than his fault, and this condition of affairs, that is, being unable to follow out to completion, lines of research once started on, is, if we understand the matter rightly, not characteristic of the applied chemist alone. This much being said, let us ask in what respects the pure chemists resemble or differ from those who work in the field of applied chemistry. They certainly are alike in this, that neither of them can devote his whole time to original work. Both must devote no small portion of their energy to other lines than making investigations. There may have been a time in the history of chemistry when investigators were so fortunately situated that they could devote their whole time and energy to finding out new truth, and giving their results to the world. All honor to such investigators. Moreover, we all know that occasionally an appropriation of funds or an endowment is made for research in some special field. But truly would it not be too much to say, that the work of any large percentage of the pure chemists of to-day is the result of such fortunate circumstances? Furthermore, the pure and applied chemists are alike in that in their original work both are seeking for the truth, and if they are successful, both are adding to the sum of human knowledge. They differ, as it seems to me, principally in this: First, the researches of the applied chemists being largely made in the interests of corporations or manufacturing establishments, the results of these investigations, in many cases, are not at once available to the world, except in so far as they lead to diminished cost of production. Those who have paid for these researches, naturally feel that they should be allowed a period of time at least, to recoup themselves for their expenditures, and so they protect themselves either by patents or secrecy. But this is only a knowledge of the truth deferred. Sooner or later the results of the investigations of all applied chemists are added to the great body of accumulated chemical knowledge. The pure chemist, on the other hand, at once gives the results of his investigations to the world, and is quite content if the publication of his researches shall bring him as his reward, a modicum of appreciation from his fellows. Second, in their original work, the pure chemists differ from the applied chemists in the ulterior purpose for which the investigation is undertaken. As has already been stated, the applied chemist usually undertakes an investigation, tries to find new truth, with the avowed purpose of at once utilizing this truth as soon as it is found. Not so the pure chemists. The problems which they attack and solve so successfully have no necessary relation to subsequent utility. The truth which they discover, and put on record, may be found to be useful at some time, but its possible immediate utility or non-utility is not taken into consideration by the pure chemist, either in his choice of a subject for investigation, or in the prosecution of his work. The truth for the truth's own sake, is his motto and guiding star.

If we have diagnosed the case correctly, then the principal differences between the pure and applied chemist are, that the latter withholds the results of his work from the world for a period of time, while the former gives his at once; and that the latter is, in his original work, seeking for truth that is at once useful as soon as it is worked out, while the former neither knows nor cares whether the truth that he discovers is either now or at any future time turned to practical or useful effect. Let us not be misunderstood. I am not attempting to belittle in any sense the work of the pure chemists. They are worthy of all honor and respect. But on the other hand, I am not at all willing to have the work of the applied chemists made light of or treated as though it were in an inferior field. To my mind there is no occasion for either to belittle the work of the other. The field of chemistry is so broad, the amount of unoccupied ground in every branch of the science is so great, that there is neither time nor energy for struggling as to who is greatest or who is least, but in whatever line a man's tastes, opportunities, or the force of circumstances may lead him, whether as a pure or an applied chemist, whether organic or inorganic, whether theoretical, physical, or agricultural, whether analytical or synthetic, provided in his mind at all times the love of the truth is above all, and honest work is being done, he is worthy of recognition, honor, and respect.

ADDRESS BY DR. CHARLES B. DUDLEY, PRESIDENT OF THE BUREAU FOR THE SAFE TRANSPORTATION OF EXPLOSIVES AND OTHER DANGEROUS ARTICLES, BEFORE THE NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS, AT THE TWENTIETH ANNUAL CONVENTION, WASHINGTON, D. C., OCTOBER 6-8, 1908.

Uniform Rules Governing the Shipment and Carriage of Explosives and Other Articles Dangerous to Transport.

Mr. President and Gentlemen: I doubt not if a vote could be taken of all the most intelligent general managers of railroads in the United States, the vote would be practically unanimous that they would prefer not to carry a single pound of explosives. In the past the hazards connected with the transportation of explosives have been so great that it has been estimated by well-informed railroad operating officers that the total revenue received from explosives was not sufficient to pay the losses.

Unfortunately explosives are as essential for the business of this country as wheat is to make bread. It is estimated by those who profess to be as well-informed as any one can be in the business of obtaining statistics, that two-fifths of the freight of many of the large railroads would absolutely disappear if it was not for explosives. You can see, therefore, that there is put upon the railroads a necessity which they cannot lay aside.

The remedy for the evils of the past we believe to be, therefore, in proper regulation of the transportation of this hazardous material. The growth of the explosive industry in this country is something phenomenal. I have been studying explosives in connection with their transportation for about twenty-five years. When I first began there were a few black powder manufactories, and I think there were three manufactories of explosives using nitroglycerin, the so-called high explosives. Those two were the principal things that the railroads were called upon to transport and the principal portion of the explosives twenty-five years ago was simply black powder, which has been carried from time almost immemorial.

At the present time, due to the growth in knowledge, we have classified explosives, for purposes of transportation, under seven different heads:

Forbidden explosives, which no railroad is allowed to carry at all.

Black powder.

High explosives

Smokeless powder, which is an entirely new product which has come up in the last twenty-five years.

Fulminates.

Ammunition.

Fireworks.

The amount of these very explosive materials that are made in the country is something almost appalling to those who are not at all familiar with the subject. Probably at the present time the figures that I am about to give you are a little high, due to the diminution in business which has been characteristic of the past year; but before the prostration came on they were the best figures that we could get. I want to stop myself long enough to say that I am trying to give you, and I can only hope to give you, close approximations, not accurate figures, because they do not exist.

It is estimated that there are made in the United States in one year about 500 million pounds of explosives of all kinds, by far the largest portion of which the railroads must necessarily transport and distribute. In order to get that figure before you, let me say that if we make certain allowances of car-load and less than car-load lots, and certain allowances based on the judgment of practical railroad-operating men as to the number of the less than car-load lots that exist practically in the matter of distribution, and then allow a certain figure, ten days on the average, for the time that the car is on the road, from the time that the explosives are loaded until they reach destination and are unloaded—we find that there are practically about 5,000 cars in the United States that have explosives on them all the while; about 5,000 of the total box cars of the United States have explosives on them continually. If we distribute those cars uniformly over the railroad mileage of the United States it means that one car containing explosives occurs on a railroad about every fifty miles. In other words, giving average figures, any of you who travel fifty miles on a railroad pass a car containing explosives. If you travel a hundred miles you pass two cars, of course. These are average figures. It is probable that the average figure does not exist, and that many railroads have very few cars containing explosives, the nature of their business not requiring it, while other railroads have a very much larger amount, and on many of the busiest railroads it is possible that this figure that I have given you may be cut in two—namely, in every twenty-five miles you may pass a car containing explosives.

Every car is a possible source of danger. I am giving you these figures to impress upon you the necessity, which is the great theme before us, of regulations for the transportation of explosives. Upon this point, just one matter further. It is believed now that we have not less than 150 manufactories in the United States making explosives, and it is possible those figures may be increased by further investigation. There are also nearly 1,000 magazines where explosives are stored temporarily for purposes of use. These magazines may be owned by the manufacturing establishments, they serving as a depot of supplies from which smaller amounts may be sent out, or they may be owned by consumers. However, by far the larger percentage of those we are dealing with are not private magazines, but magazines which may serve as sources of shipment; and since I am speaking of magazines allow me to emphasize one single point. Many explosives deteriorate rapidly with age, and become more hazardous to transport by virtue of their age. This is especially true with nitroglycerin explosives, and consequently those of us who are most interested in this subject and nearest to it believe that shipments from magazines are more hazardous to transport than the freshly made shipments from manufactories.

You will see the problem: about 150 manufactories and about 1,000 magazines which are serving as points of departure for shipments. Now, I could talk to you, Mr. President and gentlemen, for an hour, and I doubt not give you some information all the while. The subject is a tremendous one, full of infinite detail, and some extremely interesting points can be brought out as matters of general information; but I will try to condense what I have to say, and confine myself as nearly as I can to the main question at issue.

The inception of regulations for the transportation of what are known as "high explosives" runs in my mind very clearly. One of the large manufactories, the Repauno Chemical Company, located on the opposite side of the Delaware River, near Wilmington, had built a large establishment and were beginning to manufacture nitroglycerin explosives in large quantities. They had contracts out and were shipping by order. The Delaware River froze up, and they could not make shipments. At that time railroads, almost without exception, refused the so-called "high explosives"—that is, the nitroglycerin explosives—and they were compelled to ship largely by water.

They went to the general freight department of the Pennsylvania Railroad Company, explaining the situation that there was practically an embargo on the making of shipments. The third vice-president, who was in charge at that time, said:

> "But I am afraid of that stuff. Think what would happen if we should load 20,000 or 30,000 pounds of dynamite on a car, and on its passage through Philadelphia or Harrisburg or some other large city there should be an explosion. It is almost appalling to think of it."

Of course those who were manufacturing it tried to persuade the officer that the material was as safe to carry as corn meal and that there really was no risk. However, to meet the emergency they were given two weeks in which all explosives offered would be received, and meanwhile an investigation would be made and a line of policy decided upon. The matter was referred to me, as being chemist of the railroad company at that time I might possibly be the best person to study the matter. I went to the works, and a very large number of interesting experiments were made which threw a great deal of light on the subject. It is commonly believed that nitroglycerin explosives are very sensitive to shock. They are sensitive to shock under certain conditions, but actually, gentlemen, I have stood as near as from here to the wall from the place where a box containing 50 pounds of dynamite was thrown from a height of 30 feet down onto a pile of rocks below, with no explosion, as you see, for I am here. The shock that fires high explosives is of a different nature from the general shock that comes when a box, if you choose, of high explosives is broken open. All that happened on this occasion was that the box flew open, the cartridges came out, and some were broken and scattered over the ground.

Moreover, another feature. If you take a crumb of dynamite, as big as the end of your little finger, or smaller, and put it on an anvil and strike it with a hammer, usually the first blow fails to explode it. The second blow, after it has become compressed and well bedded down, if you may say so, generally fires it.

Again, I have many times made this experiment. Take a little crumb of dynamite or any other kind of nitroglycerin explosive, and lay it on a board. I have actually bedded the hammer face into the board a sixteenth of an inch without firing the explosive.

I simply cite these as bits of interesting information to show you that what we were trying to get at was a knowledge of the conditions that might lead to trouble and to understand what we were doing.

As a result of this investigation it was decided that explosives should be carried, but under proper regulations. The report went forward, and about as quickly as it could get to Philadelphia and back again the report came back, saying, "Please draw up the regulations," which was a feature that I had not anticipated.

So then followed, as the result of conference and considerable work, the first regulations that I know of that were printed in this country by the railroads at all governing the transportation of nitroglycerin products. At the same time black powder was included as having been in transport for a long time, in order to make the circular complete. It was called the circular for governing the transportation of high explosives.

That circular was adopted voluntarily by a very large percentage of the railroads of the United States, and was issued to the men with orders that from this time forward the reception and transportation of high explosives, and in fact all explosives, should be in accordance with those regulations.

Looking back over the twenty-five years, and with our present knowledge—which I hope you will have a little more information about from Colonel Dunn when he talks to you this afternoon—that circular was ludicrously inefficient. It was a step in the right direction.

From time to time the circular was revised and modifications were more or less adopted by the railroads. Two difficulties came up, however, in connection with this circular. You will understand that thus far this was a purely voluntary action on the part of the railroads to protect themselves and their traffic and their passengers. They adopted certain regulations. Some of those regulations persist to this day, and we have found nothing better; but with the growth of the industry, and with the growth of our knowledge, they have been increased so that the present regulations require a book of this stamp. (Exhibiting pamphlet.) The first regulations were printed on a circular of two and one-half pages, letter-paper size.

I say, two difficulties arose. The first which we struck right soon was this, namely, that regulations do not enforce themselves; that is a difficulty which has persisted even to this day. Second, all the railroads would not cooperate. For instance, let us take a single railroad. It has a circular of regulations for the transportation of explosives. That puts certain restrictions on the shippers, for the manufacture, the packing, the loading are elements in the safe transportation of explosives as well as the treatment during transportation. The circular, I say, puts regulations on the shippers and restrains them from certain things. In this respect there are two kinds of railroads. One enforces the regulations rigidly; the other does not, and they get the freight. That was a difficulty that came up right soon.

To meet the first difficulty, some of the very largest railroads on which the larger number of manufacturers were situated, put on special men to look after the matter. For instance, the Pennsylvania Railroad for nearly three years had a special man who did nothing else but travel over the road and instruct the men at points where the explosives were received, instruct trainmen at transfer stations where the explosives were taken out of one car and put into another, and so forth, as to how they should handle the matter.

This other difficulty, however, the one of cooperation on the part of the railroads, dragged along for a number of years. It took two or three rather vicious and destructive explosions to thoroughly arouse the railroads to the situation.

A little over four years ago the subject was taken up by the American Railway Association, which has already been referred to here, and of which Mr. Hale is a member and has spoken to you about his work. This Association appointed a committee to draft regulations which should be binding on all the railroads. I may say for your information, that with very slight exceptions the railroads of the United States, Canada, and Mexico are members of the Association, embracing over 230,000 miles of railroad.

The committee having the matter in charge took the work that had already been done as a basis, expanded it, made two or three reports to the Association, and finally ended up with a body of resolutions which were supposed to represent the best knowledge of the subject up to that time. Those regulations were adopted by the Association, and while the Association *per* *se* as a body has no absolute power of enforcement, it does have a recommended practice. Consequently these regulations were referred to each of the railroads as recommended practice.

At that time the only force apparently that would drive the railroads into conformity with these regulations was the fear that if they did not transport in accordance with the regulations, and should have an accident, they might be mulcted very seriously by juries for damages, as being blameworthy for not conforming to the best practice known.

A year was given for the trial of these regulations as drawn up and recommended practice by the American Railway Association. It was found as a result of this year's trial that quite a large number of railroads were languid in the matter; that they did almost nothing, and that those who did go into the matter and adopt the regulations still found the old difficulty I have mentioned as developing soon after we began the study of the subject, namely, that regulations do not enforce themselves.

Accordingly, after a year's trial, an organization was formed by the American Railway Association, known as the "Bureau for the Safe Transportation of Explosives and other Dangerous Articles." This organization was voluntary. No railroad was compelled to join it, but if any railroad did join this bureau, it became by virtue of that fact amenable to the regulations. The bureau, as will be explained to you by Colonel Dunn a little later, is really the executive officer of the American Railway Association, so to speak, in carrying out the regulations. I will not speak more of the bureau just at the moment, because the Colonel is going to follow me a little later and will give you a better idea than I can of the workings of the bureau. The bureau has been in existence something over a year, and among other duties has tried to get information on the situation in this country in regard to explosives. Much of the data that I gave you are from the accumulation of information by the bureau.

Now, as time has progressed we have found still two or three difficulties in the way of properly carrying out the regulation for the transportation of explosives. First, we found some antiquated legislation in the United States Revised Statutes. Now that it is all passed I can tell you about it; I should have had a little hesitancy a year ago. This legislation would practically fine every railroad $1,000 for carrying a single box of dynamite. In other words, the Revised Statutes of the United States, which were passed about forty years ago, so described the packing and other regulations in regard to dynamite that the modern dynamite could not be carried. And strangely enough, this statute had a clause that half the fine should go to the informer. I do not think it too much to say that if that statute had been enforced against several railroad companies their whole stock and bonds would not have been able to pay the fines. This statute of course was regarded as a menace. Practically the statute had been outgrown. It was passed many years ago when liquid nitroglycerin was attempted to be carried, a thing that is not thought of now, and it was designed to protect the public against explosions when liquid nitroglycerin was carried. But it happened that the act was so worded that it actually did embrace the present dynamite. That was one difficulty. There was still another difficulty, namely, strangely enough, if a man offers a railroad freight and misrepresents his shipment for the purpose of obtaining a lower rate, he can be punished under the present interstate law, but still more strangely, if a man misrepresented a shipment of explosives, called it some other substance and still paid the rate for explosives, we actually could not touch him. This was a difficulty which might have been serious. We have actually had material billed as hardware that contained a keg of powder. Further, we have had men carry dynamite in passenger cars in dress-suit cases.

There was still another difficulty connected with this subject. Notwithstanding all the circumstances that I have detailed to you in regard to the desirability of the railroads having uniform regulations, and taking precautions, some of the railroads still held out and did nothing. Accordingly Congress was asked a year ago to give a little legislation to overcome these difficulties, namely, to repeal the antiquated legislation now on the statute books, to make it criminal for a man to misrepresent a shipment, and to make regulations for the transportation of explosives binding on all railroads. That bill, known as Public Act 174, provides that the Interstate Commerce Commission shall issue regulations which shall be binding on all the railroads. I will read that section just a moment later, because I think it quite important that you should get that section before your minds.

The law also provided that the antiquated legislation which I have referred to should be repealed, and also made it criminal to do two things, either to carry explosives on passenger cars where there were passengers, or to misrepresent a shipment; both those points being covered in the bill.

The Interstate Commerce Commission immediately took hold of the matter and have issued regulations, a copy of which I hold in my hand, in regard to the transportation of explosives, and it is hoped and believed that all the railroads of the United States will within a very short time conform themselves to these regulations. As a means of executing the regulations it is also hoped that the railroads will all join the Bureau for the Safe Transportation of Explosives. The act of Congress does not give to the Interstate Commerce Commission the power of enforcement. The railroads must enforce the regulations themselves, subject to the penalties for non-enforcement which the act provides.

In order that you may get this subject clearly before you as to what this act provides, I would like to read Section 2 of the act. I also might say that Colonel Dunn is, I think, going to try to suggest to you something in regard to state legislation on this subject. Section 2 reads as follows :

> That within ninety days from the passage of this act the Interstate Commerce Commission shall formulate regulations for the safe transportation of explosives, and said regulations shall be binding upon all common carriers engaged in interstate commerce which transport explosives by land, and violations of them shall be subject to the penalties hereinafter provided.

I may say that the penalty is $2,000 for the violation of the regulations, which go into force October 15.

The Interstate Commerce Commission, on its own motion or upon application made by any interested party, may make changes or modifications of the regulations for the safe transportation of explosives, made desirable by new information or altered conditions, and such changed regulations shall have all the force of the original regulations. The regulations for the safe transportation of explosives referred to in this section shall be in accord with the best-known practicable means for securing safety in transit, covering the packing, marking, loading, handling while in transit, and the precautions necessary to determine whether the material when offered is in proper condition to transport. The regulations for the safe transportation of explosives shall take effect three months after their formulation and publication by the Interstate Commerce Commission, and shall be in effect until reversed, set aside, or modified.

EXTRACTS FROM ADDRESS OF DR. CHARLES B. DUDLEY AT THE DEDICATION OF DROWN HALL, LEHIGH UNIVERSITY.

June 15, 1908.

We all know how the habit and manner of those who surround us, affect us, when we are joyous from success or when surrounded by difficulties. If the habit and manner of a man be austere and repulsive, even though we know there is a warm heart behind it, we are thrown back upon ourselves, whether either joy or grief betide us. If, on the other hand, something in the manner of him whom we meet, a glance of the eye, an involuntary movement, a smile perhaps, indicated a generous and noble nature, a large and sympathetic heart, we are attracted at once, and almost involuntarily, and unconsciously give our confidence. Doctor Drown was a man of the latter class. To see him walk, even at a distance, inspired confidence, to look into his face when you were in difficulty was an invitation, and to hear him speak removed all uncertainty. In spite of yourself you were drawn to the man, and if conditions favored, attraction soon ripened into love.

. . . .

The magnetic sympathy of Doctor Drown was, to those of us who were intimate with him, both a stimulus and a reward. As is known perhaps to you all, we were both of us chemists, we were not very far from the same age, and our lifework threw us much together. In our younger days we were both ardent, enthusiastic, and determined to succeed; moreover, let me say modestly, both possessed of a generous rivalry, which speaking for myself alone, spurred me over many an obstacle. Ah, how vividly does memory bring up those days of struggle and hard work, each in his own field, of partial failures, which did not daunt or discourage us, and of partial successes, which did not upset or unduly elate us. Speaking for myself again, it is but the simple truth to say, that the fact that I would have something to talk over with Drown, the next time we should chance to meet, has, not once but a hundred times, stimulated me to renewed exertion when working on some more or less difficult chemical problem, that bid fair to thwart me. Indeed for a long time, I kept a note book in which were jotted down the things that I wanted to talk over with him the next time we should come together. No failure or unsolved problem was in condition to be temporarily laid aside or abandoned, and no success either great or small could properly be stowed away among the archives until it had been talked over with Drown, and the seal of his approval put upon it. And when we did come together, each with his own budget of details, it is perhaps not too much to say, that it was a choice pleasure to us both. I think the choicer pleasure was mine. He was so unselfish, so generous, so sympathetic, and his presence so brought to the surface the very best that was in one, that I fear me, I oftentimes failed to fairly requite his generosity, and received far more than I gave.

. . . .

With these thoughts in mind, and these memories rushing in on me like a flood, I cannot help saying to this noble building:

Oh, ye doors! May every one who passes your portals, take in with his first breath, some of the noble unselfishness that characterized him, whose thought led to your creation.

Oh, ye windows! May some of the heavenly guidance which we are sure permeated the life of him who for some time guided young lives in these classic shades, stream through your darkened glass and leave an impress on every one touched by its beams.

Oh, ye walls! As through the years to come ye shall listen to myriads and myriads of voices, may the echo from each as it goes back to its origin carry with it some of the gentleness, some of the sweetness, and some of the broad human sympathy of him in whose mind first, your foundations were laid.

Oh, Memorial Hall! Crystallization of a noble thought. May the tooth of time touch you lightly, may your influence be always benignant and helpful, and may you stand for ages, a monument worthy of him whose name you bear.