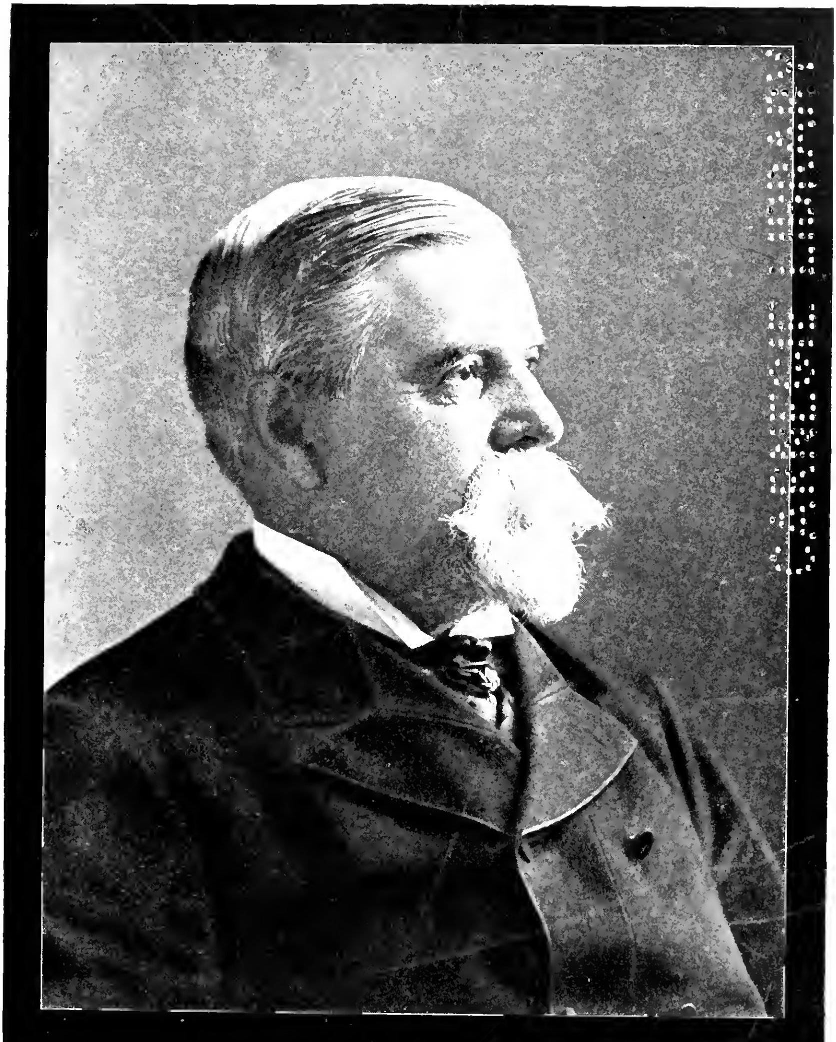
The Locomotive.

JANUARY, 1904.



J. M. Allen

In Memoriam.

J. M. A.

The Locomotive

PUBLISHED BY THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

Vol. XXV. HARTFORD, CONN., JANUARY, 1904. No. 1.

JEREMIAH MERVIN ALLEN.

In the death of President Jeremiah Mervin Allen, which occurred on December 28, 1903, the Hartford Steam Boiler Inspection and Insurance Company has met with the greatest loss that could befall it. He had been failing in health for some considerable time, and the immediate cause of his death was heart failure, brought on, without doubt, by his close and unremitting application to the affairs of this company, and to those of the numerous other organizations with which he was connected in the capacity of director or trustee.

Mr. Allen was very dear to those who knew him well, and in preparing this tribute to his worth it would be natural and pardonable to magnify and extol his strong points, and to minimize and condone his weak ones. It is not in the least necessary to do this, however, for it may be said in all sincerity that no distortion of the simple facts is required, to make the character of J. M. Allen lustrous. The real difficulty is, to choose words which shall express the affection that his immediate associates felt for him, and which shall at the same time be temperate enough to appeal to those whose relations with him were more formal and distant.

He was not only President of the Hartford Steam Boiler Inspection and Insurance Company, but he was also the personal friend of every employee; and there are many indeed who could testify with full hearts, not only to his helpful advice and wise counsel in times of trouble, but also to the more substantial assistance that he was ever ready to give to the deserving. His generosity almost amounted to a fault; and while many of his acts of kindness were matters of record, there were far more of which the public never knew. He was conspicuously a friend of the young, and he was quick to see, in a young man, the promise of future success, and to lend his aid in every way possible. He preached a gospel of hopefulness, and in times when others were disposed to be discouraged, his buoyant confidence that success must eventually follow earnest and unremitting effort when directed towards a worthy end was inspiring beyond expression. There are many who are ready with wise saws and high moral counsels, but whose lives are not in all respects based upon their own teachings; but it is a source of exceeding pleasure to the friends of Mr. Allen to be able to certify, truthfully and most positively, that he was not of this number. J. M. Allen taught not only by precept, but also, and most emphatically, by example. In his private life he carried out, practically to the letter, all of the high principles that he held up before the young as worthy of their special emulation. He was a man of very liberal mind, and in his every-day life he was democratic to a fault. He was always near to the people, and, save when the pressure of business temporarily prevented, the meanest citizen could have audience with him; and he was ever ready to consider new ideas, from whatever source they came. He was, in a word, a Christian and a gentleman; a man of integrity and of honor; a friend of all who were worthy, without regard to their station; a man who delighted in good works for their own sake; and a firm believer in the ultimate triumph of that which is right.

Mr. Allen was born at Enfield, Connecticut, May 18, 1833, and was the son of Jeremiah V. Allen and Emily (Pease) Allen. He remained at Enfield until he was twelve years old, attending the primary schools at that place. He then entered the Rev. Dr. Lawton's school at Longmeadow, Massachusetts, where he studied for two years, after which he spent four years at Westfield Academy, leaving there in 1851. For four years thereafter he was a teacher, the first half of the time at Enfield, and the second half at Dr. Hall's famous school at Ellington, Connecticut. Even in his youth Mr. Allen was most industrious, devoting much of his spare time to practical work with the microscope and telescope, and to the study of matters relating both to civil and to mechanical engineering. He was also very fond of music, and in his early life was no mean performer upon the violin. He came to Hartford in 1855, at the age of twenty-two, and became steward and assistant at the American School for the Deaf (then known as the American Asylum for the Deaf and Dumb), the Rev. W. W. Turner being principal. He retained this position for ten years, always efficient and courteous in the discharge of his duties, and beloved by all. On April 10, 1856, he married Miss Harriet S. Griswold, daughter of Herman C. Griswold of Ellington, Connecticut. Mrs. Allen is still living, and so also are their two children, one of whom, Elizabeth T., is the wife of Mr. C. E. Roberts, manager of the northeastern department of this company, while the other, Mr. William H. Allen, is assistant manager in the same department.

In 1865 Mr. Allen became general agent and adjuster of the Merchant's Fire Insurance Company of Hartford, from which position he was called to fill a similar one with the Security Fire Insurance Company in New York. It was after he had accepted this New York position that he was offered the presidency of the then newly-born steam boiler insurance company, but, being under contract with the Security Insurance Company for one year, he was obliged to decline the Hartford offer until the following year, when, his contract being fulfilled, he began his duties as President of the Hartford Steam Boiler Inspection and Insurance Company on October 1, 1867.

The first office of this company was a little room in the building of the Hartford Trust Company, and the beginnings of its business were small, almost beyond the possibility of present realization. The story of the formation and general subsequent history of the company whose development was Mr. Allen's principal life work is told elsewhere in this issue by Mr. P. H. Woodward, who was a warm personal friend of Mr. Allen for many years. At the outset, Mr. Allen was President, General Agent, and nearly everything that there was to the company, and he did much of the traveling and soliciting himself. Agents of the present time can hardly appreciate the difficulties under which he worked in those early days, for the importance of boiler insurance is now established beyond question, and it is comparatively easy to persuade a manufacturer to insure his boilers when he sees his competitors all about him insuring theirs. Then, however, insured boilers were few and far apart, and it was necessary to educate each separate boiler owner, often against his will and in the face of unmerited ridicule, until he should see the wisdom of insuring. It must be remembered, too, that in those days the rates were far higher than at present; and the Civil War, moreover, was a thing of the recent past, so that the country was poor. All these things conspired to bring about defeat, and failure must certainly have followed had he been a man less buoyant with hope, or less cheerful in adversity, or less confident that a really good thing must of very necessity succeed, if it were urged with unwearying insistence. Through all the days of trouble and doubt, however, President Allen maintained a courageous attitude; and if he secretly felt misgivings at any time, he never let that fact appear. This high note of courage and confidence, in fact, has been one of the most striking things about Mr. Allen's personality throughout his life, and in later days it has been a source of unfailing inspiration to all who have been connected with him.

Mr. Allen was a thorough American, proud of his country, his state, and his city; and he was ever ready to give his best strength to the service of Hartford and its various institutions, without the smallest thought of personal reward. He was deeply interested in the work of the Young Men's Christian Association, and was its first Vice-President, being elected to that position upon the organization of the Association, February 7, 1878. At the first regular annual meeting, in January, 1879, he was made President, retiring from that office in 1880. Mr. Allen was also prominently associated with the Hartford Board of Trade, and was one of the foremost spirits in its organization. He was also its first President, being elected to the office in 1888, and resigning it in 1898, partly on account of the pressure of other matters and partly from his desire that other members of the Board should have an opportunity of administering its affairs. Owing to his ability, and to his conscientiousness in the discharge of every duty that he undertook, he was much sought for as an administrator upon estates, and as a director and trustee in institutions of all sorts. At the time of his death he was a director of the Connecticut River Banking Company, of The Case, Lockwood & Brainard Company, of the Security Company, and of the Capewell Horse Nail Company; and he was likewise a trustee of the Retreat for the Insane, of the Society for Savings, and of the Hartford Theological Seminary. He had been a trustee of the latter institution for over twenty-five years, and at his death was the President of its Board, a position to which he was elected in 1900.

Mr. Allen was a devout Christian, and was a prominent member of the Asylum Hill Congregational Church, in which he had been interested and influential since its organization. In fact, he attended the first meeting that was held to consider the formation of the society, in 1863; and when, on June 25, 1864, the organization was actually effected, Mr. Allen was elected Clerk. He was also a member of the building committee which had to do with the erection of the church which the society now occupies, and which was dedicated on June 15, 1866. In more recent years he has held other positions in the church, and at all times his deep interest in the society has been evident, and his influence on its behalf has been felt in many ways.

Mr. Allen was especially distinguished for the diversity of his interests. He had a good knowledge of finance, and of the principles and practice of insurance, and to these he added a keen understanding of the principles of civil and mechanical engineering, and of science generally. He was also profoundly interested in archæology, and kindred subjects, and his library contains many valuable works upon topics of this sort, with the contents of which he was quite familiar. He was a subscriber to the publications of the Palestine Exploration Fund, and he took a lively interest in all of its proceedings. He belonged also to the American Historical Association, to the Connecticut Historical Society, and to the American Society of Mechanical Engineers. For many years, too, he had been a member of the American Association for the Advancement of Science; and at its recent meeting this association, unaware of his death, honored him by electing him to a fellowship. In 1899, Trinity College of Hartford, Connecticut, bestowed upon Mr. Allen the honorary degree of master of arts, a distinction which is especially significant because Trinity College is uncommonly conservative in the bestowal of its honors. A trustee of the college, when subsequently asked for the special reasons which led to the award, replied that they were three in number: "First," he said, "in recognition of Mr. Allen's broad scientific attainments; second, in recognition of his unusual ability in applying scientific principles to practical affairs; and third, on account of the generous way in which he has made use of his rare knowledge and ability for the benefit of the community, and of his fellow-men in general."

J. M. Allen was tireless in his devotion to the institution that he had created, and faithful unto death to all of the many interests with which he had to do. Even when failing strength made application to business matters painful and wearisome, he declined to take the rest that his friends urged upon him as needful until forced to do so by sheer physical necessity, for although he sorely needed respite, he felt that he must continue to attend to the interests to whose advancement he had pledged himself. He has gone from among us, and we shall never see his kindly face again; but he has left us noble traditions, and he has shown the falsity of the common belief that worldly success is incompatible with an unselfish, Christian life.

An article giving something of the history of the Hartford Steam Boiler Inspection and Insurance Company was prepared for *Cassier's Magazine* a few years ago by Mr. P. H. Woodward, who has long been an intimate and confidential friend of Mr. Allen, and who can therefore speak with authority. Mr. Woodward's article contains data that will be of much interest to all who knew Mr. Allen, and we therefore reprint the greater part of it, below:

Until quite recently, young Americans, conscious of ability and eager for a career, were largely attracted to the "learned" professions. Graduates from the academy and from college, when confronted with the necessity of choosing a vocation, felt almost confined to the pulpit, the bar, medicine, and teaching. Within half a century the marvelous progress of science, with the countless applications of its discoveries to practical affairs, has given a new trend to ambition, by opening fresh and illimitable fields to human effort. While the ancient highways, worn by the monotonous tread of generations, are still thronged with dusty travelers, pursuits variously combining science with business now attract keen and adventurous minds with growing force. On one line of this manifold and wonderful development the subject of this sketch has been both pioneer and creator, having built up an institution that has brought ample returns to the holders of its shares, while reaching with its beneficence every part of the United States and beyond.

From Samuel Allen, the emigrant ancestor who settled at Cambridge, Massachusetts, in 1632, Jeremiah Mervin Allen was the seventh in descent, and comes of sturdy Puritan stock. General Ethan Allen was a descendant of Samuel Allen, and the family intermarried with that branch of the Adams family which gave Samuel and John to the Revolution. A taste for science and mechanics seems to have been transmitted, for a long period, from father to son. One was an astronomer, at a time when the appearance of "Allen's New England Almanac" was welcomed as a notable event of the year, while another was one of the earliest in this country to engage in the manufacture of telescopes and microscopes. Still others were contractors and builders.

Jeremiah Mervin Allen was born at Enfield, Conn., May 18, 1833, and was educated at the academy in Westfield, Mass., with the view of becoming a civil engineer. Subsequently he taught school for four years, diligently improving leisure moments in reading and study. In 1865 he was made the general agent and adjuster of the Merchants' Insurance Company of Hartford, and later he accepted a similar position with the Security Fire Insurance Company of New York city. In both of these positions he labored with characteristic fidelity, and with a success that attracted the attention of insurance circles. Meanwhile the life-work for which Mr. Allen had been studiously but unconsciously preparing fell to him unsought.

In the year 1857 a number of young men in Hartford, drawn together by similarity of tastes, organized the Polytechnic Club with the view, primarily, of investigating and discussing questions of science in relation to the utilities of practical life. Among the members were Elisha K. Root, who succeeded Colonel Colt in the presidency of the armory, Francis A. Pratt, Amos W. Whitney, E. M. Reed, Professor C. B. Richards of Yale, Charles F. Howard, Joseph Blanchard, and J. M. Allen. Although few in number, the members of this little club have, along different lines of effort, made a marked impression on the events of the period. About this time, Professor Tyndall threw out the suggestion incidentally in one of his lectures that the spheroidal condition of water on the fire plates of boilers might be the cause of disastrous explosions. This hint (for it was scarcely more) became the text of frequent talks regarding the cause of boiler explosions, and the best methods of preventing them, and interest in this subject was stimulated when one of the members (Mr. Reed), on returning from a European trip, brought with him the results of the experiments that had been conducted in England, under the direction of Sir William Fairbairn. It also became known that the Manchester Steam Users' Association had already been organized in England, with the object of preventing boiler explosions by periodical inspection. Under the system as started there, the manufacturer paid a certain sum annually for the examination, receiving in return either a certificate of the safe condition of his boiler or a report condemning it; but the certificate, like those now issued in some parts of this country by direct appointees of the state, involved no pecuniary obligation on the part of the association, and, while it relieved the holder from the charge of carelessness in case of disaster, it entitled him to no indemnity.

Not one of the members of the Polytechnic Club was connected with insurance, and yet the body unconsciously drew inspiration from the local predominance of that interest, which was then making Hartford famous as the home of skilled underwriters. In the course of the debates on the subject, the attention of the young men was attracted to the feasibility of combining a guaranty with the inspection, thus giving both parties to the contract a pecuniary interest in the safety of the boiler. So far as known, the conception had not at that time materialized elsewhere; and, although it was distinctly evolved in the club, the idea waited several years for further development, on account of the intervention of the Civil War.

With the return of peace, the subject was revived; and in May, 1866, prominent manufacturers in and out of the state of Connecticut secured a charter, empowering the company formed under it "to inspect steam boilers and insure the owners against loss or damage arising from boiler explosions." In the following November the company was organized, and Mr. Allen, who had given much study to this and related subjects, was urged to take the management. Having made other arrangements for the year, he was compelled to resign, and Mr. E. C. Roberts was elected president, and H. H. Hayden secretary. In October, 1867, Mr. Allen succeeded to the presidency, and under his care the experiment, which was more than once threatened with early death, has prospered and grown, until the company has become an institution of great usefulness, strength, and influence.

For a long time the development was slow, and the way wearisome. Most persons appeared to regard the new departure as a useless novelty that must soon run its short-lived course; and the question was often asked in derision, What will Hartford insure next? In the hands of a manager less firm in conviction, or less conciliatory in manner, the prophecy of disaster must have wrought its own fulfillment; but Mr. Allen met the poison of sarcasm with the antidote of pleasantry, and toiled on to create a demand which it should be his future business to supply. For the first five years the company occupied a single room sixteen or eighteen feet square, and for the same period the floor of the vault was spread with papers for the protection of the books, from the unwillingness of the officers to go to the extravagance of fitting it up with shelves. In a moment of self-indulgence, the president did invest fourteen dollars in a desk for his own use, but such outbreaks of luxury seldom occurred.

Before the establishment of the company, the destruction of life, limb, and property, through the ignorance of boiler-makers and the incompetence of "engineers," filled a wide space in the daily record of casualties. To reduce and ultimately eliminate, so far as possible, the hazards arising from the use of steam has been the constant aim of the management; and from the very outset Mr. Allen's policy has been to prevent explosions by a system of rigid inspections. About two hundred experts are now constantly employed in making these inspections, and few persons have any adequate idea of the enormous expense that this service entails. The results have entirely justified the expense, and have abundantly proved the wisdom of Mr. Allen's policy of prevention at all costs. What the company has done under his direction may be regarded as a work of beneficence, and few attempts in the line of philanthropy have been equally fruitful in the prevention of personal suffering and financial loss.

In 1867 Mr. Allen began the publication of THE LOCOMOTIVE, a journal intended primarily to explain in detail the causes and character of specific boiler explosions, but which was afterwards enlarged in scope so that it now treats also of many matters of current technical and scientific interest. Mr. Allen has furnished plans for many of the most extensive steam plants in the country. As the designs aim, by strictly scientific methods, to secure the highest degree of economy, efficiency, and safety, the saving in operation as compared with the superseded systems has often sufficed in a few years to offset the first cost of the outfit. The company has a laboratory for the analysis of waters, and for such as are injurious to boilers the proper chemical remedies are prescribed. Toward makers, the company maintains an attitude of entire impartiality, permitting no officer or employee to have any pecuniary interest in any appliance connected with the trade.

For September 16, 1892, the twenty-fifth anniversary of Mr. Allen's election to the presidency, his associates in conducting the business in all parts of the United States arranged a surprise which was as touching to Mr. Allen as it was unexpected. Being absent from the city, he was summoned back by telegraph, and returned in the fear of being met by unpleasant news. Hurrying from the station to his residence, he was relieved to meet the welcome of a throng of familiar and beaming faces. Theodore H. Babcock, manager of the New York department of the company, speaking for all, said that the "silver anniversary" was regarded by officers, clerks, agents, and inspectors as an appropriate time to show the universal esteem in which their president was held by them. Mr. Allen was then taken into an adjoining room to see the material forms in which good will and affection had found embodiment. There reposed a solid silver tea service, salver, and complete sets of dinner, dessert, and tea cutlery, and spoons of silver. In all, there were one hundred and one pieces, of exquisite workmanship. A plate on the large mahogany case that contained most of the treasures bore this inscription:

1867. 1892.
PRESENTED TO J. M. ALLEN
BY OFFICERS, AGENTS, INSPECTORS, AND
EMPLOYEES OF THE
HARTFORD STEAM BOILER INSPECTION
AND INSURANCE COMPANY.

Besides the silver, there was an elegant album containing the photographs of about fifty persons connected with the company, and autograph letters of congratulation, both in verse and in prose.

In 1888 the Hartford Board of Trade was organized, and at the earnest solicitation of the directors Mr. Allen took the presidency, a position which he retained until, in 1898, he felt that the duties of the office were too heavy for him to sustain, in addition to those of his own company. Mr. Allen's services were widely sought in the management of corporations and in positions of trust, and, although the pressure of other duties often compelled him to decline honors of this sort, he was prominently connected with numerous important institutions. He was a nonresident lecturer at Sibley College, Cornell University, and a member of several scientific, literary, and historical societies.

FORMAL TRIBUTES TO MR. ALLEN.

BY THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

The death of Mr. Allen, long the President of this corporation, has come to the members of this Board as a personal bereavement. It is not too much to say that he created the success of our company, of which he became President in 1867. He formed and developed the plans in the execution of which the company gained and preserved the confidence of the manufacturing public. He devoted his scientific knowledge to the study and improvement of a system of steam boiler manufacture which should be so thorough as to present to manufacturers machinery competent to protect against dangers arising from defects of construction. In this study he spared neither patience, time, nor money, and the result was most beneficial, not only to the company over which he presided, but to the manufacturers of the country. In his life work Mr. Allen did not limit his activities to the constant oversight of this company. His citizenship was broad and generous. The institutions of Hartford, — business, religious, benevolent, and educational,— are under important obligations for his untiring, thoughtful, and efficient services in their behalf. They will long feel the loss of his studious, intelligent, and unselfish enthusiasm, and the community will miss the dignified and courteous presence of one whose demeanor was everywhere that of a Christian gentleman.

BY THE SECURITY COMPANY.

The announcement of the death of Mr. J. M. Allen, which occurred in this city yesterday, brings a very deep sorrow to his associates on the

Board of Trustees of The Security Company. To their sense of personal loss in the withdrawal of the counsel and companionship of their fellow-trustee, there is added the appreciation of the greater loss which Hartford has sustained in the death of one of its foremost citizens.

The universal expressions of grief at his death are a testimonial of the respect and affectionate regard in which he was held by those who were privileged to know him, and of the very important part which he bore in the business, social, and religious activities of the city.

In this minute to be inscribed on its records, the Trustees of The Security Company desire to express their appreciation of Mr. Allen's character and valuable public and private services, and to indicate their affectionate regard for him as a man.

They also tender to his family their sincere sympathy.

BY THE HARTFORD BOARD OF TRADE.

During the year, and very near its close, Mr. J. M. Allen, a member of our Board of Directors, passed from among us here. He was one of the founders of the Hartford Board of Trade, and was active in promoting its interests. He was, from the formation of the corporation until his death, a member of the Board of Directors; and he was the first President of the corporation, and continued as such for ten years. In the death of former President J. M. Allen, Hartford has lost an active, energetic, liberal minded, public spirited citizen. He was active in the social, religious, educational, financial, mechanical, and scientific life of our community, and liberally contributed of his means and time for the advancement of all. He thoroughly believed in all-round development, and, individually, lived up to that belief. His name will be naturally and properly associated with one of the very valuable and successful corporate enterprises in our community, which carries on the work of inspecting and laying out steam plants, and of insuring against loss and damage from explosions of boilers, — a business in which The Hartford Steam Boiler Inspection and Insurance Company was the pioneer, and has attained signal success. He was the practical promoter of the Company, and was the second president of it, a position which he held at the time of his death. The great success of the Company was attained solely during his administration of its affairs, and is universally and properly attributed to him.

Mr. Allen took an active interest in The Hartford Board of Trade, and during many years devoted much of his valuable time to its work, which work he deemed of great importance to the city. He never wearied in working for the good of his friends, and he deemed all of Hartford such. His ambitions were high, but he was at the same time considerate of all, even of the humblest.

He was a decidedly marked man in our community, and his removal from us is a great loss to Hartford. Memories remain with us of a charming personality and an inspiring example; but a choice, fine-grained, influential, strong man has gone out from among us, — never to return.

BY THE CONNECTICUT RIVER BANKING COMPANY.

In the death of Jeremiah M. Allen, who for twenty-five years was a fellow-Director of this bank, the members of this Board feel that they have lost a wise counsellor and a valued friend, who, by his faithful devotion to the best interests of this bank, has won their respect, and, by his uniformly genial and courteous manner, their sincere esteem. As an inadequate expression of their profound sorrow at the loss of their associate, this Board desires to testify to his many noble traits of character, to his business ability, and to his kindly, helpful ways; and it directs that this tribute be placed upon the records of the bank, and a copy thereof transmitted to his family.

BY THE HARTFORD THEOLOGICAL SEMINARY.

The death of Mr. Jeremiah Mervin Allen, on December 28, 1903, is an event that calls for special mention on the minutes of the faculty of the Hartford Seminary, not only because it involves a great and almost irreparable loss to the Seminary, but because it is a personal bereavement to all engaged in the administration of the institution.

For over twenty-six years Mr. Allen has been an invaluable member and officer of the Board of Trustees, serving continuously on its executive committee, and also as President of the board since 1900. He was the last surviving member of the custodians under whom the Seminary was transferred to its present building and set forward upon its present stage of development. In connection with that transition, and the subsequent enlargements of the Seminary's equipment, Mr. Allen will be particularly remembered for the minute supervision that he exercised over every detail of the plans, not only of Hosmer Hall, but of the Case Memorial Library and all the other buildings now occupied. For years to come, therefore, every instructor, student, and visitor in the Seminary will have cause to recall with admiration and gratitude the patience, wisdom, and skill that he expended so generously for the material comfort and efficiency of its work.

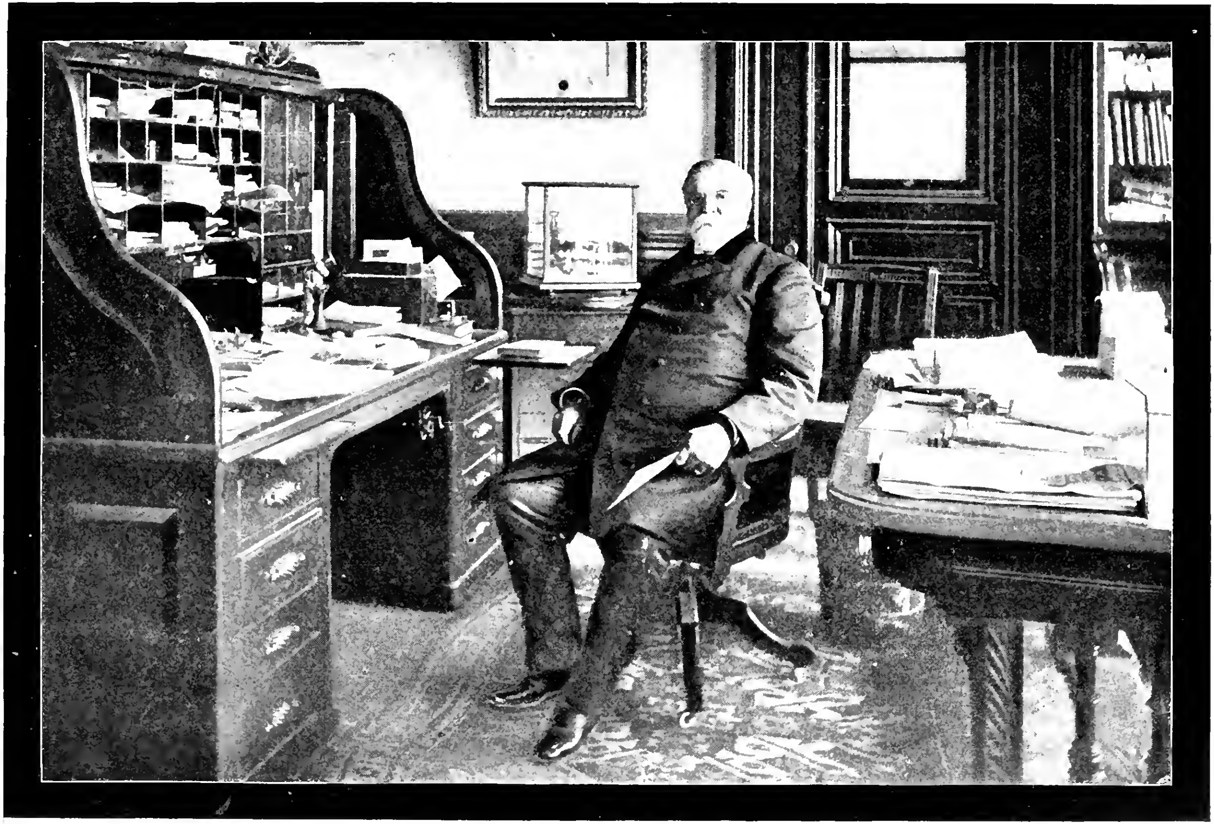
But, great and enduring as are these visible memorials of his interest and fidelity, there are other services for which Mr. Allen will long be cherished by the Seminary as among the most useful of its patrons and friends. For more than a quarter of a century he has been unremitting in his zeal for the upbuilding of the institution's resources for productive work on a large scale. In shaping its present policy as to scholarship and scope he was always among the most enterprising, energetic, and far-sighted of its counsellors. He was President Hartranft's close personal friend, and a loyal partner with him in ambition for the Seminary's expansion along its present lines. The period of his intimate connection with our work has been most eventful, and at times difficult. At every time of perplexity and crisis Mr. Allen was notably full of hope and of helpfulness, while in every time of prosperity he was not less notably prudent and careful. No single man has been able to serve in the administration of the Seminary on its strictly business side with a deeper or truer sympathy with its aims as an educational and religious force.

In acknowledging these great services, the members of the faculty would further express their grateful sense of Mr. Allen's striking personal qualities as a Christian man and citizen, as they have been privileged to know them. He was a man of the most sterling integrity, and of genuine nobility. He was a student and thinker in manifold fields, not only in those of science and the technical arts, but also in those of religious, philanthropic, and missionary interest. He was a loyal, generous, true-hearted friend. He was a genuine and enthusiastic worker in the Kingdom of Christ. His manliness, his zeal, his faith and hope, his sense of all things spiritual and eternal, will not be forgotten by any who knew him; and the memory of these splendid qualities will long be an inspiration to us all.

BY THE CAPEWELL HORSE NAIL COMPANY.

Jeremiah M. Allen, recently deceased, having been for many years a director in this company, we place upon our records this minute in testimony of our appreciation of his high character, distinguished abilities, and valuable services as a member of this board. His business foresight, good judgment, and high courage in times of difficulty in the management of the business, in the later history of this company, have been of inestimable value, and have contributed largely to the successful solution of the serious problems confronting the board of direction.

Socially, Mr. Allen was a kind and exceptionally courteous gentleman, an agreeable companion to persons in all conditions of life, and generous in helpfulness to any in need of aid, answering to every call for service in municipal affairs, in the service of the church, and in the benevolent institutions and the educational interests of our city. He was in all things a just and honorable man, and he has furnished a good example of a well-ordered life, worthy of imitation.



PRESIDENT ALLEN AT HIS DESK.

JEREMIAH MERVIN ALLEN.

BORN, MAY 18, 1833.

DIED, DECEMBER 28, 1903.

The Case, Lockwood & Brainard Company
Printers, Hartford, Connecticut.

The Locomotive

PUBLISHED BY THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

VOL. XXV. HARTFORD, CONN., APRIL, 1904. No. 2.

A Disastrous Boiler Explosion.

A terrible boiler explosion occurred, on the 21st day of last December, in the Geyer Avenue plant of the St. Louis Traction Company, at St. Louis, Mo. Seven water-tube boilers exploded simultaneously, six of them being blown to pieces, while the seventh had fifty-two of its tubes blown out, and was itself

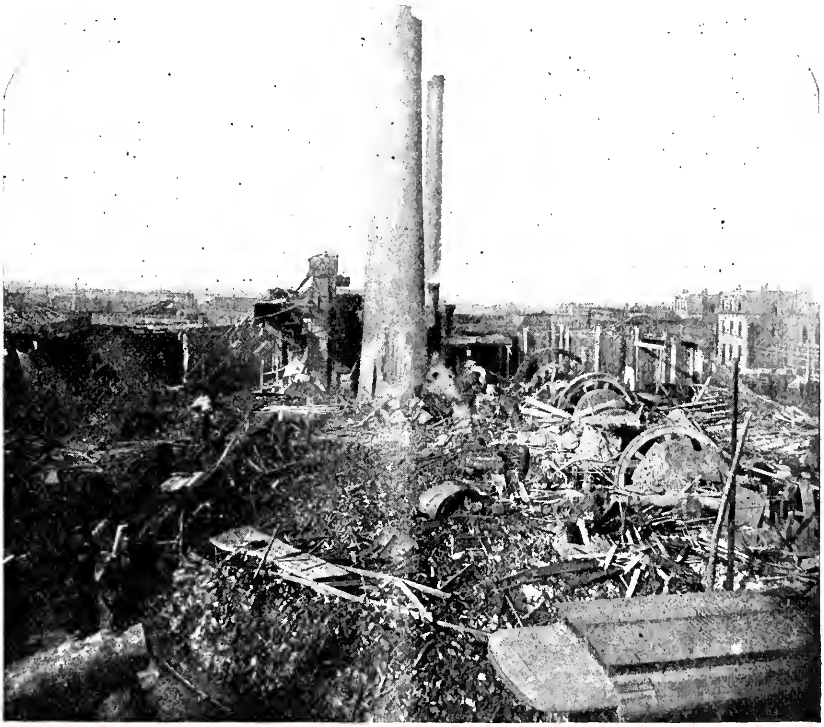


FIG. 1. — GENERAL VIEW OF THE RUINED PLANT.

thrown into the street. Water-tube boilers are often called "safety boilers"; but this designation is manifestly undeserved, because in the present case there were eight men killed and twenty-one others injured. The explosion was equally disastrous, if judged by the extent of the damage done to property, for the buildings and machinery that were destroyed covered an area of something like thirty thousand square feet, and were valued at about $75,000.

The plant at which the explosion occurred was built in 1891 by the Union Depot Railway Company. It was demolished by the cyclone of 1896, but was rebuilt shortly afterwards. We shall concern ourselves with the seven boilers, whose original positions are indicated by dotted lines, in Fig. 2. The boilers were of the water-tube type, as has been already explained, each being provided with two drums 18 ft. 5 in. long and 30 in. in diameter, built mostly of ¼ in. steel plate. The longitudinal joints on the drums were of the double riveted type, with ⅝ rivets in $\frac{11}{16}$ in. holes, the rivets being pitched 1⅞ in. from center to center.

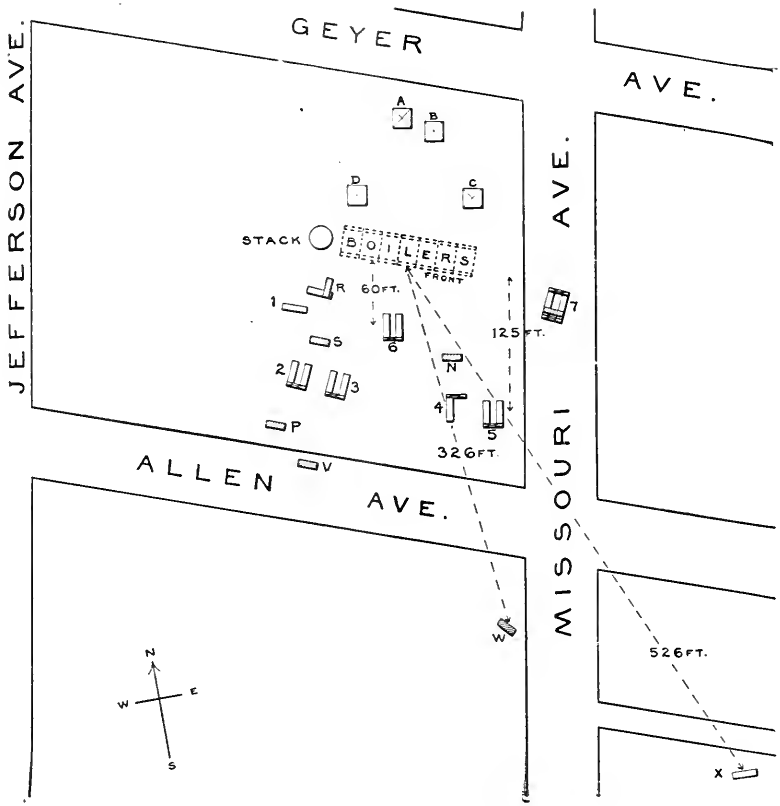


Fig. 2. — Showing the Distribution of the Fragments.

Cross steam drums were also provided, each of which was 7 ft. long by 30 in. in diameter, and from the top of each steam drum a 6 in. steam pipe was led away. A spring pop safety-valve was also located on each steam drum. The water legs were 3 ft. 6 in. high, 7 ft. 9 in. wide, and 9 in. in inside depth, and were built of ½ in. plate. The stay bolts were pitched 7 in. each way, and were hollow, being 1⅝ in. in external diameter, with a ⅞ in. hole. Each boiler contained one hundred and thirteen tubes, each 3½ in. in diameter, and 15 ft. 10 in. long between the legs. All boilers were fed into a common steam header, and received water from a common feed line. The boilers were hand fired, and the gases from the furnace were baffled horizontally.

The force of the explosion was very great. The boilers, fronts, piping, and attachments generally were broken, and the fragments were scattered over a large area. The windows and doors in houses surrounding the power house were smashed, the adjoining car shed was partly wrecked, and a number of street cars were demolished. It is a remarkable fact that all the rear water-legs went north, while the drums and front water-legs went south. It is also remarkable that no drum was ruptured through the longitudinal joints. In Fig. 2 we have indicated the distribution of most of the pieces after the accident. The rear water-legs are represented by the rectangles A to D, inclusive. The stay-bolting of these legs held remarkably well, no broken stay-bolts being found, and only a

Fig. 3. — Showing the Bursted Tube. (See the White Cross.)

few having pulled through the sheets. The rear heads remained with the rear legs, the lines of rupture being through the inside girth leg joint, across the short horizontal leg joint, through the solid sheet, and then either following the head joint (as in most cases), or, as in a couple of instances, tearing through the manhole. Of boilers Nos. 2, 3, 5, and 6, two drums and the front leg remained together; of No. 4, the front leg and one drum remained together, the other drum being found at the point marked "X" in Fig. 2, at a distance of 526 feet from its original position. All the elements of boiler No. 1 (i. e., the legs, drums, steam drum, etc.), were separated from one another. Boiler No. 7, as already stated, remained practically intact, save for the blowing out of fifty-two of its tubes. Three tubes remained in boiler No. 4, and a like number in boiler No. 5; but from all the other boilers all the tubes were blown out. Most of the tubes were found where the boilers originally stood. Most of the drums showed a V-shaped tear where the drum pulled away from the steam-drum leg. The steam drums were scattered about as shown by the cross-hatched rectangles R, S, N, P, V, W, in Fig. 2. One tube was found ruptured, it having opened out flat for a length of about six feet. (This tube is shown somewhat unsatisfactorily in Fig. 3, where it is indicated by the white cross.) A few tubes were found to be slightly bulged, but not ruptured. Many of the tubes were thin, one which was taken from boiler No. 4 measuring only 0.034 in. in thickness, an inch and a half from the end which was expanded into the front leg. The accompanying photoengravings will give an idea of the havoc which was wrought.

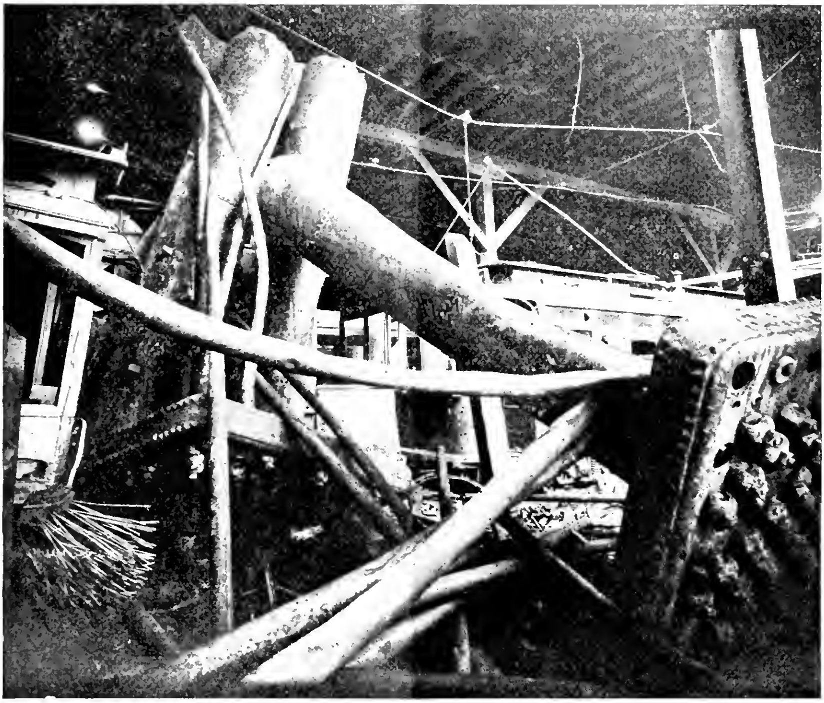


FIG. 4. — SHOWING THE RUINS OF BOILERS NOS. 4 AND 5.

As most of the attendants were killed, it is doubtful if a knowledge of the exact conditions that existed in the boiler room at the time of the explosion will ever be obtainable. A study of the circumstances under which the plant was operated will throw a good deal of light upon the subject, however. There are, in St. Louis, two rival street railway companies, which are commonly known as The Transit Company and The Suburban Company, respectively. These two companies carry all the passenger traffic of the city, and in the morning and evening hours, all the cars are crowded. Early on the morning of the day of the explosion the Suburban lines were tied up as the result of the bursting of the feed pipe in the main power house, and they continued to be tied up until the next morning. To the Transit Company, therefore, fell the work of hauling the entire passenger traffic of the city, for a period of about twenty-four hours. Added to this is the fact that the evening load is greater than the morning load, as the ground rises from the river, and the greater part of the city lies upon the rising ground. The explosion occurred at 5.13 P. M., when the load was heaviest; and to carry this heavy load the boilers of the Transit Company were forced to their utmost, not only as regards capacity, but also with respect to pressure. The boilers of the company were not insured with the Hartford Company, but we understand that the company that did insure them allowed them to carry a load of 125 pounds per square inch, and the city inspector allowed the same amount. After the explosion the safety-valves were tested, and it was found that one lifted at 142 lbs., two at 155 lbs., and one at 170 lbs. The other three valves

FIG. 5. — GENERAL VIEW, SHOWING BOILER NO. 7 IN THE FOREGROUND.

were broken at the time of the explosion. Under these circumstances we are probably justified in assuming that the pressure carried at the time of the explosion may have approached 160 lbs., which gives a factor of safety on the shells of only about 3.6. The No. 1 boiler, which was nearest to the stack, therefore had the best draft, and naturally was worked the hardest; and it is a fact that this boiler was the one most completely demolished; while the No. 7, at the other end of the battery, was damaged only slightly.

Boiler No. 1 was twelve years old; the tubes were thin; the factor of safety was apparently low; the draft was good, and the boiler was being urged to its utmost capacity. At the high rate of evaporation that there is good reason to believe was prevailing, it may well have been that the lower tubes were not filled with a solid body of water; and it must be admitted that the presence in these tubes of any considerable amount of steam would have permitted a slight overheating to occur. Also, it should be remembered that the tubes were at most ⅛ in. thick, while the tube sheet was ½ in. thick; and owing to this difference in thickness, and to the manner of heating, it is reasonable to assume that the tube sheet was hotter than the tube, and that the unequal expansion, extending as it did over a number of years, had somewhat reduced the efficiency of the joint between the tube and the tube sheet.

The boiler showed signs of distress under the exacting service to which it was subjected, and possibly a leakage occurred at the tube-ends; for it is known that a telephone message was sent to the central station, to throw some of the load off of this plant. The initial rupture, in the opinion of the expert who viewed the ruins on our behalf, consisted in the failure of the tube shown by the white cross in Fig. 2; this tube evidently having opened out flat for a length of about six feet. There is nothing unusual in a failure of this sort, for tubes in water-tube boilers rupture in this manner very frequently. Sometimes the rupture is due to a defective weld, but it is oftener due to the presence of scale in the tube, the scale keeping the water away from the tube, and thereby allowing overheating to occur, rupture following as a natural consequence. Under the severe conditions mentioned above, the rupture of this one tube would undoubtedly be sufficient to precipitate the explosion which actually occurred. The reaction of the steam and water escaping from this one tube would suffice, in all probability, to tear other tubes out of the tube-sheets; and the reaction on the water-legs of the steam and water escaping from the openings so made would tend to spread the legs apart. The front leg, however, rested solidly upon the brickwork, while the rear leg had a roller under it, and was therefore more free to move. Or, it may have been that as the boiler settled on the mass of brick (the tubes sloping to the rear), the rear ends were torn out of the rear legs first, and the reaction of the water and steam flowing out of the tube holes caused the rear legs to fly backwards, or towards the north.

It appears likely that the complete destruction of boiler No. 1 caused the partial destruction of the brickwork around No. 2, and as No. 2 settled on its mass of brickwork its lower ends were pulled out of the rear water-leg, and the leg was blown northward; and so on down the line, the available energy decreasing all the time, as shown by the fact that No. 7 was only slightly damaged.

It will be understood, of course, that the actual course of events in the case of a disastrous explosion of this sort is always more or less conjectural; and it must be expected that different authorities will differ with regard to it, according as they assign more or less weight to one or another of the indications that the ruins afford, upon subsequent inspection. The idea that the explosion was caused by dynamite, however, is absurd; for none of the boilers showed any signs of the characteristic tears that a dynamite explosion produces in steel. The assumption that a boiler was being cut out at the time also appears to be improbable, for it does not appear that there is any sufficient evidence that this was the case, and as the Traction Company knew of the exceptionally heavy load that they would be called upon to carry it would have been most natural to have all the boilers in service for at least an hour previous to the time of the explosion. It does not appear to us to be likely that the initial rupture occurred (as has been suggested) in the large steam header, for if the steam pipes had been wrenched off from the steam drums it appears probable that the drums themselves would have been torn to pieces, and as a matter of fact they remained intact. The same reasoning appears also to negative the suggestion that the explosion was due to the lifting of the water in the drums, owing to a sudden demand for steam; and, as indicated above, we are strongly inclined to the belief that the first disturbance was among the tubes.

The present explosion may well serve as a text for examining the claims that are often advanced, to the effect that the energy stored up in a water-tube boiler is much less than that stored up in a horizontal tubular boiler that is capable of yielding the same horse power. It is well known that (other things being equal) that boiler which contains the greatest amount of water contains also the greatest amount of stored energy. Let us therefore compare, on this basis, one of the boilers that exploded in this instance with an ordinary horizontal tubular boiler, 72 in. in diameter and 20 feet long. The heating surface of a horizontal tubular boiler of these dimensions will depend to a considerable extent upon the number and size of the tubes. A particular boiler of the horizontal tubular type, and of average design with respect to tubes, which we have examined for the purposes of this comparison, has 1,743 square feet of heating surface, which is approximately the same as the heating surface of one of the water-tube boilers here under consideration. We may therefore fairly compare this horizontal tubular boiler with a water-tube boiler similar to those that exploded in the present instance. Suppose the horizontal tubular boiler to operate at 100 lbs., and let us assume that the water-tube boiler, owing to the smaller diameter of its drums, can carry 160 lbs., even with a thinner shell, and yet have a larger calculated factor of safety. The water-tube boiler will contain about 11,500 pounds of water, and the horizontal tubular boiler about 16,180 pounds. The "amount of energy contained in one pound of water which can be liberated by explosion or by expansion to 212° Fahr." is given, by Thurston, as 8,087 for the conditions assumed above in connection with the horizontal tubular boiler, and as 12,508 for those assumed for the water-tube boiler. The total amount of mechanical energy that can be developed by an explosion is therefore about 130,800,000 foot-pounds for the horizontal tubular boiler, and, for the water-tube boiler, about 143,800,000 foot-pounds; the excess in the case of the water-tube boiler being therefore about 10 per cent. Remembering that a horse power is defined as the expenditure of 550 foot-pounds of work per second, we see that if all the energy that could be expended in the performance of mechanical work were actually so expended in one second the water-tube boiler would develop, for that one second, no less than 260,000 horse power. This calculation shows that the destructive effects that were actually observed in the present instance were no greater than can be abundantly accounted for by the quantity of available mechanical energy that is represented by the contents of the seven boilers that exploded.

For the foregoing data concerning the boilers and the distribution of the wreckage, and the general line of reasoning as to the cause of the explosion, we are indebted to Mr. Victor Hugo, chief inspector of the Hartford Steam Boiler Inspection and Insurance Company in its southwestern department. Mr. Hugo, whose headquarters are at St. Louis, had a good opportunity of examining the wreck and determining the numercial data that he gives, by actual count and measurement; and we have no doubt but that these data, as presented above, are substantially correct in all cases. The opinion that the initial rupture consisted in the failure of one of the tubes in No. 1 boiler was formed after a careful examination of all of the larger fragments of the entire seven boilers.

Inspectors' Reports for July, August, and September, 1903.

Nature of Defects.	July.		August.		September.	
	Total defects	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,347	41	1,205	53	1,161	62
Cases of incrustation and scale,	3,727	85	3.352	82	3,166	63
Cases of internal grooving,	221	12	270	16	206	15
Cases of internal corrosion,	1,567	54	1,353	41	882	34
Cases of external corrosion,	979	61	890	76	778	68
Defective braces and stays,	161	36	213	42	251	53
Settings defective,	575	58	408	28	476	23
Furnaces out of shape,	520	15	533	21	432	17
Fractured plates,	411	158	282	55	334	46
Burned plates,	418	46	442	66	399	46
Blistered plates,	141	1	104	9	122	10
Cases of defective riveting,	387	25	443	17	548	198
Defective heads,	149	12	104	6	74	10
Leakage around tubes,	1,690	323	1,119	129	1,215	125
Leakage at joints,	705	10	508	23	458	24
Water-gauges defective,	314	75	230	55	329	38
Blow-offs defective,	342	94	306	63	311	86
Cases of deficiency of water,	6	4	3	1	12	8
Safety-valves overloaded,	86	21	78	22	65	13
Safety-valves defective,	64	30	61	18	88	26
Pressure gauges defective,	518	33	458	37	439	35
Boilers without pressure gauges,	17	17	27	27	15	15
Unclassified defects,	15	10	16	3	20	7
Totals,	14,366	1,221	12,405	890	11,781	1,022

Inspectors' Reports for October, November, and December, 1903.

Nature of Defects.	October.		November.		December.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,236	70	1,194	58	1,041	63
Cases of incrustation and scale,	3,140	105	3,547	85	3,510	80
Cases of internal grooving,	222	23	155	7	168	28
Cases of internal corrosion,	842	72	784	33	950	73
Cases of external corrosion,	734	56	802	76	829	47
Defective braces and stays,	307	87	180	31	198	34
Settings defective,	427	29	392	32	444	37
Furnaces out of shape,	457	18	467	20	495	16
Fractured plates,	305	59	311	46	382	56
Burned plates,	422	47	400	30	408	30
Blistered plates,	109	9	87	15	95	7
Defective rivets,	430	98	187	27	163	26
Defective heads,	89	12	67	9	94	11
Leakage around tubes,	1,281	204	1,029	240	1,459	210
Leakage at joints,	486	30	469	16	559	22
Water-gauges defective,	325	48	305	46	292	62
Blow-offs defective,	309	67	218	57	276	97
Cases of deficiency of water,	20	8	24	7	28	19
Safety-valves overloaded,	82	26	77	15	121	47
Safety-valves defective,	85	35	92	20	85	16
Pressure gauges defective,	461	29	443	28	429	23
Boilers without pressure gauges,	36	36	37	37	18	18
Unclassified defects,	4	1	0	0	2	0
Totals,	11,809	1,169	11,267	935	12,046	1,022

*

Summary of Inspectors' Reports for the Year 1903.

During the year 1903 our inspectors made 153,951 visits of inspection, examined 293,122 boilers, inspected 116,643 boilers both internally and externally, subjected 12,232 to hydrostatic pressure, and found 933 unsafe for further use. The whole number of defects reported was 147,707, of which 12,304 were considered dangerous. The usual classification by defects is given below, and a summary by months is given on page 27.

Summary, by Defects, for the Year 1903.

Nature of Defects.	Whole Number.	Dangerous.
Cases of deposit of sediment,	14,606	753
Cases of incrustation and scale,	40,949	1,095
Cases of internal grooving,	2,487	191
Cases of internal corrosion,	12,421	594
Cases of external corrosion,	9,427	674
Defective braces and stays,	2,362	546
Settings defective,	5,306	410
Furnaces out of shape,	6,083	200
Fractured plates,	4,030	731
Burned plates,	5,126	539
Blistered plates,	1,270	85
Cases of defective riveting,	4,137	743
Defective heads,	1,151	145
Leakage around tubes,	16,852	2,199
Leakage at joints,	6,335	296
Water gauges defective,	3,612	692
Blow-offs defective,	3,495	937
Cases of deficiency of water,	202	90
Safety-valves overloaded,	1,063	324
Safety-valves defective,	978	323
Pressure gauges defective,	5,461	471
Boilers without pressure gauges,	240	240
Unclassified defects,	114	26
Total,	147,707	12,304

Comparison of Inspectors' Work during the Years 1902 and 1903.

	1902.	1903.
Visits of inspection made,	142,006	153,951
Whole number of boilers inspected,	264,708	293,122
Complete internal inspections,	105,675	116,643
Boilers tested by hydrostatic pressure,	11,726	12,232
Total number of defects discovered,	145,489	147,707
" " dangerous defects,	13,032	12,304
" " of boilers condemned,	1,004	933

Summary by Months, for 1903.

Month.	Visits of inspection.	Number of boilers examined.	No. inspected internally and externally.	No. tested hydro-statically.	No. con-demned.	Total No. of defects found.	Number of dangerous de-fects found.
January,	13,836	26,895	8,342	846	75	11,900	1,232
February,	11,697	22,933	7,293	733	76	9,781	1,029
March,	13,953	25,776	9,736	1,031	79	12,594	880
April,	12,593	24,348	9,966	1,073	75	12,250	913
May,	12,523	23,995	10,482	1,047	69	13,590	1,014
June,	12,323	22,800	11,215	1,097	131	13,918	977
July,	12,915	24,142	11,894	1,277	62	14,366	1,221
August,	11,921	22,022	10,097	1,031	116	12,405	890
September,	12,813	24,193	9,910	1,091	65	11,781	1,022
October,	13,386	25,840	9,393	1,092	57	11,809	1,169
November,	12,629	24,014	9,276	933	49	11,267	935
December,	13,362	26,164	9,039	981	79	12,046	1,022
Totals,	153,951	293,122	116,643	12,232	933	147,707	12,304

The following table is also of interest. It shows that our inspectors have made nearly two million visits of inspection, and that they have made more than three and three-quarters millions of inspections, nearly a million and a half of which were complete internal inspections. The hydrostatic test has been applied in almost two hundred thousand cases. Upwards of two and a half million defects have been discovered and pointed out to the owners of the boilers; and more than a quarter of a million of these defects were, in our opinion, dangerous. Sixteen thousand boilers have been condemned as unsafe, good and sufficient reasons for the condemnation being given in each case.

Grand Total of the Inspectors' Work since the Company Began Business, to January 1, 1904.

Visits of inspection made,	1,969,416
Whole number of boilers inspected,	3,861,960
Complete internal inspections,	1,498,300
Boilers tested by hydrostatic pressure,	198,051
Total number of defects discovered,	2,707,299
" " of dangerous defects,	283,160
" " of boilers condemned,	16,102

We append also a summary of the work of the inspectors of this company from 1870 to 1903 inclusive. The years 1876 and 1878 are omitted, because the data that we have at hand for those years are not complete. The figures, so far as we have them, indicate that the work during those years was in good accordance with the general progression observable in other years. Previous to 1875 it was the custom of the company to publish its reports on the first of September, but in that year the custom was changed and the summaries were made out up to January 1st, so as to agree with the calendar year. The figures given opposite 1875, therefore, are for sixteen months, beginning September 1, 1874, and ending December 31, 1875.

Summary of Inspectors' Work since 1870.

Year.	Visits of inspection made.	Whole number of boilers inspected.	Complete internal inspections.	Boilers tested by hydrostatic pressure.	Total number of defects discovered.	Total number of dangerous defects discovered.	Boilers condemned.
1870	5,439	10,569	2,585	882	4,686	485	45
1871	6,826	13,476	3,889	1,484	6,253	954	60
1872	10,447	21,066	6,533	2,102	11,176	2,260	155
1873	12,824	24,998	8,511	2,175	11,998	2,892	178
1874	14,368	29,200	9,451	2,078	14,256	3,486	163
1875	22,612	44,763	14,181	3,149	24,040	6,149	216
1877	....	32,975	11,629	2,367	15,964	3,690	133
1879	17,179	36,169	13,045	2,540	16,238	3,816	246
1880	20,939	41,166	16,010	3,490	21,033	5,444	377
1881	22,412	47,245	17,590	4,286	21,110	5,801	363
1882	25,742	55,679	21,428	4,564	33,690	6,867	478
1883	29,324	60,142	24,403	4,275	40,953	7,472	545
1884	34,048	66,695	24,855	4,180	44,900	7,449	493
1885	37,018	71,334	26,637	4,809	47,230	7,325	449
1886	39,777	77,275	30,868	5,252	71,983	9,960	509
1887	46,761	89,994	36,166	5,741	99,642	11,522	622
1888	51,483	102,314	40,240	6,536	91,567	8,967	426
1889	56,752	110,394	44,563	7,187	105,187	8,420	478
1890	61,750	118,098	49,983	7,207	115,821	9,387	402
1891	71,227	137,741	57,312	7,859	127,609	10,858	526
1892	74,830	148,603	59,883	7,585	120,659	11,705	681
1893	81,904	163,328	66,695	7,861	122,893	12,390	597
1894	94,982	191,932	79,000	7,686	135,021	13,753	595
1895	98,349	199,096	76,744	8,373	144,857	14,556	799
1896	102,911	205,957	78,118	8,187	143,217	12,988	663
1897	105,062	206,657	76,770	7,870	131,192	11,775	588
1898	106,128	208,990	78,349	8,713	130,743	11,727	603
1899	112,464	221,706	85,804	9,371	157,804	12,800	779
1900	122,811	234,805	92,526	10,191	177,113	12,862	782
1901	134,027	254,927	99,885	11,507	187,847	12,614	950
1902	142,006	264,708	105,675	11,726	145,489	13,032	1,004
1903	153,951	293,122	116,643	12,232	147,707	12,304	933

The Hartford Steam Boiler Inspection and Insurance Company publishes a little pocket volume entitled *The Metric System,* which gives a short explanation and history of the subject, and also over 140 pages of conversion tables, for comparing this system with that now in use in the United States. A first-class edition for $1.25, postpaid, and a somewhat more substantial edition, on bond paper, for $1.50. Those familiar with it pronounce it the best and most complete book of the kind yet published.

Boiler Explosions.

October, 1903.

(263.) — On October 1st a slight explosion occurred in connection with a pulp digestor in a paper mill at Marinette, Wis. Charles Desjardin was scalded to death.

(264.) — The boiler of a threshing machine outfit exploded, on October 2d, at Janesville, Wis. A. T. Brown was killed.

(265.) — A boiler exploded, on October 2d, in Joseph Erikson's cotton gin, four miles from Brookhaven, Miss. Mr. Erikson was slightly injured, but nobody else was hurt.

(266.) — On October 3d a cooker exploded in the Corning distillery, at Peoria, Ill. The explosion was very violent, and resulted in the deaths of Guy Branham, G. C. George, James McManus, James O'Keefe, Charles C. Powell, E. Shafer, and J. M. Wilson. Daniel Cashin, J. Cin, Charles Lane, and James Walsh were also injured. The total property loss will probably amount to $100,000, three five-story buildings being destroyed, together with much valuable machinery.

(267.) — On October 5th a boiler exploded in Belle Metcalfe's sawmill, about seven miles from Mobile, Ala. Thomas Davis, Charles Crockett, and Thomas Metcalfe, manager of the mill, were killed, and Moses Cook and Benjamin McMillan were badly injured.

(268.) — A heating boiler exploded, on October 5th, in the post-office at Springhill, near Amherst, N. S. The post-office was completely demolished. It had been occupied only about a year, and was considered to be one of the handsomest post-offices in Nova Scotia. Janitor Samuel McDonnell was instantly killed, and Frederick Eaton and two other persons were injured.

(269.) — A boiler exploded on October 5th, in the Turner Burkhead hosiery mill at Beverly, N. J. Watchman Alfred Stucke was instantly killed, and the factory was partially demolished, the loss being probably $8,000.

(270.) — A threshing machine boiler exploded, on October 7th, on the farm of Stephen Mills, at Frederickburg, near Toronto, Ont. George Chambers was seriously injured, and the machine was completely wrecked.

(271.) — A boiler exploded, on October 7th, in S. H. Parsons' sawmill, near Seaford, Del. The fireman, whose name we have not learned, was fatally injured.

(272.) — On October 8th a boiler exploded in the Standard Oil Company's stave mill at Crossville, Tenn. Walter Gilbert, fireman Polk, and foreman Gooch were killed, and several other persons were seriously injured.

(273.) — A boiler exploded, on October 8th, in Potts Bros.' sawmill, near Myrtle Creek Station, Ore. Benjamin Sanders was killed, and Frank Dunning and Albert Potts were fatally injured. The mill was totally wrecked.

(274.) — A slight boiler explosion occurred, on October 10th, in the Glenn Mills Paper Company's plant, at West Chester, Penn. Robert Harper, James Walton, and another man, whose name we do not know, were painfully scalded.

(275.) — On October 10th a boiler exploded at Dakon, Wetzel Co., W. Va. John Adams was fearfully injured, and the boiler house was torn to pieces.

(276.) — On October 10th a boiler exploded in the Younts & Council's brick plant, at High Points, N. C. No lives were lost.

(277.) — A boiler exploded, on October 10th, in Bynum & Cortner's cotton gin at Wheeler, near Cortland, Ala. Mr. Cortner was injured, and so also was the fireman, whose name we did not learn. The boiler-room and engine-room were completely wrecked.

(278.) — On October 14th a boiler exploded in George Weaver's sawmill at Portsmouth, Ohio. Elven Weaver, a son of the owner of the mill, and George Smith, a sawyer, were instantly killed, and several other employees were seriously injured. The property loss was some thousands of dollars.

(279.) — On October 15th a small boiler exploded in the shop of Keefe & Kane at Oil City, Penn. The shop was completely wrecked, but nobody was killed. Harry Kane, one of the owners of the shop, received minor injuries.

(280.) — A boiler exploded, on October 17th, in Biggio's quarry at Ocean View, near San Francisco, Cal. One man was instantly killed, and three others were seriously injured.

(281.) — A boiler exploded, on October 21st, in J. W. Gammon's sawmill at Kelso, Tenn. Fortunately nobody was injured.

(282.) — On October 21st a boiler exploded in a sash and door factory at Muscatine, Iowa. Nobody was injured, but the factory was considerably damaged.

(283.) — The boiler of a West Virginia Central freight locomotive exploded on October 21st, in the yards at Elkins, W. Va. William O. Little, Henry Collett, John Harper, and Mrs. Kate Rabbit were killed. Brakeman John Dougherty and an Italian, whose name we have not learned, was severely and perhaps fatally injured. Mrs. Rabbit was in her residence, some 500 feet from the boiler, but was struck by a fragment of flying iron and instantly killed.

(284.) — On October 21st a tube failed in a safety boiler at the pumping station of the Chartiers Valley water works at Becks Run, near Pittsburg, Pa. Hugh Close was instantly killed, and James Walls was painfully injured.

(285.) — On October 22d a boiler exploded at the Barton mines at Martins Ferry, Ohio. Engineer Benjamin Jones was fatally injured, and lived but a short time.

(286.) — A slight boiler explosion occurred, on October 23d, in the Lexington Mill and Elevator Company's plant at Lexington, Neb. The accident consisted in the fracture of a stop valve. Nobody was seriously injured.

(287.) — A boiler exploded, on October 23d, in the oil fields near Piney, W. Va. John Adams, a tool dresser, was severely injured.

(288.) — A heating boiler exploded, on October 23d, in the grocery store of E. P. & W. H. Stevens at St. Albans, Vt. Nobody was injured, but the store was badly damaged.

(289.) — A boiler exploded, on October 23d, in the cotton gin of J. E. Tignor & Sons at Mifflin, near Jackson, Tenn. Nobody was injured. The property loss was about $600.00.

(290.) — The boiler of a threshing outfit exploded, on October 23d, on the

Clarke rice plantation, about eight miles southwest of Abbeville, La. Frank Cockran was injured so badly that he died within a few minutes.

(291.) — On October 23d a small boiler exploded at pumping station No. 2 of the Higgins Oil and Fuel Company at Gladys City, near Beaumont, Tex. Fireman George Mahovel was thrown to a distance of sixty feet, and was almost instantly killed. The buildings were damaged to a considerable extent, and the property loss was estimated at from $8,000 to $10,000.

(292.) — The boiler of freight locomotive No. 2318, of the Pennsylvania railroad, exploded on October 26th at Rohrerstown, near Lancaster, Pa. James Rowan, Leslie A. Heim, and Sherman E. Swingler were killed, and engineer A. R. Lutz was fatally injured. The explosion was very violent, fragments of the locomotive being thrown to distances of several hundred yards.

(293.) — On October 26th a boiler exploded on the steamer *W. F. Sauber,* near Sault Ste. Marie, Mich. The explosion blew Captain W. E. Morris into the lake, and he was drowned.

(294.) — The boiler of a threshing outfit exploded, on October 27th, on George Heinsechs' farm, near Hastings, Neb. Fragments of the machinery were thrown to a distance of half a mile. Nobody was injured, as the crew was at dinner at the time.

(295.) — A boiler exploded, on October 28th, in Dickenson's cotton gin, eight miles northeast of Jasper, Tex. Eugene Dickenson was fatally injured, and Augustus Harris was also injured seriously.

(296.) — A boiler exploded, on October 29th, at the River Coal Company's plant at Brownsville, Pa. Amos Bescott and Thomas Morgan were seriously burned and bruised, and John Williams received minor injuries. The property loss was not large, consisting almost entirely in the destruction of the boiler.

(297.) — A small boiler exploded, on October 29th, in the basement of Julius Boehmer's restaurant at Hoboken, N. J. Nobody was injured, and the damage was small.

(298.) — On October 30th a boiler exploded in William F. Kalberer's slaughter house at Lafayette, Ind. The building, which was a frame structure, was completely wrecked, nothing remaining of it but a few feet of the west wall. Nobody was seriously injured.

(299.) — On October 31st a boiler exploded in the Anderton & McDowell flouring mill at Winchester, Tenn. James Jernegan and Henry Wise were seriously but not fatally scalded.

(300.) — A boiler exploded, on October 31st, in a stave mill about twelve miles east of Bledsoe, Ky. Three men, named Hendricks, Gilbert, and Adams, were instantly killed, and two more were seriously and perhaps fatally injured.

November, 1903.

(301.) — The boiler of a threshing machine outfit exploded, on November 1st, on Otis Johnson's farm in Glanford township, near Hamilton, Ont. Robert Hostein was seriously injured, his skull being fractured.

(302.) — A slight boiler explosion occurred, on November 2d, in one of the Pillsbury flouring mills at Minneapolis, Minn. Engineer Matthew Collins was fatally scalded and died later in the day.

(303.) — On November 3d a boiler explosion on the dredge boat *J. Israel Tarte,* on Lake St. Peter, near Montreal, P. Q. A sailor named Dansereau was instantly killed, and two other men were seriously injured.

(304.) — A heating boiler exploded, on November 5th, during the course of the fire by which the St. Bernard parochial school was destroyed, at Alpena, Mich.

(305.) — The boiler of a harvesting machine exploded, on November 6th, at the State University, Columbus, Ohio. Engineer Charles W. Pepper and Milton H. Dalgern were killed, and Frank Bradford, Vernon H. Davis, George Denny, Sherman Hawley, Edgar Burke, N. G. Shaw, H. G. Sheperd, and Mrs. L. F. Manter were painfully injured. The students of the agricultural department were watching the harvesting of a field of corn for ensilage purposes, when the boiler gave way without warning. One of the wheels of the machine was thrown to a distance of 500 feet.

(306.) — On November 7th the boiler of a threshing machine outfit exploded on John Fardahl's farm, about three miles from Adams, near Ausin, Minn. Walter Hildreth was slightly injured.

(307.) — The boiler of an Ohio Central locomotive exploded, on November 7th, at Readsville, near Corning, Ohio. The engineer was instantly killed, and the fireman was fatally injured.

(308.) — A flue failed, on November 9th, in a boiler in the Simon Linser Brewing Company's plant at Zanesville, Ohio. Peter Crowley was scalded to death.

(309.) — A boiler exploded, on November 10th, in the Collins Colliery Company's plant at Glen Jean, Fayette County, W. Va. The fireman was killed, and considerable damage was done to surrounding property.

(310.) — On November 11th the boiler of a steam road roller exploded on the Base Line road, near Gresham, Ore. Merrill Prettyman was slightly injured, and the roller was damaged to the extent of about $1,000.

(311.) — On November 13th a blow-off pipe burst in the Lull Carriage Company's plant at Kalamazoo, Mich. Night watchman Charles W. Morse was killed.

(312.) — A boiler exploded, on November 13th, in W. H. Baker's planing mill, near the Norfolk & Western station, at Blackstone, Nottaway County, Va. Fireman Henry Allen was fatally injured, and W. H. Baker, the proprietor, received minor injuries. A child in the neighborhood was also struck with a piece of flying wreckage, but was not seriously injured.

(313.) — A heating boiler exploded, on November 14th, in the basement of the Hamilton National Bank at Hamilton, N. Y. Nobody was injured, but the building was somewhat damaged, part of the boiler passing up through the inlaid floor of the banking room. The boiler was a hot-water heater and was not supposed to carry any pressure.

(314.) — An upright portable boiler, used for shredding corn, exploded, on November 14th, on Columbus Cole's farm, four miles south of Stillwell, Laporte

County, Ind. Columbus Cole was instantly killed, and Wade Cole was fatally injured. George Bowen, Harold Cole, and Frank Coil were also more or less seriously injured.

(315.) — A rendering tank exploded, on November 17th, in the soap factory of Joseph Stern & Sons on West Fortieth Street, New York city. Alexander Duberlant, George Simon, Nathan Swesky, Peter Campbell, and Joseph McGuire were seriously scalded.

(316.) — A small horizontal boiler, used to operate a stone crusher, exploded, on November 18th, at North Tiverton, R. I. Frederick Hathaway, Distand Geltans, and Giuseppe Boltano were seriously injured.

(317.) — A boiler exploded, on November 18th, in the Myers flouring mill at East Sandy, near Oil City, Pa. Solomon Myers, one of the owners, was injured, and the mill was demolished.

(318.) — On November 18th a boiler exploded in William Rogers' sawmill at Flatrock, near Columbus, Ind. The explosion was preceded by the breaking of a belt and the racing of the engine, and the workmen had all left the building, in search of safety.

(319.) — A boiler exploded, on November 18th, in the woodenware plant of the United Factories Company, Limited, of Newmarket, Ont. John Agnew and Frank Burch were killed, and Timothy Foran, Parnell Howard, William Bell, Daniel Cook, and Henry Trivet were seriously injured. Seymour Evans, C. Conwell, Graham Boyle, and Silas Wright were also injured less severely. The middle part of the plant was wrecked, and the property loss was estimated at $20,000.

(320.) — On November 19th a head-on collision occurred between a freight train and a work train on the Big Four railroad, between Mackinaw and Tremont, near Peoria, Ill. Immediately after the collision the boiler of the locomotive on the work train exploded. The collision resulted in the death of thirty-one men, but the damage done by the explosion itself was trifling.

(321.) — A boiler used for heating the Park theater and the Armory building at Butler, Pa., exploded on November 20th, the explosion being followed by a fire which resulted in the injury of five men and the destruction of property valued at $300,000.

(322.) — An upright boiler exploded, on November 21st, in John C. Wilroy's cotton gin at Driver, near Suffolk, Va. W. E. Byrd, the night watchman, was critically injured, and the building was destroyed.

(323.) — On November 21st a boiler exploded at the shaft of the Carbon Coal Company, two miles and a half from Verne, near Saginaw, Mich. August Mortina and August Moshner were killed, and Edward Kime and Henry Lester were fatally injured. William Tryan, August Knoeinger, and Nicholas Kosely were also injured severely but not fatally. The boiler house was blown to atoms.

(324.) — A boiler exploded, on November 22d, in the power house of the Northampton and Amherst Street Railway Company at Hadley, Mass. William Saunders was seriously but not fatally scalded and burned. The property loss was small. The exploded boiler was less than a year old, and at the time of the explosion it was carrying a pressure only about two-thirds as great as the usual load.

(325.) — A heating boiler exploded, on November 23d, in the residence of Rev. P. A. Baker of Columbus, Ohio. Nobody was injured, but the property loss will amount to several hundred dollars.

(326.) — On November 23d two tubes failed in a boiler in the Shreveport Delinter Company's plant at Shreveport, La. The setting of the damaged boiler was thrown down, but nobody was injured.

(327.) — A boiler used to run a feed cutter exploded, on November 27th, on Mrs. Satterwhite's plantation, near Oxford, N. C. The fireman, named May, was killed.

(328.) — The boiler of the tow-boat *Monie Bauer* exploded, on November 28th, in the Ohio River, near Paducah, Ohio. Watchman Joseph Riley Beard was scalded so badly that he died within a few hours. Engineer Schouse was also painfully scalded on the hand.

(329.) — On November 28th a boiler exploded on the steam wrecking scow belonging to the Empire Shipbuilding Company, at Buffalo, N. Y. Adolph Langer, second mate of the steamer *China*, was struck by a piece of flying wreckage and fatally injured. William Brennan, Charles Klauck, Albert McMinn, and James Doyle were also injured severely but not fatally. The scow was wrecked.

(330.) — The boiler of a small locomotive exploded, on November 29th, in the yards of the Duquesne Steel Works, at Pittsburg, Pa. George Zewe was injured so badly that he lived only about three hours, and John A. Schmidt, the engineer, was severely burned and scalded.

December, 1903.

(331.) — A boiler exploded, on December 2d, in the pumping house of the I. C. R. R., at Amboy, near Dixon, Ill. Nobody was injured.

(332.) — As the result of a collision, the boiler of a freight locomotive exploded, on December 2d, at Greenwood, near Dover, Del. The conductor of one of the locomotives, and a brakeman, were killed, and several other persons were injured.

(333.) — A boiler used for operating a corn shredding machine exploded, on December 4th, on Herbert A. Sias' farm, just outside of Midland, Mich. Rufus Eddy, Andrew McLaughlin, Herbert A. Sias, and P. Richardson were more or less seriously injured.

(334.) — A boiler exploded, on December 5th, in the brick works of Mills Bros., near Braddock, Pa., during the course of a fire which destroyed the plant. The immediate loss due to the explosion was small, and cannot be estimated with accuracy.

(335.) — The boiler of a threshing machine outfit exploded, on December 5th, on Leander Yankey's farm, near Waynesboro, Pa. A young man named Frederick was badly scalded.

(336.) — A heating boiler exploded, on December 6th, in the station of the Central New England Railroad at Campbell Hall, N. Y. The station was considerably damaged, the crown sheet of the boiler being thrown through the roof of the building, and the floor of the waiting-room being torn up. Erving Everett, a brakeman, who was in the waiting-room, was severely bruised.

(337.) — A heating boiler burst, on December 6th, in the Methodist Church at South Bend, Ind. We have not learned further particulars.

(338.) — The boiler of an Illinois Central freight locomotive exploded, on December 7th, at Whitesboro, near Logan, Iowa. Nobody was seriously injured, but the locomotive was wrecked.

(339.) — A boiler exploded, on December 7th, in the shops of the Forest Oil Company, at Taylorstown, Washington County, Pa. Frank H. Green was instantly killed, and Daniel Verner was fatally injured.

(340.) — On December 4th a boiler exploded on the South Penn Oil Company's Ritchie Mine lease, near McFarlan, W. Va. One man was slightly injured.

(341.) — William Dougherty, Martin Dunleavy, and George Warnock were fatally injured, on December 7th, by an accident to a safety water-tube boiler in the Baldwin Locomotive Works, at Philadelphia, Pa.

(342.) — A heating boiler exploded, on December 7th, in the basement of Peter Weins' saloon, South St. Paul, Minn. The place was partially wrecked. Twenty-five persons were in the building at the time, but no one was injured.

(343.) — A boiler exploded, on December 8th, on the tug *James Kennedy*, off Fire Island, N. Y. The tug was damaged so badly that she sank almost immediately, though we understand that her crew was rescued.

(344.) — On December 9th a boiler exploded in a portable sawmill at Ponto, six miles south of Bluffton, Ind. Elmer Betts, owner of the mill, was fatally injured, and Nelson Fuller was also injured in a lesser degree.

(345.) — The building occupied by the Thibert Sanitary Cuspidor & Tool Company, at Jamesville, Mass., was wrecked, on December 9th, by the explosion of a boiler. Nobody was injured.

(346.) — A heating boiler exploded, on December 10th, in the Normal School at Fremont, Neb. Nobody was injured, and the damage was mainly confined to the boiler.

(347.) — On or about December 11th a heating boiler exploded in the Miller block, at Olathe, Kan. The damage was small, and we have not learned of any personal injuries.

(348.) — A heating boiler exploded, on December 11th, in H. G. Selfridge's greenhouse, at Lake Geneva, Wis. The building was wrecked, and the property loss amounted to some thousands of dollars.

(349.) — A boiler used for operating a rock drill exploded, on December 11th, at the Nelson Bennett Company's works, some two miles west of Milner, Idaho. Carl W. Peterson was instantly killed.

(350.) — A boiler exploded, on December 11th, in the Armstrong cork factory at Pittsburg, Pa., setting fire to the building, and causing a total property loss of $40,000. Robert Hanlin was buried in the débris, and, according to the information received by us, was killed. George Friel, James Kennan, Thomas Hannan, Andrew Kerr, Thomas Fitzgerald, and William Rockford were injured.

(351.) — A boiler exploded, on December 11th, in a stove foundry and washing machine works, at Augusta, Ky. Several persons were badly bruised and cut by flying wreckage, but nobody was killed. The boiler passed through the plant, and nearly wrecked it.

(352.) — A small boiler exploded, on December 11th, in George L. Ribaud's market, at Silver Springs, N. Y. Lewis Ribaud was badly burned.

(353.) — On December 12th a boiler exploded in Palmer & Montgomery's sawmill, on Onion Creek, near Montrose, Col. John McGovern, James Burns, and Norman Wolff were instantly killed, and Augustus Palmer was fatally injured. The buildings were completely wrecked, and the machinery hurled in all directions.

(354.) — A boiler belonging to Daniel Shawver exploded, on December 14th, at Bloomer, Ohio. Nobody was injured.

(355.) — A boiler used for heating water exploded, on December 14th, in the Dale street infirmary, St. Paul, Minn. C. J. Paulusse, a nurse, was seriously injured, and the property loss was estimated at $1,000.

(356.) — A heating boiler burst, on December 15th, in the new opera house at Yankton, S. D. Nobody was injured. The property loss was estimated at $500.

(357.) — On December 15th a heating boiler exploded in the Shaffer street school building, at Springfield, Ohio. Nobody was injured.

(358.) — A boiler exploded, on December 15th, in Emil Krug's slaughter house, at Swissvale, Pa. Frederick Krug, a son of the proprietor, was fatally injured. Julius Kolofsky and Julius Krueger were also scalded seriously, but not fatally. The property loss is estimated at $5,000.

(359.) — On December 16th a boiler exploded in W. P. Black's distillery, at Asheville, N. C. Nobody was injured.

(360.) — A boiler exploded, on December 16th, in mill No. 3 of the Atlantic Coast Lumber Corporation, at Georgetown, N. C. The sawyer and several other employees were seriously scalded.

(361.) — On December 16th a boiler exploded in the headquarters of Fire Truck Company No. 1, at Trenton, N. J., setting fire to the building, and causing a total property loss of some thousands of dollars.

(362.) — The office building of the Memphis Floral Company, of Memphis, Tenn., was considerably damaged, on December 17th, by the explosion of a small heating boiler. Nobody was injured.

(363.) — The boiler of a Western Maryland freight locomotive exploded, on December 17th, at Greendale, twelve miles north of Hagerstown, Md. William Neidigh, William N. Thomas, William Bender, and Frank Bender were seriously injured, and Neidigh, at last accounts, was not expected to recover. The explosion consisted in the failure of the crown sheet.

(364.) — On December 18th a boiler exploded in a grist mill belonging to Lee Chambers, and situated at Chambers' Station, some thirteen miles from Mt. Sterling, Ky. William Goodpastor and William Montgomery were instantly killed, and Frank Brown, Charles Swabby, and Henry Swickert were injured seriously and perhaps fatally. The property loss was estimated at $2,000.

(365.) — A boiler exploded, on December 19th, in Thomas Griffin's cotton gin, in Franklin Parish, near Winnsboro, La. Thomas Griffin (the owner), Morris Jones, and Edward Black were killed, and several other men were seriously injured, two of them fatally so.

(366.) — A boiler exploded, on December 19th, in the heating plant of Science Hall, at Fort Worth University, Fort Worth, Tex. Nobody was injured. The property loss is estimated at $1,500.

(367.) — On December 19th a boiler exploded in a sawmill at Jonesboro, near Richmond, Va. Several employees were injured.

(368.) — A battery of seven "safety" boilers exploded, on December 21st, in the power house of the St. Louis Transit Company, St. Louis, Mo. The explosion resulted in the death of eight persons and the more or less serious injury of twenty-one others. The property loss was probably in the vicinity of $75,000. (An illustrated account of this explosion is given in the present issue of The Locomotive.)

(369.) — A boiler exploded, on December 23d, in the city electric light plant at Moundsville, W. Va. The accident was not serious, and nobody was injured.

(370.) — A boiler exploded, on December 26th, at the Owosso Coal Company's mines, Owosso, Mich. It does not appear that anybody was injured.

(371.) — Two boilers exploded, on December 27th, in the Wolseley Barracks, London, Ont. The boiler-room is in the basement, immediately underneath the officers' mess; and at the time of the explosion four men were in the mess-room. Corporal Burnett was killed outright, and Privates Thomas and Walter Warswick were fatally injured. Sergeant Dunlevy was also injured seriously, but not fatally. The boiler which wrought these personal injuries exploded at one o'clock A. M., and it is said that a second boiler in the battery exploded fifteen minutes later, adding materially to the property damage.

(372.) — Fireman Walter Hartley and Brakeman Frank Scott and Walter Lonyo were severely bruised and scalded, on December 27th, by the explosion of the boiler of a Baltimore & Ohio locomotive, between Easton and Warwick, near Akron, Ohio. The explosion consisted in the failure of the crown sheet.

(373.) — On December 29th a boiler exploded in Gregory's mill, near Frankfort, Ky., instantly killing Albert Perry and fatally injuring Solomon Wainscott. The mill was wrecked.

(374.) — The boiler of locomotive No. 1317 of the Erie Railroad exploded, on December 29th, at Kellam's bridge, near Port Jervis, N. Y. Frank Loven was instantly killed, and Engineer Ira Wallace and Track Walker Mark Carr were injured very seriosly. Brakeman Frank Boyle was also injured less seriously.

Boiler Explosions During 1903.

We present, herewith, our usual annual summary of boiler explosions, giving a tabulated statement of the number of explosions that have occurred in the United States during the year 1903, together with the number of persons killed and injured by them. We desire to say, once more, that it is by no means easy to make out accurate lists of boiler explosions, because the accounts that we receive are often unsatisfactory; but, as usual, we have spared no pains to make the present summary as nearly correct as possible. In preparing the detailed monthly lists upon which it is based (and which are published regularly in The Locomotive), it is our custom to obtain as many distinct accounts of each explosion as possible, and then to compare these different accounts diligently, in order that the general facts may be stated with some considerable degree of accuracy. We do not pretend that this summary includes all of the boiler explosions of 1903. In fact, it is likely that only a fraction of these explosions is here represented; for many accidents have doubtless occurred that were not considered by the newspapers to be sufficiently "newsy" to interest the general public.

The total number of boiler explosions in 1903, according to the best information we have been able to obtain, was 383, which is 8 less than were recorded for 1902. There were 391 in 1902, 423 in 1901, 373 in 1900, and 383 in 1899. In several instances during the year 1903 two or more boilers exploded simultaneously. In each case of this sort we have counted each boiler separately in making out the summary, believing that by so doing we should represent the actual damage done more accurately than we should if we simply

Summary of Boiler Explosions for 1903.

Month.	Number of Explosions.	Persons Killed.	Persons Injured.	Total of Killed and Injured.
January,	42	46	59	105
February,	31	14	41	55
March,	23	13	21	34
April,	28	22	55	77
May,	27	21	48	69
June,	25	14	17	31
July,	26	13	28	41
August,	25	24	38	62
September,	37	28	65	93
October,	38	40	40	80
November,	30	22	47	69
December,	51	36	63	99
Totals,	383	293	522	815

recorded the number of separate occasions on which boilers have exploded. The difference in the figures, as given by these two methods, however, is trifling.

The number of persons killed in 1903 was 293, against 304 in 1902, 312 in 1901, 268 in 1900, and 298 in 1899; and the number of persons injured in 1903 was 522, against 529 in 1902, 646 in 1901, 520 in 1900, and 456 in 1899.

The most serious explosion during the year was perhaps that which occurred in St. Louis on December 21st, and which is described in the leading article of the present issue of The Locomotive, 8 persons being killed and 21 injured, and the property loss being probably $75,000.

We are aware that it would greatly increase the interest of this annual summary to give some estimate of the total property loss from boiler explosions during the year. We are often asked about this point, and we should be glad to give the desired information if we could get it. Usually, however, it is very difficult to obtain reliable estimates of the loss resulting from a boiler explosion, unless the boiler is insured; and hence it is impossible to arrive at any trustworthy figures for the total destruction of property for the year.

The Locomotive.

Founded by J. M. Allen, A.M., M.E.

HARTFORD, APRIL 15, 1904.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each. (*Any volume can be supplied.*)

Obituary.

Mr. James F. Nolan.

We regret to record the death of Mr. James F. Nolan, an inspector of the Hartford Steam Boiler Inspection and Insurance Company, who was fatally injured by a gas explosion, while examining a boiler in the gas works of the Sayles Bleachery, at Pawtucket, R. I. The accident occurred on March 13th, and Mr. Nolan died on March 18th. He was born at Charlestown, Massachusetts, on May 7, 1875, and was the son of Mr. Thomas Nolan, and the oldest of a large family of children. He was a young man of unimpeachable character, and was highly esteemed by a large circle of friends and acquaintances. He took great pleasure in music, and was a talented musician. As a boy he attended the Charlestown schools, afterwards taking special courses in mechanical studies, and serving a five-years apprenticeship at the Cunningham Iron Works, then at Charlestown. He was later employed at the Atlantic Works, East Boston, at the Morse Iron Works, Brooklyn, and in the construction and repair department of the Navy Yard at Charlestown. He left the last-named position to become an inspector for the Hartford Steam Boiler Inspection and Insurance Company, in which capacity he had distinguished himself by the faithfulness and intelligence with which his duties were performed. His mechanical abilities were at once recognized by his comrades, and by the officers of the company, to all of whom he had endeared himself, and by whom he will long be remembered with sorrowful affection.

With the death of General William B. Franklin, on March 8, 1903, the office of Vice-President of the Hartford Steam Boiler Inspection and Insurance Company, which he had held continuously since 1873, became vacant. No election was held to fill this vacancy until the death of President Allen made it necessary to take some action in this respect. In January, 1904, Mr. Charles M. Beach was accordingly chosen as Vice-President, with the stipulation, on his part, that he would accept the office temporarily, until the Board of Directors found it convenient to select a permanent incumbent. The appointment of Mr. Beach to the office, even though it was merely temporary, was singularly appropriate, not only because he has served continuously and from the earliest days upon the directorate of the company, but also because Mr. Beach was our first Vice-President, he having been General Franklin's immediate predecessor.

In February, 1904, and in pursuance of the understanding under which Mr.

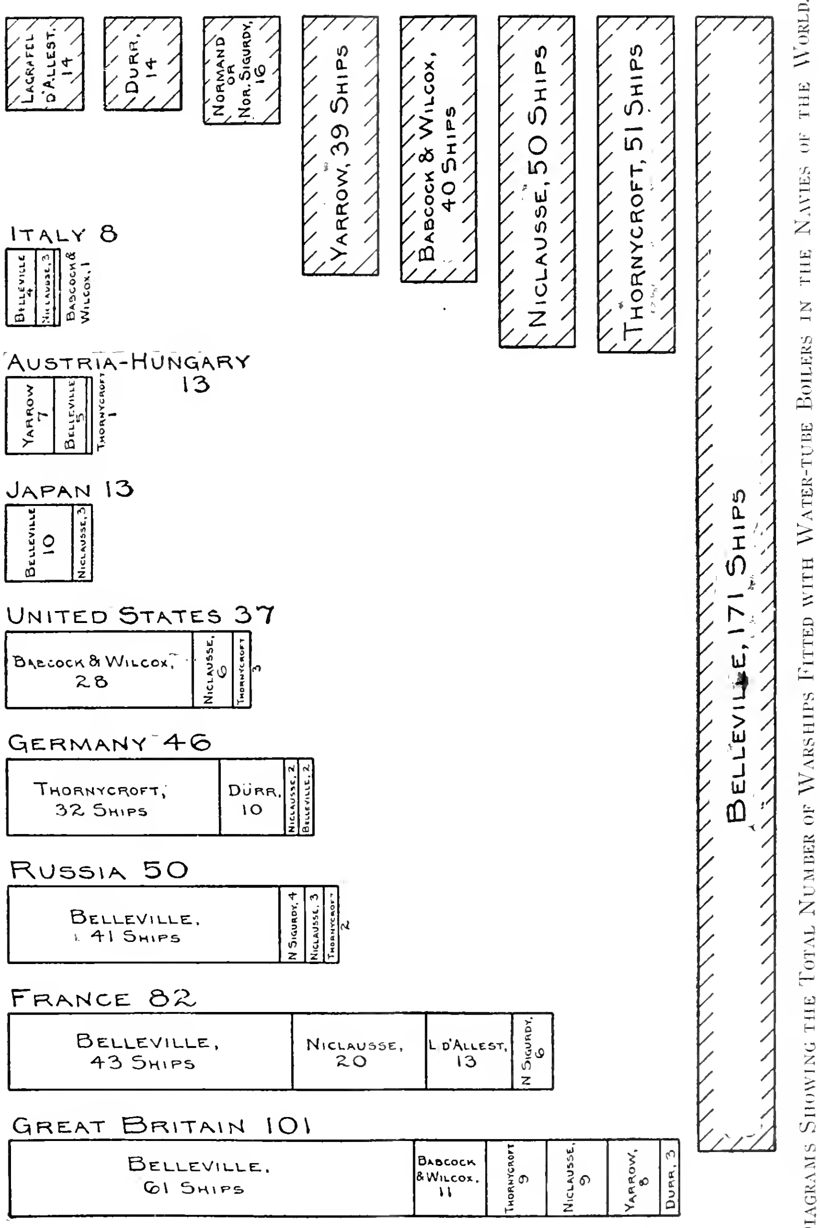
Beach had been temporarily appointed to the office, the Board of Directors of the Hartford Steam Boiler Inspection and Insurance Company elected Mr. Francis B. Allen as the permanent Vice-President. Mr. Allen has long been in the service of the company, and is exceedingly well fitted to perform the new duties to which he has succeeded. He entered the employ of the company in 1872 as special agent in the New York Department, where he continued for ten years. In 1882 he was transferred to the Hartford office, where he was promoted to the office of Supervising General Agent, a position which he filled with marked success until, in 1888, he was made Second Vice-President. Mr. Allen's practical knowledge of the field work that must be done in connection with boiler insurance, his extensive experience in mechanical engineering, and his long term of faithful service in the interests of the company that he represents will lead his friends and associates to regard his advancement as a simple act of justice, by which the Directors have honored themselves as well as him.

A. D. RISTEEN.

PRESIDENT J. M. ALLEN began the publication of THE LOCOMOTIVE in 1867, in the form of a large pamphlet, about nine inches wide and eleven inches long. It was nominally, at that time and for some years afterwards, a four-page monthly periodical, although it was not uncommon to publish a single issue of eight pages. In 1880 the present size of the journal was adopted, and the number of pages in each issue was increased to sixteen; this size, and the monthly period of publication, being retained up to the beginning of the present year. For some time past the management has had under consideration the advisability of making the journal a quarterly, to be issued in January, April, July, and October, and with the present year this plan has been definitely adopted, so that hereafter THE LOCOMOTIVE will appear at intervals of three months, on the dates indicated. It is proposed to increase the number of pages in each issue, and to confine the subject-matter more closely to steam engineering and to such matters as have a more or less direct bearing upon that subject. Subscribers to THE LOCOMOTIVE will therefore receive, during the year, approximately the same amount of engineering information as heretofore, although the journal will be less frequently received by them. The subscription price will not be altered, but will remain at fifty cents per annum, in advance, as in the past.

Water-Tube Boilers in the World's Navies.

The *Statesman's Year-Book* for 1904 contains an interesting chart, which we reproduce herewith, showing the number of vessels in the principal navies of the world which were fitted wholly or partially with water-tube boilers at the beginning of the present year. Two methods of classification are adopted, as will be seen; the rectangles which are to be viewed by holding the page sidewise giving the total number of ships that carried water-tube boilers of the several kinds specified, while those that are to be viewed by holding the page in the usual upright position give the number of ships in certain of the more important navies which are provided with such boilers. Several of the types of boilers here represented were described and illustrated in THE LOCOMOTIVE for November, 1902, to which we would refer readers who desire further information concerning them.



Diagrams Showing the Number of Warships Fitted with Water-tube Boilers in the Navies of the Great Powers.

Manufacture of Seamless Cold-Drawn Steel Boiler Tubes.

By G. M. Kohler, Asst. Engineer, U. S. R. C. S.

Very few engineers have ever had the opportunity of witnessing the manufacture of seamless boiler tubes. It is for the benefit of those who have never had this opportunity that this article is written.

A seamless tube is one that is made from a solid piece of steel, or "billet," as it is called. These billets are open-hearth basic steel and show approximately the following analysis: carbon, .17 per cent.; manganese, .45 per cent.; sulphur, .025 per cent.; phosphorus, .10 per cent. Steel having more than .18 per cent. carbon is not used.

The material is received from the steel mills in solid pieces about ten feet long and four or five inches in diameter. The first step in the manufacture of the tube is to cut these long bars into smaller pieces of such length as to contain enough metal to make one tube of the required size. A piece about 18 inches long and 5 inches diameter will make a 3½-inch tube about 14 feet long. These

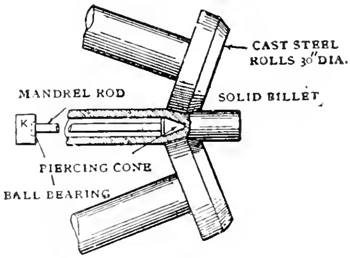


Fig. 1.

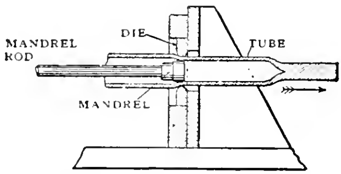


Fig. 4.

small pieces or billets are cut from the long bars, either hot or cold, by means of saws. It requires about sixteen minutes to cut a 5-inch diameter bar when cold and a much shorter time if the bar be heated to a cherry red. These saws are of the best steel suited for the purpose, and one saw will run about eighteen hours without being sharpened. Some mills cut the billet from the bar by the use of a steam hammer and knife; this method, while being very quick and cheap, leaves the end of the billet rough and ragged, causing the end of the tube after drawing to be of poor quality and unfit for use.

After the billets are cut they are taken to a drill press, where a 1-inch hole is drilled in the center of one end to a depth of about one-half inch. This hole is for the purpose of centering the piercing cone in the piercing mill.

Piercing the Billets.

The most interesting part in the manufacture of the tubes is the piercing of the solid billets. After they are centered in the drill press they are placed in a gas furnace made of firebrick and rectangular in shape. The fuel used is gas obtained from the distillation of bituminous coal. These furnaces are so arranged that the billets enter the coolest part and gradually roll to the hottest part. This is for the purpose of slowly heating the billet so as to have it of the same temperature throughout. It requires about three hours for the billet to pass through the furnace, at the end of which time it is at a bright-yellow heat and is ready for the piercing mill.

This mill pierces a hole through the billet longitudinally, and at the same time increases its length about 100 per cent. As shown in Fig. 1, the piercing mill consists of two large cast-steel disks, about 30 inches in diameter and 16 inches thick, which revolve at about 100 revolutions per minute. The piercing cone fits loosely on a mandrel which is free to turn and is fitted in a ball-bearing socket at the end *K*. This bearing takes up the thrust due to the disks forcing the solid billet over the piercing cone. The thrust is very large, and if it were not for the ball bearing the mandrel and piercing cone would not revolve, as they would be held from doing so by the friction at the end of the rod.

When the billet is taken from the furnace at a yellow heat it is placed in a guide, such that it enters between the disks, as shown, in the same plane as the axis of the shafts which revolve the disks; the piercing cone then enters the center of the billet and in the small hole which was drilled for this purpose. As soon as the billet comes in contact with the revolving disks it is given their circular motion and at the same time thrust forward by them over the piercing cone. This thrust is of the same nature as that which causes a belt to climb to

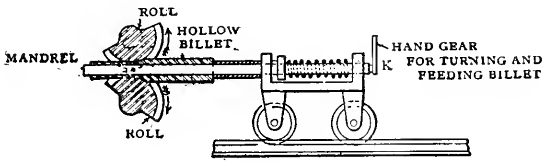


FIG. 2.

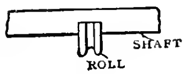


FIG. 3.

the highest part of a revolving pulley. After each billet is pierced the cone and mandrel are thrown into cold water and allowed to cool; a stream of water is also turned on the disks for the same purpose.

ROLLING THE HOLLOW BILLETS.

The billet, which is now known as a hollow billet, and is still at a good yellow heat is now ready to be rolled to reduce the thickness of the walls and at the same time to increase its length. The rolling is carried out to such an extent that the tube is about one-half inch larger in diameter and about five gauges B. W. G. thicker than the finished tube. There are two different methods of rolling. Some mills use the ordinary cast-iron rolls, the tube being placed on a mandrel whose point is held between the rolls. The tube is given about six to eight passes through the rolls, care being taken that it is turned through 90 degrees after each pass, so that the walls may be rolled of even thickness throughout its entire length.

A somewhat different method of rolling is roughly illustrated by Fig. 2, from which it is seen that there are two semicircular rolls, each forged on a shaft. These rolls are about 24 inches in diameter, and are grooved as shown in Fig. 3. The hollow billet, as soon as it comes from the piercing mill, is placed on a mandrel, the end of which is then inserted into a socket and carried on a truck. The truck is then pushed forward until the end of the mandrel and billet comes between the rolls. The rolls revolve in the direction shown by the arrows, which tends to thrust the billet out from under the rolls. To overcome this the socket in which the mandrel is secured is fitted with helical springs, which are compressed when the rolls push the billet out. As soon as the rolls leave the billet the energy which is stored in the springs pushes it back, so that by the time the rolls come around again the billet is back in its proper position under the rolls. As the billet is rolled out it must be fed under the rolls, and also turned on its axis to prevent uneven rolling. For both of these purposes there is a suitable hand gear located as shown.

The tube is now about six to eight times the length of the original billet. The inside of the tube is smooth and free from scale, but the outside has considerable scale on it. The tubes are allowed to cool in the open air, after which one end is heated in a gas furnace, then taken out and pointed under a small steam hammer: this point is about one foot long and serves as gripping surface for the pliers on the cold-drawing benches. To remove the scale the tubes are sent to the pickling room and immersed in a solution of sulphuric acid. After the scale has been loosened up, the tubes are rinsed off with water, then placed in another tank containing a mixture of tallow, flour, and warm water. This operation is called "doping." They are left in the doping tank for about one-half hour; then they are dried and are ready for the first pass on the cold-drawing bench.

Cold Drawing.

Fig. 4 illustrates the principle involved, from which it is seen that one end of the tube is open and the other closed or pointed. As stated above, this point is for the purpose of gripping the tube by the pliers which pull it through the die. The mandrel is carried on the end of a long rod, the end of which is fastened to the end of the draw bench. After the mandrel is placed in the tube the pointed end of the tube is passed through the die and the drawing pliers made to grip it. By a suitable connection with an endless chain, the pliers draw the tube slowly through the die (about nine to twelve feet per minute). As the tube passes through the die it is reduced in thickness and diameter and also lengthened about 20 per cent.

The cold drawing of the tube causes the metal to become brittle, so that after each pass it is found necessary to anneal and dope them. To anneal them they are heated to a cherry red in an oven, then allowed to gradually cool in the open air. They are then doped again and given another pass at the cold-drawing benches.

The number of cold passes given to the tube depends upon, first, the strength of the mandrel rod; second, the strength of the material in the tube; third, the thickness of the walls of the tube. From Fig. 4 it is clear that, in drawing, the pliers tend to pull the tube apart at the die; also, the mandrel rod tends to come through the die, due to the friction between the metal of the tube and the mandrel; hence the pull of the pliers must not equal the tensile strength of the tube or the mandrel rod. It usually requires about three passes on the cold-drawing bench, though for tubes with thin walls twice this number of passes may be necessary.

After the tubes are finished in the bench room the pointed end is cut off in a lathe and this end of the tube gauged for thickness. If the walls are of the proper thickness and concentric, the tube is cut to length and gauged at the end last cut off.

The surface of the tube as it comes from the cold-drawing benches is very smooth, almost polished, but the metal, as stated above, is hard and brittle, requiring a final annealing. This is carried out in closed sheet-iron retorts, about 14 inches in diameter and about 25 feet long, with the ends fitted with cast-iron headers. The tubes are placed in the retorts, the ends closed, and the retort then pulled into a long, rectangular furnace. About every twenty minutes the retort is turned around 90 degrees by rolling it toward the other end of the furnace; finally, about two or three hours after it first entered, when the tubes are at a cherry-red heat, the retort reaches the other end of the furnace and is taken out and allowed to cool for about twelve hours. The tubes are then removed from the retort.

The tubes after being annealed are very crooked and need to be straightened. This is done by supporting the tube, with curved part upward, on two grooved rollers about five feet apart; between these rollers is a die working vertically, which, as it descends, forces the curved part of the tube downward; the tube is moved along the rollers, and, by repeated operations of the die, is made perfectly straight.

Boiler Explosions Since 1879.

The tables presented herewith show the number of boiler explosions that have occurred in this country since the beginning of the year 1879, and also the number of deaths that have resulted from them, and the number of persons that have been injured.

According to Table 1 there were 6,769 boiler explosions during the twenty-five years between January 1, 1879, and January 1, 1904. These explosions, it will be seen from Tables 2 and 3, resulted in the death of 7,295 persons, and in more or less serious injury to 10,868 others; so that the total number of persons killed and injured during this time, by boiler explosions, was 18,163.

In Table 4 the number of explosions each year, and the number of killed and injured, are shown in such a manner as to facilitate comparison. We see, from the last line of this table, that (on an average) 1.078 persons are killed per explosion, and 1.605 are injured. That is, 2.683 persons were either killed or injured, on an average, by every explosion.

Table 1. — Summary of Boiler Explosions by Months.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1879	10	16	9	12	5	10	7	14	8	10	13	18	132
1880	19	14	11	11	12	10	14	11	16	11	16	25	170
1881	22	16	15	8	8	15	8	11	14	16	13	13	159
1882	26	15	16	13	14	11	9	18	14	13	7	16	172
1883	22	12	16	10	17	17	10	18	17	15	20	10	184
1884	14	10	15	12	16	16	19	14	12	12	6	6	152
1885	14	20	14	7	12	12	10	9	11	14	15	17	155
1886	19	18	18	7	9	13	26	17	15	10	17	16	185
1887	26	12	8	17	18	14	14	10	14	21	28	16	198
1888	29	22	22	18	16	19	24	20	25	13	15	23	246
1889	18	14	17	14	9	5	17	16	14	28	19	9	180
1890	24	26	22	13	18	20	8	21	15	20	18	21	226
1891	21	26	19	14	24	14	24	23	15	26	26	25	257
1892	35	19	20	14	15	11	20	16	25	28	32	34	269
1893	39	29	26	28	23	14	18	29	22	29	33	26	316
1894	30	26	20	23	22	22	25	37	28	62	39	28	362
1895	30	46	26	16	26	23	20	35	26	43	33	31	355
1896	35	30	28	24	24	24	24	42	36	25	28	26	346
1897	27	31	24	16	28	25	31	37	40	27	32	51	369
1898	26	26	25	26	22	26	36	27	49	40	42	38	383
1899	49	29	42	21	28	22	25	43	31	27	29	37	383
1900	36	33	25	27	18	36	32	32	35	31	41	27	373
1901	41	30	45	30	31	23	29	41	29	40	44	40	423
1902	36	38	32	29	33	17	34	32	33	37	34	36	391
1903	42	31	23	28	27	25	26	25	37	38	30	51	383
Total Number of Explosions,													6,769

TABLE 2. — SUMMARY OF DEATHS BY BOILER EXPLOSIONS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1879	18	38	4	9	3	34	12	17	12	11	16	34	208
1880	16	22	31	12	30	30	20	9	14	23	18	34	259
1881	38	18	28	6	11	41	16	19	25	15	18	16	251
1882	15	22	27	31	14	18	6	41	18	16	15	48	271
1883	29	18	17	11	30	25	18	18	30	12	37	18	263
1884	17	7	25	18	30	26	37	13	15	31	22	13	254
1885	24	22	20	9	18	14	7	11	11	19	34	31	220
1886	17	6	28	3	18	14	40	30	10	37	26	25	254
1887	27	6	7	14	25	15	15	7	11	71	40	26	264
1888	22	59	23	20	20	20	17	54	37	13	22	24	331
1889	27	45	18	15	7	6	28	27	34	66	21	10	304
1890	24	31	18	11	16	20	12	30	11	28	25	18	244
1891	23	36	11	7	21	22	23	13	19	36	20	32	263
1892	45	22	36	13	12	13	30	11	34	24	32	26	298
1893	29	20	35	29	37	9	17	43	28	22	33	25	327
1894	27	24	19	32	22	22	28	37	35	35	18	32	331
1895	34	28	30	12	23	27	19	70	14	40	60	17	374
1896	40	32	19	28	51	29	15	48	28	35	24	33	382
1897	25	24	28	10	32	43	42	63	41	21	31	38	398
1898	32	15	18	22	17	25	27	23	34	43	45	23	324
1899	21	12	35	21	19	11	26	46	33	28	19	27	298
1900	21	23	19	19	18	27	28	16	25	18	27	27	268
1901	9	13	23	21	22	19	22	45	20	34	56	28	312
1902	24	22	22	14	22	9	28	35	22	25	53	28	304
1903	46	14	13	22	21	14	13	24	28	40	22	36	293
Total Number of Persons Killed,													7,295

TABLE 3. — SUMMARY OF PERSONS INJURED BY BOILER EXPLOSIONS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1879	15	36	20	15	10	20	18	19	11	15	16	18	213
1880	44	23	59	46	59	132	41	21	35	28	33	34	555
1881	35	31	51	11	23	38	19	14	19	32	20	20	313
1882	36	38	31	34	17	26	34	55	28	8	8	44	359
1883	63	23	22	24	38	29	35	17	50	24	65	22	412
1884	19	13	27	15	31	23	35	16	20	17	25	10	251
1885	35	30	28	9	32	6	21	21	13	40	22	21	278
1886	64	25	21	12	19	24	33	24	20	17	27	28	314
1887	31	17	23	43	39	41	20	19	19	65	53	18	388
1888	56	68	37	40	35	38	40	41	56	15	29	50	505
1889	40	33	66	24	18	13	105	36	13	48	19	18	433
1890	44	38	44	19	21	37	12	38	10	32	36	20	351
1891	28	43	31	10	27	25	45	31	15	52	34	30	371
1892	46	25	51	24	31	38	36	18	54	49	25	45	442
1893	42	35	30	31	35	13	17	34	26	30	49	36	385
1894	39	27	34	36	42	20	12	54	48	55	51	54	472
1895	32	37	57	22	32	52	30	79	35	58	59	26	519
1896	99	28	36	34	44	18	25	67	46	66	40	26	529
1897	27	59	29	28	43	23	64	51	48	54	48	54	528
1898	52	36	25	27	21	50	68	43	83	58	70	44	577
1899	50	27	41	23	31	19	38	68	47	43	33	36	456
1900	56	41	35	64	22	41	58	41	45	45	50	22	520
1901	54	30	63	37	55	20	48	99	43	78	73	46	646
1902	45	48	32	29	33	12	71	44	37	48	90	40	529
1903	59	41	21	55	48	17	28	38	65	40	47	63	522
Total Number of Persons Injured,													10,868

TABLE 4. — SUMMARY OF EXPLOSIONS AND OF KILLED AND INJURED.

Year.	Explosions.	Killed.	Injured.	Total of Killed and Injured.
1879,	132	208	213	421
1880,	170	259	555	814
1881,	159	251	313	564
1882,	172	271	359	630
1883,	184	263	412	675
1884,	152	254	251	505
1885,	155	220	278	498
1886,	185	254	314	568
1887,	198	264	388	652
1888,	246	331	505	836
1889,	180	304	433	737
1890,	226	244	351	595
1891,	257	263	371	634
1892,	269	298	442	740
1893,	316	327	385	712
1894,	362	331	472	803
1895,	355	374	519	893
1896,	346	382	529	911
1897,	369	398	528	926
1898,	383	324	577	901
1899,	383	298	456	754
1900,	373	268	520	788
1901,	423	312	646	958
1902,	391	304	529	833
1903,	383	293	522	815
Totals,	6,769	7,295	10,868	18,163

The Hartford Fire Insurance Companies.

Hard hit by the Baltimore ash heap, the Hartford fire underwriting corporations are able to stand it. The blaze will take upwards of $2,000,000 from their treasuries, but the companies are in no wise embarrassed by the demand suddenly thrust upon them. The losses incurred by the local underwriting interests will be paid promptly and in full.

The moral of it all is obvious, and that moral proves the advantage of carrying policies in the strong companies. Insurance may be had at cheaper rates in concerns that have to be kept alive by the oxygen treatment and that can't weather a hurricane. Insurance that's worth having and that really insures can't be bought for a song. It is bound to cost money. Security is the thing that counts, and security can't be had in a tottering company.

The appalling catastrophe that has overtaken the queen city of the Chesapeake will tend to give strong companies still better control of the fire underwriting situation. It will be likely still further to weed out the weak concerns which take risks at cut-throat rates, which inject an element of demoralization into conditions, and which are unable to undergo heavy losses all in a heap. It is sure to impress upon policy-holders the desirability of placing their hazards with corporations of demonstrated strength and of patronizing concerns that can breast the hardest gale without fainting or flinching. One ultimate effect of the Baltimore disaster will be to bring still larger amounts of business to the Hartford companies, which have repeatedly proved their soundness and which can stand erect under burdens that would send weaker concerns sprawling. — *Hartford Post.*

The Locomotive

PUBLISHED BY THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

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Water-Hammer in Steam Pipes.

We have frequently, in the pages of THE LOCOMOTIVE, called attention to the danger of putting in steam pipes in such a way that they can act as traps, and collect any considerable quantity of water of condensation. When steam is turned into a pipe containing entrapped water, it is an unfortunately common experience that the entering steam causes the water to surge about in some way that is not entirely understood, so that it is often thrown against the fittings with such violence as to cause some part of the pipe line, or its connections, to break. The

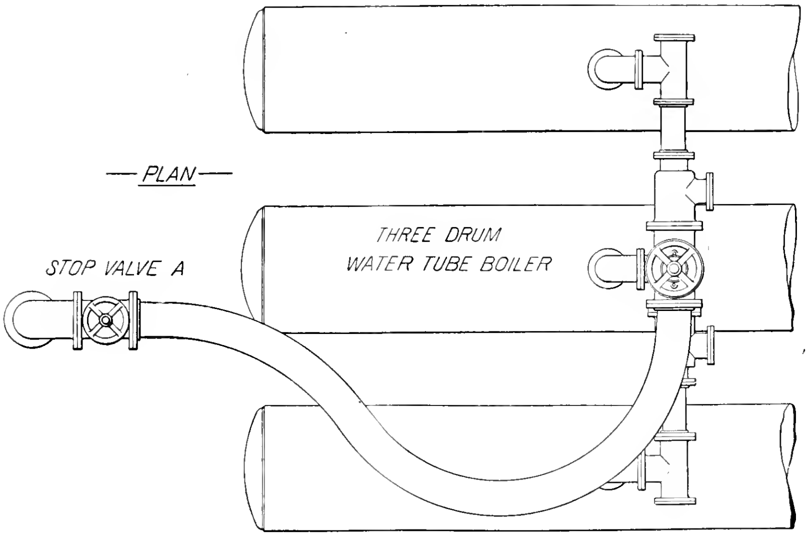

FIG. 1.

reality of the danger from entrapped water in piping is often disputed by those who have not seen its results; but the extensive experience of the Hartford Steam Boiler Inspection and Insurance Company indicates that accidents from this cause not only happen, but happen often. In the present article we give several cases of the kind that have recently come under our notice.

Figs. 1, 2, and 3 represent certain steam connections which gave trouble, not long ago, in an electric lighting plant. The boilers were of the water-tube type, with three drums each; the drums of one of these boilers being shown. Immediately upon the top of this boiler there was a safety stop valve, *B*, which was designed to close automatically in case of any abnormally violent rush of steam through the feeder to which it was attached. This automatic valve was closed at the time of the accident, and another stop valve, *A*, situated on the same feeder where it entered the boiler, had also been closed. The boiler had been out of service for a time, but pressure had been raised upon it again, and it was about to be "cut in" with the other boilers in the battery. For this purpose the stop valve *A* was opened, the intention being to open the automatic valve, *B*, immediately afterwards. It is probable that, owing to leakage through one or the

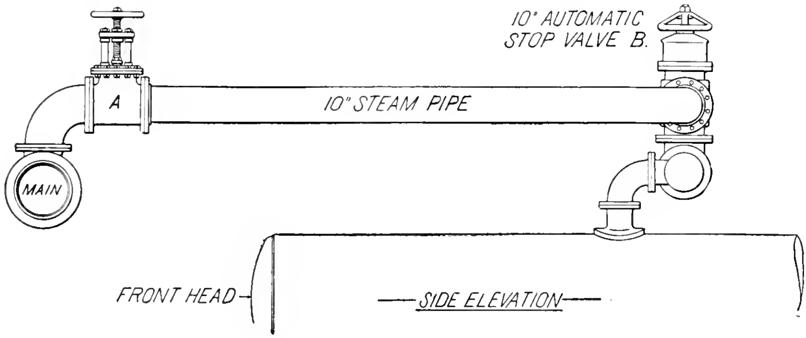

FIG. 2.

other of the two valves, there had been an accumulation of water in the space between these valves; the entering steam causing this water to surge around through the curved pipe in such a way as to throw it violently against the automatic valve. At all events, the stop valve, *A*, was hardly opened when a section of the casing of the automatic valve was knocked out, as indicated by the shaded area in Fig. 3; several men who were standing near by being also scalded. Where two valves are used on a steam pipe in this manner, provision should always be made for draining the space between them before either valve is opened; and when one of the valves is opened, it should be opened very slowly indeed. Furthermore,

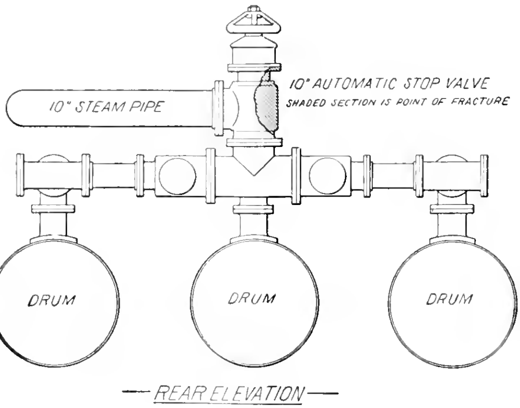

FIG. 3.

before any considerable quantity of steam is admitted to the pipe, both valves should be eased off from their seats slightly, to establish a moderate circulation, this being allowed to continue for some moments before the valves are opened further.

Fig. 4 illustrates another case, quite similar in its general aspects to the one described above. The boiler was here of the vertical water-tube type, and there was a gate valve in the branch pipe near the boiler, as well as a globe angle valve where the branch pipe entered the large main. From the circumstances attending the accident here under consideration, and from the close similiarity between it and other accidents in which water-hammer was undoubtedly the chief and perhaps the sole factor in determining the destruction, we are confident that this was also a case of water-hammer action. There had undoubtedly been leakage through one or both of the valves shown, so that the steam pipe had become more or less filled with water. At any rate, when the valve *B* was opened, the casing of the valve *Y* was almost immediately fractured, being broken into several pieces. It will be understood that in an accident of this kind it is often very difficult indeed to prove, beyond further argument, just what the cause was. In the present case, it has been pointed out that the valve *B*, being a gate valve, would naturally not be opened very rapidly; and it has been argued that this

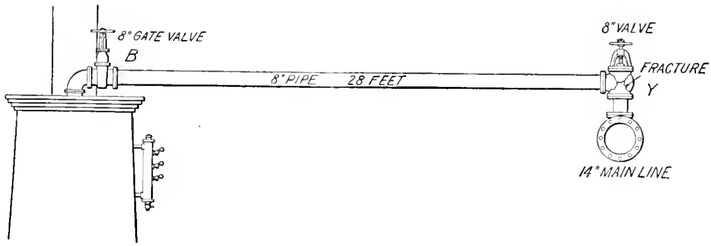

Fig. 4.

lessens the probability that the accident was due to water-hammer action. However, the fact remains that the casing of the broken valve appears to have been abundantly strong to withstand any strain that could legitimately come upon it in its natural service, and, moreover, an examination of the fractured areas of the casing showed that they were sound, and without defects. It is also certain that the pipe would have trapped water if either of the valves had leaked, and that the accident occurred immediately upon steam being admitted through the valve *B*. Taking these various circumstances into account, we feel assured that the cause was either water-hammer, or the sudden lifting of water from the boiler itself, as the steam was carried over into the comparatively cold pipe. Of these two explanations, that which assumes the presence of entrapped water appears to us to be the more probable, because, unless the gate valve, *B*, were opened with very unusual quickness, it is not probable that any great amount of water would be actually lifted from the boiler and thrown with violence down to the valve *Y*.

Drips are excellent things on a pipe line, if they are faithfully used; but there is a temptation to neglect them, after the attendant has operated the plant for a considerable time without trouble, and it is always better to design the pipe line so that no drips will be necessary, the pipe emptying itself by the natural action of gravity. The same precaution may be repeated here which was mentioned above — namely, in throwing a boiler into service which is connected with the main steam line by a pipe containing a double valve, the valves should be opened very slowly, each being eased from its seat and allowed to stand for a time, until the pipe becomes thoroughly heated, and any entrapped water that it may contain has had an opportunity to pass away.

In Fig. 5 we illustrate another accident, in which water-hammer was more evidently the cause of the trouble. In this case, the feeder pipe from the boiler to the main was bent, in order to clear a fore-and-aft line of pipe. There was only one valve, in this instance, between the main pipe and the boiler; but it is easy to see that with the boiler out of service, and steam in the main pipe, there must be condensation in the bent feeder, and the water of condensation must collect, in large measure, in the lowest part of the feeder, near the stop valve. Some changes had been made in the steam plant where this accident occurred, and the valve was being opened for the first time. We are informed that two men were engaged in opening the valve, from which we infer that it may not have been found to work entirely satisfactorily. We are further informed that there was a difference in pressure of 30 pounds between the boiler and the steam main, the pressure in the main being 150 lbs., and that in the boiler 120 lbs.

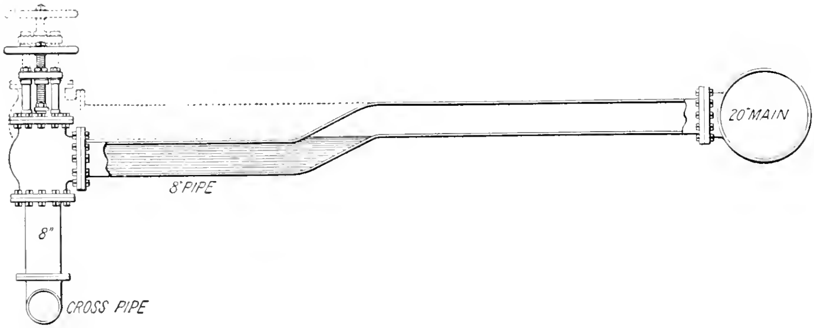

Fig. 5.

We have called attention to the danger of cutting in a boiler while any considerable difference of pressure exists between it and the steam main so often that it is rather discouraging to attempt to accomplish anything by a further reiteration of the caution. A boiler should never, under any circumstances whatever, be "cut in" with other boilers until the pressure within it is practically identical with that in the steam main; because, if this condition is violated, there is grave danger of the rupture of some part of the structure, owing to the suddenness with which the stresses are changed when the valve is opened. In the present case, water had collected in the lower part of the bent feeder, and when the valve was opened this water was thrown against the valve with such violence that the casing of the valve was fractured, the arch cap of the valve being broken away from the body of the chamber, and the valve disk, stem and part of the arch being blown up through the roof of the building. The casing of the valve was 5/8 in. thick, and subsequent examination showed that it contained a small blow-hole, though this defect was too trifling to affect the strength of the casting to any serious extent. Two men were seriously injured by this accident, one of them losing his eyesight entirely, while the other one lost one eye. The dotted lines in Fig. 5 show the ideal way in which this steam feeder should have been run, in order to avoid entrapped water. If it was necessary to bend the feeder, however, in order to avoid the fore-and-aft line of pipe referred to above, the feeder should have been bent in such a way that its highest part should come next to the boiler, instead of next to the steam main; the riser being correspondingly lengthened. There would then be no pocket in which water could collect, and the feeder would have drained itself into the steam main.

In conclusion, and by way of résumé, let us repeat that a steam line should never be arranged so that it can possibly entrap water. If there is any doubt about the perfect drainage in any particular case, drip pipes should be provided so that the doubtful part can be thoroughly drained before steam is turned into it; but it should always be remembered that any pipe whose safe condition depends upon opening of a drip, as a distinct operation to be performed before the valve is opened, must be regarded as an element of weakness about the plant. Steam valves, under all circumstances, should be opened and closed very slowly, and when a pipe contains more than one valve they should all be eased from their seats slightly for some moments, so as to permit of the establishment of a certain amount of circulation, before they are opened up fully. By attending to these various precautions, it should be quite possible to avoid, in large measure, the serious accidents that are continually occurring in connection with pipe lines, and which are attributable to water-hammer action, or to other analogous causes.

Boiler Explosions.

January, 1904.

(1.) — On January 2d two heating boilers exploded in the Chesley & Rugg factory, at Haverhill, Mass. We have not learned of any personal injuries.

(2.) — A boiler exploded, on January 2d, in the plant of the American Ice Company, at Catskill, N. Y. William Egner, John Conlon, and Charles Pealey were injured. Parts of the boiler were thrown across a neighboring creek, and the ice-house was somewhat damaged.

(3.) — The boiler of a heavy Reading freight locomotive exploded, on January 3d, on the New York division of the Reading Railroad, at Woodbourne, N. J., twenty-five miles from Philadelphia, Pa. Frank August, the fireman, was instantly killed, and brakeman Harry Sheetz was injured so badly that he died within a few hours. Engineer A. Finger was injured severely, but not fatally.

(4.) — A hot-water heating boiler exploded, on January 3d, in the residence of George W. Doty, at Asbury Park, N. J. The building took fire, but the flames were extinguished before much damage was done.

(5.) — A heating boiler exploded, on January 4th, in John Iwaine's grocery and meat store, at Springfield, Mass. Nobody was injured, and the property loss was small.

(6.) — The boiler of a Delaware & Hudson locomotive exploded, on January 4th, at Addison Junction, N. Y., on the Champlain division. Fireman J. Saborious was seriously injured.

(7.) — On January 4th a heating boiler exploded in James E. Johnston's store, on Lippincott street, Toronto, Can. Nobody was injured, and the damage to property was small.

(8.) — A boiler exploded, on January 4th, in a knitting mill at Scranton, Pa. We have not learned of any personal injuries.

(9.) — On January 5th the boiler of a Pennsylvania Railroad locomotive exploded at Newbold, N. J. Engineer Albert Zellers and brakeman James Ebersole were seriously burned.

(10.) — A small boiler exploded, on January 5th, in Spencer & McNeil's meat market, at Walker, Minn. Job Spencer, one of the firm, was killed, and Lester McNeil and D. C. Spencer were painfully but not fatally injured.

(11.) — A heating boiler exploded, on January 5th, in the basement of the five-story brick building at 527 West Broadway, New York City. The boiler was directly under the office of the firm of Luigi Gandolfi Co., dealers in imported wines and fruits, and several members of the firm were in the office at the time. Nobody was seriously injured, however, although the office itself was wrecked.

(12.) — A heating boiler exploded, on January 6th, in William Bell's greenhouse, at Bay Side, L. I. Fire followed the explosion, and the total damage to the greenhouse and its contents was estimated at $8,000. We have not learned of any personal injuries.

(13.) — A boiler used to run the elevators in the Smith & Lansing icehouses, at Rensselaer, N. Y., exploded on January 9th. Frank Hitchcock, George Hitchcock, and Frank Wiltsie were badly but not fatally scalded. One side of the icehouse and part of the roof were blown away.

(14.) — A flue failed, on January 11th, in a boiler at the Electric Light & Power House, at Cedar Rapids, Iowa. Engineer Archibald Campbell and fireman William Miner were seriously injured.

(15.) — On January 11th a boiler exploded at the Kern River Oil Company's plant, at McKittrick, near Bakersfield, Cal. Frank Pickle, a pumper, was seriously injured about the eyes, and at last accounts it was thought that he would lose his sight. Two boiler houses were demolished, and débris was scattered about over a radius of 300 feet.

(16.) — The boiler of Southern Railway freight locomotive No. 805 exploded with great violence, on January 11th, at Franklin, Va. The locomotive and two freight cars were wrecked, and the track was littered with débris for some distance. The engineer and fireman appear to have had some warning of the impending accident, for they both jumped from the cab, and escaped without serious injuries.

(17.) — On January 11th a boiler exploded at the Kennan & Marsh mill, near Camp Twenty, Hartwick Township, Mich. L. L. Moyse, Edwin Powers, Glen Dalton, William Chase, Albert Veeder, and Matthew Bradley were killed, and William Wood, Adelbert Douglass, Horton Patton, and Philip Laske were injured. It was believed, at last accounts, that Douglass and Patton could not recover. The mill was blown to pieces, and fragments of it were thrown hundreds of feet from the original site.

(18.) — A heating boiler exploded, on January 12th, in the building occupied by the Hennebry Clothing Company, at Fort Dodge, Iowa. Nobody was injured, and the property loss was trifling.

(19.) — On January 12th a small boiler exploded in the feed yard of Martinez Brothers, at West Berkeley, Cal. H. S. Martinez was severely injured, and a barn was wrecked.

(20.) — On January 12th a boiler exploded on the Ohio Oil Company's lease, on the S. O. Ridenour farm, near Perry, Ohio. The power house was wrecked, and A. C. Crandall, a pumper, was severely injured.

(21.) — Two heating boilers exploded in quick succession, on January 13th, in the City Hall, at Bayonne, N. J. Nobody was seriously injured, but the building, which was valued at $40,000, was wrecked.

(22.) — The crown sheet of a boiler used for shredding corn failed, on January 14th, at Budd, near Streator, Ill. Nobody was injured.

(23.) — A boiler exploded, on January 14th, at the Big Muddy Coal & Coke Company's new shaft, at West Frankfort, Ill. Charles Fells was instantly killed, and John Seymour, James Nickerson, and Berryman Holland were seriously injured.

(24.) — The boiler of locomotive No. 337, of the Chicago, Hamilton & Dayton railroad, exploded, on January 14th, at Julietta, six miles east of Irvington, Ind. Engineer Charles Achey and fireman R. B. Barniclo were seriously injured, and brakeman John Rogers was also injured in a lesser degree.

(25.) — A locomotive boiler exploded, on January 14th, at Narcissus, near White Marsh, on the Trenton, N. J., cut-off of the Pennsylvania Railroad. Harry Hemphill, Harry P. Bowman, and Frank P. Harple were seriously and perhaps fatally injured.

(26.) — On January 15th the crown-sheet of locomotive No. 1147, of the Lehigh Valley Railroad, exploded near the Iron Pier at Syracuse, N. Y. Engineer George Mitchell and brakeman R. N. Weatherlow were instantly killed, and fireman Frank Heary was seriously and perhaps fatally scalded. The boiler of the locomotive was thrown clear of the trucks, and passed over two freight trains before it again struck the ground.

(27.) — A small boiler used for heating water exploded, on January 18th, in Adolphe Isselis' barber shop, at Fall River, Mass. Nobody was present at the time, and hence, although considerable damage was done, there were no personal injuries.

(28.) — A tube failed, on January 18th, in a boiler in the Grand street power house of the Public Service Corporation, at Jersey City, N. J. Nobody was injured, and the damage was confined to the boiler in which the bursted tube was situated.

(29.) — A heating boiler exploded, on January 18th, in the residence of S. Hirshburg, on Beacon street, Boston, Mass. The boiler passed up through three stories of the house, and tore a large opening in the roof. The dwelling was demolished, but there were no personal injuries, because nobody was in the house at the time.

(30.) — A boiler exploded, on January 18th, in S. E. Sullivan's sawmill, at James City, near Newbern, N. C. William Sparrow, Alexander Smithwick, Sidney Pritchard, George Blount, Samuel Neal, James Small, and Mary E. Small were instantly killed. The mill and its machinery were also demolished.

(31.) — A boiler exploded, on January 19th, on the oil lands of M. G. Zinn, near Parkersburg, W. Va. The boiler was thrown to a distance of 180 feet, but nobody was present at the time, and hence there are no personal injuries to record.

(32.) — A boiler exploded, on January 19th, in George J. Hummerle's sausage factory, on North Twenty-first street, Philadelphia, Pa. William Kiefer was killed.

(33.) — On January 19th a boiler exploded in the basement of the Hollenbeck Hotel, at Los Angeles, Cal. No great damage was done, but assistant night engineer E. H. Marshall was painfully burned.

(34.) — A boiler exploded, on January 20th, in the Downie Pump Company's plant, at Downieville, Butler County, Pa. J. P. Brenem and a man named Hayes were seriously injured. The property loss was not large.

(35.) — On January 21st a boiler exploded in a sawmill at Doolittle's Mills, Perry County, Ind. George Parmale received injuries which resulted in his death, and another employee was badly scalded, but not fatally so.

(36.) — A portable steam boiler which was used for thawing out frozen water pipes exploded, on January 23d, at Albany, N. Y., on Broadway, near Pine street.

(37.) — A small boiler used for heating purposes exploded, on January 25th, in the works of the Castner Electrolytic Alkali Company, on Buffalo avenue, Niagara Falls, N. Y. Earl W. Davies was struck by a fragment of the boiler, and almost instantly killed. Considerable damage was done to the room in which the boiler stood.

(38.) — A heating boiler exploded, on January 25th, in the City Hall, at Ann Arbor, Mich. The damage was small, and nobody was injured.

(39.) — Two hot water boilers exploded, on January 26th, in the Palace Hotel, at Crookston, N. D., shattering the walls, windows, and entire furnishing of that establishment's kitchen and serving room. Janitor Frank Delude was seriously injured, and night clerk Moffat was injured less seriously.

(40.) — A heating boiler exploded, on January 27th, in the Presbyterian Church, at Lyons, N. Y. Nobody was injured. The property loss was estimated at from $500 to $800.

(41.) — On January 28th a heating boiler exploded in the Central Methodist Episcopal Church, at Sault Ste. Marie, Mich. Fire followed the explosion, and the building, which was new and was valued at $30,000, was totally destroyed.

(42.) — The crown sheet of a traction engine failed, on January 28th, at the Wood County Infirmary, Bowling Green, Ohio. Philip Lecrom and Ensell Powell were badly injured.

(43.) — A boiler exploded, on January 28th, in the laundry room of a two-story flat building on South Springfield avenue, Chicago, Ill. Mme. H. L. Belisle, Ruth Belisle, Mrs. Malverá Rochelle, Mrs. G. A. Harris, and Florence Harris were injured. The building was damaged somewhat, but the property loss was not large.

(44.) — A slight boiler explosion occurred, on January 30th, at the plant of the Crystal Ice Company, Quincy, Ind. Robert Townsend and Thomas Riley were slightly injured.

(45.) — A boiler exploded, on January 31st, in the plant of the Wilmington Coal Washing Company, at Central City, near Joliet, Ill. Fireman John H. Green was burned about the face.

Boiler Explosions.

February, 1904

(46.) — On February 4th a boiler exploded in Julius Callahan's saw and grist mill, near Columbia, Ky. Della Heron was instantly killed, and a son of the owner of the plant was fatally injured. Mr. Callahan himself was thrown thirty feet or more, and seriously injured.

(47.) — A small cast-iron boiler exploded, on February 5th, at the plant of the East Hampton Bell Company, East Hampton, Conn. Nobody was injured, although a number of workmen were about the boiler at the time.

(48.) — A small boiler used for heating water in the bathing establishment of Charles Harris, on East Second street, New York, exploded, on February 6th, creating a panic, one of the features of which was the hasty appearance of some twenty undressed men on the public streets. Nobody was hurt, and the property loss was only about $300.

(49.) — By the failure of a valve on a boiler in a factory at Eighteenth and Halsted streets, Chicago, Cleveland Hilliard was injured so badly that he died in a short time.

(50.) — A tube failed, on February 8th, in the Eighth street power house of the Cincinnati Traction Company, at Cincinnati, Ohio. One fireman was painfully scalded.

(51.) — On February 9th a boiler exploded in Groves' lime kiln, near Frederick, Md. Isaac Steel was scalded to death, and the brick setting of the boiler was thrown down.

(52.) — A slight boiler explosion occurred, on February 9th, in the residence of G. C. Mansfield, at Johnson Creek, Jefferson County, Wis.

(53.) — On February 9th a boiler exploded in Carey Middleton's cotton gin, at Brent, some thirty miles south of Greenwood, Miss. One of Mr. Middleton's sons was killed, and another was very seriously injured. The shed under which the boiler stood was completely demolished, and a large fragment of wreckage passed through a vacant store some 200 or 300 yards away, making a clean hole some eight or ten feet square, completely through the building.

(54.) — The boiler of locomotive No. 25 of the Wiggins Ferry Company exploded, on February 9th, at Hall and North Market streets, St. Louis, Mo. Nobody was injured.

(55.) — A boiler exploded, on February 10th, in the Harrison Roller Mills, at Parkhill, near Stratford, Ont. Nobody was injured, but the boiler house was demolished, and a woolen mill near by was badly wrecked.

(56.) — On February 12th a small boiler used in connection with a coal chute exploded at Laurens, S. C. Nobody was injured. The boiler was thrown to a distance of 400 yards.

(57.) — A boiler used to operate an ore washer exploded, on February 13th, at Ironton, near Anniston, Ala. Mell Cotton and Roper Harris were injured so badly that they died within a day or so.

(58.) — A heating boiler exploded, on February 14th, in the Vaughan Hotel at Caribou, near Lewiston, Me. John Kayne, a porter, was injured, and the laundry and one room over the boiler were somewhat damaged. The property loss was estimated at $500.

(59.) — On February 15th a boiler exploded on the farm of James Slack, four miles southeast of Calhoun, near Clinton, Mo. An employee named Hayes was injured so badly that he died a few hours later.

(60.) — A boiler exploded, on February 15th, in Murray's coal yard, at Cohoes, N. Y. Jules Bishop was injured so badly that he died almost immediately, and fragments of the boiler were thrown to considerable distances.

(61.) — The boiler of a traction engine exploded, on February 16th, on Frank Taylor's farm, four miles east of Elmwood, near Farmington, Ill. William Short, Harland Nicholson, and W. Robbins were seriously injured. The boiler was in use, at the time of the explosion, for shelling corn.

(62.) — A slight boiler explosion occurred, on February 16th, in the Perth Amboy Terra Cotta Works, at Perth Amboy, N. J. Jorgen Hansen was severely scalded and burned. The damage to property was small.

(63.) — A boiler exploded, on February 16th, in Gibbs' mill, Ouchita Township, near Mount Ida, Ark. Mrs. Luana Whisenhunt was killed.

(64.) — A heating boiler exploded, on February 17th, in the barracks at Fort Trumbull, New London, Conn. The explosion occurred in the night, and several of the sleeping soldiers were slightly injured by the débris.

(65.) — On February 17th a boiler exploded in the basement of Kluss' harness shop, at Elkader, Iowa.

(66.) — A slight boiler explosion occurred, on February 18th, in the Chicago avenue pumping station, Chicago, Ill. Nobody was injured.

(67.) — On February 18th a small boiler exploded in James Bissell's bicycle repair shop, at Morton, N. Y. Mr. Bissell was seriously bruised and scalded.

(68.) — A boiler used for heating the tobacco warehouse of E. A. Fuller & Company exploded, on February 18th, at Suffield, Conn. No considerable damage was done, and nobody was injured.

(69.) — A small portable boiler, used for thawing frozen water pipes, exploded, on February 18th, in the American Hotel at Allentown, Pa. Nobody was injured.

(70.) — The creamery at Jacobs' Mills, Heidelberg Township, Pa., was wrecked, on February 21st, by the explosion of a boiler. Nobody was present at the time.

(71.) — The boiler of locomotive No. 2080 of the Pittsburg division of the Pennsylvania Railroad exploded, on February 22d, at Ehrenfeld, Pa. Harry Tyson, John Dontz, and George Britner were killed, and Robert Remorick and Elmer Furl were fatally injured. The wheels and truck of the locomotive did not leave the track, but the boiler was thrown ahead 180 feet.

(72.) — On February 23d the boiler of a locomotive on the Philadelphia & Erie Railroad exploded near Kane, Pa. Lewis Swatzer and John Mahey were killed, and John Jones was injured.

(73.) — A boiler exploded, on February 25th, at the plant of the Carnegie Steel Works, at Duquesne, Pa. Michael Dufee was fatally injured, and Michael Brosaw and John Brew were injured very seriously.

(74.) — On February 25th a boiler exploded in Krug's bakery and restaurant, at Dayton, Ohio. Nobody was injured. The property loss probably did not exceed a few hundred dollars.

(75.) — A flue failed, on February 25th, in a locomotive of the Western Maryland Railroad. We have not learned of any personal injuries.

(76.) — On February 27th a boiler exploded on C. H. Horne's plantation, near Jackson station, fifty miles from Augusta, Ga., on the Port Royal Railroad. Charles Williams was instantly killed, and Henry Ramsey and two other men were seriously injured.

(77.) — A hot water boiler exploded, on February 27th, in the residence of Joseph F. Appleton, on North street, Salem, Mass. Nobody was injured. The property loss was estimated at $1,000.

(78.) — A slight boiler explosion occurred, on February 27th, in the old plant of the Columbus Buggy Company, on North Front street, Columbus, Ohio. Fireman Theodore Artis was seriously injured.

(79.) — On February 27th a boiler exploded in the Waterloo Bending Works, Waterloo, Ind. Jacob Kohl was fatally scalded.

(80.) — A boiler exploded, on February 29th, near Drifton, Pa. Frank Dougherty, Simon Brute, Michael Treasch, and Spatsko Emory were injured.

MARCH, 1904.

(81.) — On March 1st the elbow of a blowoff pipe burst at the International Paper Company's plant, at Piercefield Falls, N. Y. Fireman D. Thompson was injured. The property loss was small.

(82.) — On March 2d Samuel Haldeman was instantly killed by the explosion of a boiler in a sawmill at Dimock, Pa. Nobody was injured, as the employees had just left off work for the day.

(83.) — By the explosion of a boiler in a sawmill at Greenwood, Monroe Township, Pa., on March 4th, P. L. Brown (the owner) and two employees named Wallace Tice and Robert Compton were instantly killed. The mill is said to have been totally wrecked.

(84.) — A tube burst, on March 5th, in a water-tube boiler at the Cleveland Stone Company's plant, North Amherst, Ohio. Bohmer Istman was injured. The property loss was not serious.

(85.) — A small boiler used for thawing out frozen water pipes exploded, on March 5th, at Dunton, near Jamaica, L. I. Peter Smith and John Lucas were seriously injured, and at last accounts it was thought that the former would lose his eyesight.

(86.) — On March 8th a tube failed in a water-tube boiler at the Inland Steel Company's plant, Indiana Harbor, Ind. Peter Operis was injured.

(87.) — At the plant of the Ohio Tool Company, Columbus, Ohio, the blowoff pipe of a boiler failed near the rear head, on March 9th. Nobody was injured, but the property loss was considerable.

(88.) — On March 9th a slight boiler explosion occurred at the Cook & Brady creamery, Centerville, Md. The property loss was small.

(89.) — The header of a water-tube boiler failed, on March 9th, in the Shenango Valley Steel Works of the Carnegie Steel Company, at Newcastle, Pa. The property loss was small.

(90.) — A hot water tank exploded, on March 10th, in the Jewish synagogue of Chesed Shel Emeth, at Boston, Mass. The ground floor of the building was almost totally wrecked. The property loss was estimated at $1,500.

(91.) — Julius Wolfe, Charles Setter, and Henry Drailly were severely scalded, on March 11th, by the explosion of a steam main in the Thirty-ninth street power house of the Brooklyn Rapid Transit Company, Brooklyn, N. Y.

(92.) — A boiler exploded, on March 11th, in a sawmill near Rochester, Ky., about fifteen miles from Morgantown. Elsa Thompson was thrown about forty feet, and terribly scalded and otherwise injured, so that he died about six hours after the accident.

(93.) — On March 12th a boiler, refitted from an old traction engine, exploded in C. B. Davis' blacksmith shop, at Dana, Ind. C. B. Davis, Jefferson Harper, and Jonas Hanaby were seriously scalded, and the shop was destroyed.

(94.) — A boiler exploded, on March 15th, in Alexander Ford's sawmill, at Knoxville, Tenn. Newman Johnson was badly scalded, and Taylor Ford had an arm broken.

(95.) — A tube failed, on March 16th, in a water-tube boiler at the Homer street plant of the Newton & Boston Street Railway Company, Newtonville, Mass. Nobody was injured, and the property loss was small.

(96.) — On March 17th a slight boiler explosion occurred in the Chicago Home for Incurables, at Chicago, Ill. Nobody was injured. The property loss was estimated at from $500 to $600.

(97.) — A slight explosion occurred, on March 17th, in Sheuerman Bros.' woolen mill, at Des Moines, Iowa. Fireman Augustus Toepfer was killed. The accident consisted in the failure of the blowoff pipe.

(98.) — By the explosion of a boiler, on March 18th, in a grist mill at Edinburgh, Mo., Isaac Winningham was killed, and S. B. Endicott, W. B. Welsh, Reilly Gentry, and two other men named Doyle and Gillespie were seriously injured. Wilbur Robertson also received lesser injuries.

(99.) — A boiler exploded during a fire, on March 18th, in the plant of the Herndon Lumber Company, at Herndon, Va. Large plate glass windows were broken in stores several hundred yards away, but nobody was injured.

(100.) — A boiler exploded, on March 18th, in a sawmill near Harrisburg, Ark. John Gant, the owner of the mill, was killed.

(101.) — On March 18th a heating boiler exploded in the Ladies' Literary Club building, at Grand Rapids, Mich. The boiler was completely wrecked, but the damage to the building was trifling. Nobody was injured.

(102.) — The dome of a boiler exploded, on March 19th, in the plant of the Leonard Wagon Material Company, at Brookport, Ill. Nobody was injured, but the building was partially wrecked.

(103.) — An 18-inch steam main exploded, on March 20th, in the plant of the John A. Roebling Sons Company, at Trenton, N. J. Andrew Petro was fatally injured, and Stephen Sabo, John Wargo, Andrew Gill, and three other men whose names we have not learned were injured seriously but not fatally. (This steam main was connected to sixteen boilers, eleven of which were under steam at the time. None of the boilers was moved from its setting.)

(104.) — A slight boiler explosion occurred, on March 21st, at Riverhead, L. I. A traction engine was being hauled through the streets behind a wagon, when one of its tubes failed. Nobody was injured, and the property loss was small.

(105.) — At Bowling Green, Ky., a small boiler exploded in a barber shop, on March 22, while the place was full of customers. Nobody was injured.

(106.) — A slight boiler explosion occurred at the Denison shops of the Panhandle Railroad, at Ulrichsville, Ohio, on March 22d, a plug being blown out of the boiler of a locomotive. Richard Morgan was killed, N. C. Smith was fatally scalded, and George Rhoads was scalded badly but not fatally.

(107.) — A header of a water-tube boiler ruptured, on March 22d, in the Thirteenth and Mount Vernon street power house of the Philadelphia Rapid Transit Company, Philadelphia, Pa. The loss was small, and we have not learned of any personal injuries.

(108.) — A tube failed, on March 23d, in the plant of the Norfolk Cold Storage Company, at Norfolk, Va. Nobody was injured, and the property loss was small.

(109.) — A digester, used for reducing garbage, exploded, on March 23d, in the plant of the New England Sanitary Product Company, on Spectacle Island, Boston, Mass. The roof of the building was wrecked. Patrick Burnes, John Byrne, and John Dolan were injured. The digester was found about 1,000 feet away from its original position.

(110.) — The boiler of locomotive No. 1108 of the Lehigh Valley Railroad exploded, on March 23d, near Wende, N. Y. Engineer Thomas Finkler was killed, and fireman Elmer Osgood was injured so seriously that he died shortly afterwards. Daniel Gorom also received lesser injuries.

(111.) — A boiler exploded, on March 24th, in the plant of the Sunset Brick & Tile Company, at Santa Monica, Cal. Engineer Charles E. Thomas was injured. The boiler was destroyed, and the walls of the engine room were badly shattered.

(112.) — A slight boiler explosion occurred, on March 24th, at the plant of the Star Lubricating Oil Company, Cleveland, Ohio. Nobody was injured.

(113.) — A tube ruptured, on March 25th, in a water-tube boiler at the plant of the American Sugar Refining Company, at Jersey City, N. J. Nobody was injured.

(114.) — On March 25th a boiler exploded in O. T. Kilby's sawmill, at Barton Landing, Vt. The boiler house was demolished, and the main building greatly damaged. Nobody was injured, as the employees were all at dinner at the time of the accident.

(115.) — A boiler exploded, on March 26th, in the works of the Stadacona Oil Company, at Canon City, Colo. We have not received further particulars.

(116.) — A heating boiler exploded, on March 27th, in the Milan Public School building, at Milan, Ohio. The damage was small, and nobody was in the building at the time.

(117.) — A main stop valve, next to one of the boilers of the Phœnix Powder Company, ruptured, on March 28th, at Phœnixville, Ill. The property loss was trifling, and nobody was injured.

April, 1904.

(118.) — The boiler of a freight locomotive exploded, on April 2d, on the Southern Railway, near Amherst, Va. Engineer Joshua Beasley, fireman J. J. Willard, and front brakeman Thomas E. Hamm were badly scalded.

(119.) — On April 4th a boiler exploded in the Erickson flouring mill, at Albert Lea, Minn. Engineer Christopher Rood was instantly killed. The side of the building was blown out, and parts of it were hurled to a considerable distance, some of them striking an Illinois Central Railway car and almost completely ruining it. Several small buildings in the vicinity were more or less shattered.

(120.) — The boiler of a freight locomotive exploded, on April 4th, at Junction City, Ia., on the Arkansas Southern Railroad. Fireman Brown was instantly killed, and engineer Labrey was seriously injured.

(121.) — A boiler exploded, on April 5th, in the Masonic Fraternity Temple Association building, at Chicago, Ill. Lawrence Peterson was injured. The property loss was small.

(122.) — On April 5th a boiler exploded in J. J. Evans' sawmill, on Little Clear Creek, eleven miles from Pineville, Ky. Sillous Evans was fatally injured, and Mrs. K. T. Evans, who happened to be near, was injured seriously. Several other persons also received minor injuries. The mill and a neighboring grocery store were completely wrecked.

(123.) — A tube burst, on April 7th, in a water-tube boiler in the Central Power Station of the Brooklyn Heights R. R. Co., Brooklyn, N. Y. Fireman Daniel Flynn was badly scalded.

(124.) — The boiler of a narrow gauge locomotive exploded, on April 7th, in the yards of the Duquesne blast furnaces, Duquesne, Pa. Engineer Joseph Richards was seriously injured.

(125.) — The boiler of a Baltimore & Ohio locomotive exploded, on April 8th, near Marriottsville, Md., seriously injuring the conductor, the engineer, the fireman, and two brakemen.

(126.) — A tube exploded, on April 10th, in a water-tube boiler in the plant of the Merchants' Heat & Light Company, Indianapolis, Ind. Nobody was injured, and the property loss was trifling. (See No. 128, below.)

(127.) — An elbow on a large steam main ruptured, on April 12th, in the Columbus Iron & Steel Company's plant, at Columbus, Ohio, wrecking the settings of five vertical water-tube boilers. Nobody was injured.

(128.) — On April 13th a tube exploded in a water-tube boiler at the Merchants' Heat & Light Company's plant, Indianapolis, Ind. Nobody was injured. (This explosion is distinct from No. 126, which occurred at the same place a few days before.)

(129.) — The boiler of locomotive No. 471 of the Atchison, Topeka & Santa Fé Railroad exploded, on April 13th, at Florence, Kan. Fireman Hauhn was killed, and engineer Moody was injured so badly that he died shortly afterwards. The boiler of the locomotive was completely demolished.

(130.) — A boiler exploded, on April 15th, in Harris & Fuqua's heading establishment, at Milan, Tenn. Fortunately nobody was injured, but considerable damage was done to the building.

(131.) — The boiler used for operating the large peanut roaster in the Olympia Confectionery, at Minneapolis, Minn., exploded on April 18th. Nicholas Ronner was slightly injured by flying glass. The roaster was completely wrecked.

(132.) — A tube ruptured, on April 18th, in a water-tube boiler at the plant of the Star Furnace Company, Jackson, Ohio.

(133.) — A slight boiler explosion occurred, on April 19th, at the waterworks and electric light plant of the village of East Norwood, Ohio. The property loss was small, and nobody was injured.

(134.) — A header of a safety boiler exploded, on April 19th, at the Market street station of the Pennsylvania Railroad, Newark, N. J. Lee H. Griggs, the engineer in charge, was seriously scalded. Several of the other headers were badly damaged, and the brickwork of the setting and part of the wall of the building were wrecked.

(135.) — On April 21st a slight boiler explosion occurred in the waterworks at Traverse City, Mich.

(136.) — A boiler exploded, on April 25th, in the sawmill of Frank Hammes, near Pound, Wis. The boiler was completely wrecked, as was also a mud drum attached to a boiler beside the exploded one. Fragments of the wreckage were thrown hundreds of feet away, the boiler house and part of the mill being demolished. William Squires was killed, and Charles Kasakoski and Frank Scheuren were injured.

(137.) — A tube exploded, on April 25th, in a safety boiler in the Pennsylvania Railroad ferryboat *St. Louis*, on the Cortland street line, New York City. William Kindeville and William Blackburn were badly scalded.

(138.) — On April 27th there was a slight explosion of the boiler of shifting locomotive No. 1134 of the Baltimore & Ohio Railroad in the yards of the National Tube Works, at McKeesport, Pa. No one was injured.

(139.) — The boiler of a steam drill belonging to William Caudill exploded, on April 27th, at Flat Gap, Johnson County, Ky. M. M. Woodward and Charles Pritchard, the operators of the drill, were blown some distance and fatally injured.

(140.) — On April 27th a boiler exploded in I. E. Fisk's stave mill, at Bluehill, Me., completely wrecking the plant. Otis Gray, Jr., a Mr. Young, and two other employees, whose names we have not learned, were slightly injured.

(141.) — The boiler of freight locomotive No. 2220 of the Baltimore & Ohio Railroad exploded, on April 27th, at Braddock, Pa. Frederick I. Daegle was injured so badly that he died within a short time. M. A. Hunter, I. J. Zorn, Harry Dowling, Warren Dowling, and George Bordock were seriously injured, and Miss Loretta Dowling and Miss Sadie Dowling were cut about the body and limbs. The explosion was a very violent one, wrecking five buildings and causing a large property loss.

(142.) — A small copper boiler, used for operating a peanut roaster, exploded, on April 27th, in front of a confectionery store at Winona, Minn. The property loss was estimated at from $900 to $1,300. Nobody was injured, although there were numerous narrow escapes.

(143.) — The flouring mill of David Gault, situated between Cooperdale and West Carlisle, Ohio, was entirely destroyed, on April 28th, by the explosion of a boiler. Fortunately all the employees were at dinner at the time, so that nobody was injured.

(144.) — On April 30th the boiler of a Reading locomotive exploded near Gwynedd, Pa. Fireman Morris Heil was severely scalded about the face, arms, and body.

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(145.) — A double explosion occurred, on May 3d, in a quarry operated by the New England Lime Company, at Canaan, Conn. A tube collapsed in a boiler, and the shock exploded a box of dynamite which had been left in the boiler house over night. The main thing left behind after the explosion was a goodly sized hole in the ground.

(146.) — A boiler exploded, on May 4th, on the scow *Thomas E. Jennings,* owned by the Postal Telegraph Company, opposite Liberty Island, New York Harbor, while the scow was being towed by the tug *Seven Brothers.* James Colligan, Oscar Johnson, William O'Doherty, and Otto Kanz were badly scalded and otherwise injured.

(147.) — The crown sheet of locomotive No. 2159 of the Philadelphia division of the Pennsylvania Railroad failed, on May 6th, at Ship Road, some twenty-six miles west of Philadelphia, Pa. Brakeman R. G. Bowman was fatally injured, and fireman A. C. Wilkes was injured seriously but not fatally.

(148.) — The boiler of locomotive No. 508 of the Denver & Rio Grande Railroad exploded, on May 8th, near Colorado Springs, Colo. Engineer T. V. McOsker and fireman Thomas Weston were seriously injured.

(149.) — The boiler of a shingle mill exploded, on May 9th, near Martickville, Pa. Nobody was injured.

(150.) — On May 9th the boiler of a locomotive exploded on the Philadelphia, Baltimore & Washington Railroad, at Halethorpe, Md. Engineer Andrew J. Williams was injured so badly that he died while being taken to the hospital, and fireman Claud W. Carter sustained serious injuries from which, at last accounts, it was thought that he could not recover.

(151.) — On May 10th a boiler exploded at the Gate City Rolling Mills, Birmingham, Ala. Nobody was injured.

(152.) — On May 11th a boiler furnishing steam for making paste exploded at the plant of the American Bill Posting Company, Scranton, Pa. John Schultz, a boy of 15 years, was instantly killed.

(153.) — A boiler exploded, on May 11th, in Joseph Doll's bakery, at Portsmouth, Ohio. Nobody was injured.

(154.) — On May 14th a water-tube boiler exploded at a Bridgeport plant of the United Illuminating Company, causing considerable damage, and slightly injuring engineer Daniel J. Stokes.

(155.) — A locomotive boiler exploded, on May 15th, on the Santa Fé Railroad, near Bagdad, Cal. Engineer S. Ebbutt received injuries from which he died shortly afterwards. Fireman J. F. Showalter also received minor injuries.

(156.) — The cast-iron mud drum of a water-tube boiler exploded, on May 16th, at the Braddock, Pa., works of the American Steel & Wire Company. John Harshrick, Andrew Ivan, John Whalen, and Edward Welch were injured, and there was also a considerable property damage.

(157.) — A tube exploded, on May 16th, in the cement mill of the Alpha Portland Cement Company, at Alpha, N. J. Julius Vargai was severely scalded.

(158.) — A slight boiler explosion occurred, on May 16th, at the Wynn works of the H. C. Frick Coke Company, Georges Township, Pa. Nobody was injured.

(159.) — A boiler used by the Standard Oil Company in drilling an oil well exploded, on May 17th, on the Scott farm, near Hartford City, Ind. Wilson Pierce was injured so badly that at last accounts it was believed that he could not recover.

(160.) — On May 23d the boiler of a locomotive belonging to the Reading Railroad exploded near Pottstown, Pa. David Martin, a fireman, was fatally injured, and George Beard, a road foreman of engines, was injured so badly that at last accounts it was doubtful if he could recover.

(161.) — On May 26th the boilers of the Ohio River steamboat *Fred Wilson* exploded with great violence near Riverview Park, Louisville, Ky. The boat was destroyed, and sank. Joseph Price, William Quinn, Albert Miller, Sherman Shibler, Joseph Warren, William Thornton, W. A. Holland, Hugh Hoskins, J. C. Johnson, and Patrick White were killed, and Gabriel Letzicouch was injured so badly that he died soon afterwards. Carl Cody, William M. Timmons, John Miller, William Miller, Albert E. Stewart, Mrs. Emma Williamson, Joseph Chadwick, Orville Bates, George Morrow, Frank Knight, Daniel Hall, John Jones, Peter Kinnel, Frank Higgin, and Thomas Dowadenny were also injured.

(162) — Three of the cast-iron headers on No. 2 water-tube boiler of the California Vigorit Power Works burst, on May 27th, at Point Isabel, Cal. The engineer and fireman fortunately escaped, and nobody was injured.

(163.) — A boiler located at the Newsam mine, at Kingston, Ill., exploded on May 28th. There was considerable property damage, but no personal injuries.

We tender our most sincere apologies to our excellent contemporary, *Marine Engineering;* for in the April issue of The Locomotive we printed, without credit, an article from that journal entitled "The Manufacture of Seamless Cold-Drawn Steel Boiler Tubes." The credit (as we hardly need to state) was omitted by accident.

Inspectors' Reports for January, February, March, and April, 1904.

Nature of Defects.	January.		February.		March.		April.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment, .	1,210	45	875	41	1,280	57	1,671	97
Cases of incrustation and scale,	3,188	70	2,730	57	3,406	92	3,938	100
Cases of internal grooving, .	173	15	152	10	174	15	256	18
Cases of internal corrosion, .	783	31	676	30	847	48	1,146	163
Cases of external corrosion, .	661	31	570	36	837	53	942	75
Defective braces and stays, .	141	50	107	77	220	85	227	74
Settings defective, . . .	379	25	203	20	381	20	462	45
Furnaces out of shape, . .	468	17	341	13	454	17	551	35
Fractured plates, . . .	357	63	312	46	291	50	300	49
Burned plates, ...	418	62	478	42	423	50	485	54
Blistered plates, . . .	64	3	41	6	72	6	80	4
Cases of defective riveting, .	178	46	261	63	244	87	237	52
Defective heads, . . .	42	6	53	15	82	15	108	13
Leakage around tubes, . .	1,641	503	1,320	195	1,085	197	1,059	107
Leakage at joints, . . .	531	18	488	24	486	25	430	21
Water-gauges defective, . .	363	53	315	47	288	36	333	67
Blow-offs defective, . . .	204	75	260	53	354	85	350	118
Cases of deficiency of water, .	16	7	19	10	14	6	24	11
Safety-valves overloaded, .	115	27	66	16	95	30	105	45
Safety-valves defective, . .	111	17	99	33	92	23	126	41
Pressure gauges defective, .	387	20	381	25	519	31	614	46
Boilers without pressure gauges,	103	103	7	7	16	16	14	14
Unclassified defects, . . .	0	0	10	2	0	0	0	0
Totals, ...	11,623	1,287	9,953	868	11,660	1,044	13,458	1,249

Inspector's Reports.

On page 66 we present a general summary, by defects, of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company, during the months of January, February, March, and April, 1904. We also give, below, a summary of these months, showing the number of visits of inspection made, the total number of boilers examined, the total number inspected internally, the number tested by hydrostatic pressure, and the number of boilers condemned.

	Month (1904).			
	January.	February.	March.	April.
Visits of inspection,	13,618	11,807	13,559	12,616
Total number of boilers examined,	26,261	23,314	25,262	21,645
Number inspected internally,	8,384	6,689	9,069	11,597
Number of hydrostatic tests,	577	684	990	946
Number of boilers condemned,	72	73	78	93

Lord Ross and the Boiler.

Here is a little story from the *Louisville Courier-Journal*, which, we take it, is intended to pay Lord Ross [Lord Rosse?] the doubtful compliment of demonstrating that he knows something about steam boilers. We call it a "doubtful compliment" because the point of every story of this character appears to lie in the element of surprise at the end, when it is discovered that the titled personage really did have some practical knowledge, although one wouldn't have supposed it, in advance! Anyhow, here is the story:

"They had been talking about Englishmen of title who took up useful work. Somebody mentioned Lord Ross, who is a good practical engineer, and then somebody else told this story: Lord Ross having once — unknown to the employees — entered the engine room of a large manufactory, the attention of the engineer was attracted by his odd behavior. 'Well, what's up now?' he growled to the peer; 'what are you shaking your head and pulling out your watch for? What have you got to find fault with?' 'Oh!' replied his lordship, 'it is all the same to me. I have no fault to find. I am just waiting till the boiler explodes.'

"'The boiler explodes? Why, man, you are crazy,' exclaimed the engineer angrily, preparing to turn the peer out as a dangerous crank. 'Well,' retorted the earl, 'if you work ten minutes longer with that screw loose there, the boiler will certainly explode.'

"The engineer, gazing in the direction indicated, paled and jumped to stop the engine. 'Why didn't you say so sooner?' he blurted out. 'Why should I?' asked the peer; 'I have never yet had an opportunity of seeing a boiler explode.'"

We have thought long and hard over this story, and have tried to cipher out what the screw was whose looseness would have brought about the destruction of the boiler with such positiveness, and at the end of so definite a time. We haven't had any luck at it, yet, and we are now powerfully inclined to the belief that the screw that was loose was about the person of his lordship, or else about the man who got this story up; and we have a most particular suspicion that it wasn't about his lordship.

The Locomotive.

Founded by J. M. Allen, A.M., M.E.

HARTFORD, JULY 15, 1904.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each. (Any volume can be supplied.)

Staybolt Iron.

The high pressure and large boilers now used have increased the breakages of staybolts, and have given rise to many devices for overcoming the difficulty. The two principal difficulties are: (1) leakage, (2) breakage. Breakages are caused by the vibration due to unequal expansion of the inside and outside sheets. The object of flexible staybolts is to provide for the vibration. Such staybolts have not proved altogether satisfactory for the reason that with incrusting waters the ball joint becomes filled with scale and becomes rigid. They are also expensive to apply and to maintain, and usually give more trouble from leakage than the ordinary staybolt because the thread in the firebox side is apt to be stripped in driving, inasmuch as there is less support for holding on, and also because of the tendency to drive them when in service without taking off the caps so as to enable the workman to hold on to the bolt.

Designers have been trying to reduce failures by increasing the length of the bolts and by decreasing their diameter. There are several reasons why a ⅞-in. bolt should last longer than the 1-in. bolt, notwithstanding the fact that it has a smaller area. Staybolts are not loaded to a definite fiber stress (in which case the bolt of larger diameter would be the more serviceable), but they are deflected through a given angle, and the amount to which they are deflected cannot be altered by any increase in strength or in diameter. Inasmuch as the angle through which the bolt is bent is independent of the diameter of the bolt, the outer fiber of the smaller bolts is strained less, and a crack will start sooner in the 1-in. bolt than in the ⅞-in. bolt. The time between the starting of the crack and the breakage of the bolt will be greater for bolts of large diameter than for bolts of small diameter. However, the bolt which remains in service the shortest time after a crack is started is the more desirable bolt, for after it is cracked, the sooner it is removed the better.

A cable composed of a large number of strands will bend and twist many times without breaking, although the tensile strength is very much less than the strength of a solid bar of the same diameter. The nearer we approach to this condition in boiler design the less trouble we will have. Boilers have been built with bolts of ¾-in. diameter, but the bolts were spaced more closely than is usually the practice.

Small bolts also have an advantage in heading, for the hard hammering necessary to head a bolt of large diameter or of hard iron is liable to strip the thread of the bolt. Bolts of small diameter will not require heavy hammering and will therefore probably give less trouble from leakage than bolts of large diameter. Furthermore, the head of the bolt of small diameter would not be heated to as high a temperature as the bolt of large diameter, because it is more readily cooled by the water, and hence it would not expand as much. When the metal in the bolt expands it enlarges the hole in the sheet and puts a permanent set in the sheet and thus causes leakage. Another advantage in the use of bolts of small diameter is that they can be replaced many times without greatly increasing the diameter. The life of the firebox would thus be increased. The future will probably see the more general use of ¾-in. bolts with closer spacing. The present practice of using a ⅞-in. bolt is a compromise between the most advanced and most conservative practice. An analysis of the stress in staybolts shows that the extent to which the bolt is strained increases in direct proportion to the diameter and decreases as the square of the distance between the sheets. Assuming as a basis a staybolt 1 in. in diameter and deflected .03 in. and a distance between sheets of 6 in., we find that the bolt has a fiber stress of 35,000 lbs. per sq. in. If the diameter is reduced to ¾ in. the staybolt is strained to but 26,250 lbs. By decreasing the distance between the sheets to 5 in. the bolts are strained to 50,400 lbs. for the 1-in. bolt, and 37,700 lbs. for the ¾-in. bolt. These results show very clearly the cause of staybolt breakage and what should be done in order to reduce the trouble to a minimum, namely make the water space as wide as possible, and use a small bolt with a closer space if necessary.

A few railroads have recently specified very high tensile strength for staybolt iron. The question arises, is the tensile test a proper one upon which to rate staybolt iron? If a member is subjected to a direct tensional strain or a definite load a high tensile strength or elastic limit is desirable because it gives a high factor of safety. If, however, a member is subjected to a definite deflection, then the stiffer the iron the greater the load necessary to produce this deflection. In other words, a bolt of high tensile strength is subjected to a higher fiber stress than a soft bolt of low tensile strength. It is for this reason that steel gives excellent results in axles, etc., which are loaded to a definite fiber stress, but it will not answer for staybolts which are bent through a given angle. The manner in which the iron is piled and rolled plays a far more important part in the life of the bolt than the tensile strength, and after many experiments, those who have given the subject thought have decided upon a fagotted bar-piled iron. The central core is composed of a number of bars, approaching in appearance a bundle of wires. This core is enclosed by an outside sheath of metal with circular fibers. This insures a good thread and prevents the bolt being strained in a direction at right angles to the fibers. A soft ductile iron piled in this way undoubtedly gives better results than a hard iron of high tensile strength piled in the usual slab form. Staybolt iron made in this manner may be strained by bending in a direction at right angles to the fibers, and it would then have a very low life.

This subject has been thoroughly demonstrated by making vibratory tests of various makes of staybolt iron, and the results obtained in the vibratory machine have been confirmed by practice. The writer's attention has recently been directed to a marked difference in the life of staybolts on two groups of engines of precisely the same design and in operation on the same division. Upon investigation it was found that a very high-priced special brand of high tensile strength staybolt iron was used in the engines which gave trouble, while a good grade of well piled soft and ductile iron was used in the engines which were giving good service. The requirements specified by a number of roads in this country follow:

Railroad.	Tensile Strength.	Elongation, Per Cent.
Atchison, Topeka & Santa Fe,	48,000 lbs.	28 % in 8 in.
Baltimore & Ohio,	48,000 "	25 " " 8 "
Chesapeake & Ohio,	48,000 "	25 " " 2 "
Burlington & Missouri River,	48,000 "	30 " " 2 "
Chicago, Burlington & Quincy,	49,000 "	28 " " 8 "
Lehigh Valley,	50,000 "	30 " " 4 "
Missouri Pacific,	47,000 "	26 " " 8 "
Mexican Central,	48,000 "	25 " " 8 "
New York Central,	48,000 "	28 " " 8 "
Norfolk & Western,	48,000 "	25 " " 8 "
Pennsylvania,	48,000 "	25 " " 8 "
Philadelphia & Reading,	46,000 "	45 " " 2 "
Seaboard Air Line,	48,000 "	25 " " 8 "
Southern,	52,000 "	28 " " 8 "
Harriman associated lines,	52,000 "	28 " " 8 "

It is almost universal practice to specify 48,000 lbs. tensile strength, it being generally realized that an iron is thus secured which is strong, which will take a good head without hammering enough to strip the thread, and which will withstand the alternate bending.

A staybolt should be tested in a manner similar to which it is strained in service. Some years ago this matter was thoroughly agitated, and a large number of experiments were made with makeshift apparatus. The results varied widely, largely because of the different methods of holding the bolt, and because the bolts were vibrated in one plane. Very good results would be obtained if the bolt was vibrated in a plane parallel to the direction of piling, while very poor results would follow if it were vibrated at right angles thereto. A machine has been designed to record the number of vibrations of a given amplitude which a test bar will withstand. It is especially adapted to the requirements of staybolt testing, and will hold staybolts from 3 inches to 8 inches long. The upper end is held rigidly while the lower end is given a circular vibratory motion, which can be adjusted from zero to a circle of 3/8 in. in diameter. — Abstract of a paper by H. V. Wille, read at the Atlantic City meeting of the American Society for Testing Materials, as given in the *Railroad Gazette*.

The Coefficients of Expansion of Gases.

An accurate knowledge of the coefficients of expansion of air and certain of the other so-called "permanent gases" is of the highest importance in certain physical investigations, and especially in connection with accurate thermometry. The "gas thermometer" is the standard in all modern precise thermometry, and although mercury thermometers are greatly used on account of their practical convenience, their readings are supposed to be reduced to the scale of the gas thermometer. For many years engineers and physicists relied almost absolutely for their knowledge of the coefficients of expansion of gases upon the measures made by Regnault; but at the present time numerous other determinations of great value have been made, so that it is no longer permissible to adopt Regnault's results to the exclusion of all others. The writer of this article has had occasion to make a critical comparison of all the data that are available with regard to the coefficients of expansion of gases, and the results of his investigations are given below.

We have to distinguish, in general, between the "coefficient of expansion at constant volume" and the "coefficient of expansion at constant pressure." The difference between these two coefficients may be explained, briefly, as follows: Suppose, first, that the gas under consideration is subjected to a definite pressure, at the freezing point of water, its volume under these circumstances being carefully measured. If we now heat the gas up to the boiling point of water, we shall find that it is impossible to do so without permitting a simultaneous increase either in the volume, or in the pressure, or in both. If we raise the temperature of the gas from the freezing point to the boiling point of water while keeping the pressure constant, we shall find that the volume increases by a considerable amount; and if we divide the increase of volume so observed by the original volume at the freezing point, and then divide again by the number of degrees of temperature between the freezing and boiling points (i. e., 100° on the centigrade scale, or 180° on the Fahrenheit scale), we shall obtain the "coefficient of expansion" of the gas, at the given constant pressure. If, in heating the gas from the freezing point to the boiling point, we had kept the *volume* of the gas rigorously constant, there would be no real "expansion" at all, though there would be a substantial increase in the pressure of the gas. It is customary, however, in spite of the fact that there is no real expansion at all, to speak, under these circumstances, of the "expansion of the gas at constant volume," although it would be much more exact to speak of its "increase of elastic pressure at constant volume." Following the customary phraseology, however, let us suppose that the gas, originally at the freezing point, and at some known pressure and volume, is heated to the boiling point, while keeping the volume rigorously constant. The pressure will thereby be materially increased; and if we divide the increase in pressure by the original pressure at the freezing point, and again by the number of degrees between the freezing and boiling points, we shall obtain what is called the "coefficient of expansion" of the gas "at constant volume"; — that is, at the constant volume at which the increase of pressure has taken place.

The coefficients of expansion, both at constant volume and at constant pressure, have been made the subject of many careful experimental investigations. In what follows, only the best of the data so obtained will be considered, since it would be a difficult and unfruitful task to consider all of the determinations that have been made, without regard to their probable value, as inferred from a general knowledge of the methods employed by the observers, and the precautions taken to ensure accuracy.

The coefficient of expansion of hydrogen gas, at constant volume, has been determined with high precision by Chappuis, of the International Bureau of Weights and Measures, at Sèvres, France, and his results are without doubt the best that have thus far been obtained. In the sixth volume of the Travaux et Mémoires of the International Bureau he gives seven determinations of the coefficient at constant volume, the mean of which is 0.00366253, if we adopt the centigrade scale of temperature (as we shall do throughout this article). Any coefficient on the Fahrenheit scale may be found easily enough by dividing the corresponding coefficient on the centigrade scale by 1.8, there being 180 degrees between the freezing and boiling points on the Fahrenheit scale, instead of 100 degrees, as on the centigrade scale. The seven determinations whose mean value is given above were made with the hydrogen enclosed in a reservoir of platin-iridium. A subsequent series, made with the hydrogen enclosed in a reservoir of French hard glass ("verre dur"), whose coefficient of expansion had been previously determined with the greatest care, gave 0.00366217 as the value of the foregoing coefficient. (Rapports présentés au Congrès International de Physique, vol. 1, p. 133.) Taking the mean of these two independent determinations, we have, as the concluded value of the coefficient of expansion of hydrogen gas at constant volume, and with an initial pressure corresponding to that due to 1,000 millimeters of ice-cold mercury at sea-level in latitude 45°, the number 0.0036624; the eighth place of decimals being rejected, as of no value.

For the coefficient of expansion of hydrogen at a constant pressure of 1,000 millimeters of ice-cold mercury at sea-level in latitude 45°, Chappuis gives (Rapports, vol. 1, p. 133) the value 0.0036600. (It may be well to say, once for all, that when the International Bureau authorities speak of the pressure due to a certain number of millimeters of mercury, it is invariably understood that the conditions are as here stated. That is, the mercury is invariably understood to be ice-cold, and the place of the experiment is understood to be at sea-level in latitude 45°.)

Passing now to the coefficient of expansion of nitrogen, we find that Chappuis gives several values, based on as many different sets of experiments. In the Travaux et Mémoires, vol. 6, p. 64, he gives for the coefficient of expansion of nitrogen at constant volume and an initial pressure of 995.9 millimeters of mercury, the value 0.00367466. In a subsequent series of experiments on nitrogen at constant volume, and for an initial pressure of approximately 1,000 millimeters (Procès-Verbaux for 1888, p. 26), he found 0.00367442 as the coefficient. In the Rapports, above referred to, he takes the mean of these two general results,— namely, 0.0036745 — as the definitive value of the coefficient of expansion of nitrogen at constant volume, for an initial pressure of approximately 1,000 millimeters of mercury. The averaging of the two coefficients is logical enough, even though they do refer to slightly different initial pressures; for the coefficient does not vary greatly with the initial pressure, unless the difference in that pressure is very large. In quoting the value of 0.00367466 for the coefficient of nitrogen, however, Chappuis in one place states that it is for an initial pressure of 1387 millimeters of mercury; and it may be well to state that this is a mistake, the true initial pressure for which this determination was made being 1,000 millimeters.

In a joint paper with J. A. Harker, entitled "A Comparison of Platinum and Gas Thermometers, etc." (Phil. Trans., 1900 A, vol. 194, p. 37), Chappuis gives the coefficient of expansion of nitrogen at constant volume, for an initial pressure of 793.5 millimeters of mercury, as 0.00367180; this being the mean of four determinations. In the same paper five values are also given for this coefficient for an initial pressure of 532.9 millimeters, and thirteen for an initial pressure of about 528.8 millimeters. The initial pressures are here so nearly equal that, if we choose, we may combine the results as though they were all made at the mean initial pressure 530.8 millimeters. The mean of the eighteen determinations, under these conditions, is 0.00366821. In the joint paper with Harker a series of twelve determinations of the nitrogen coefficient at constant volume was also made for an initial pressure of 391.9 millimeters of mercury, the resulting value of the coefficient being 0.00366771. The authors refer to this determination in language which makes it evident that they were doubtful about its accuracy. They employed it in their thermometric work, however, but Chappuis does not quote it, nor refer to it in any manner, in his paper in the Paris "Rapports." We are inclined to the opinion that the determination is a good one, however, and we see no adequate reason for questioning it. The reason that Chappuis distrusted it can easily be seen; but we cannot enter into a discussion of the point in the present place, it being sufficient to say that his objection does not appear to be well founded. His experimental work, in other words, appears to be better than he realizes.

Morley and Miller have obtained values of the pressure-coefficients of nitrogen, air, oxygen, and carbon dioxide, by a differential method, which appears to be capable of giving very good results. Their work does not appear to have been published anywhere in detail, but an abstract of it is given in the "Proceedings" of the American Association for the Advancement of Science for 1897, on page 123. The pressure coefficient for nitrogen (the initial pressure being 760 millimeters) was found to be 0.0036718, according to an abstract published in "Science" for October 29, 1897, page 652.

The only accurate measures of the coefficient of expansion of nitrogen at constant pressure that the writer has been able to discover are those by Chappuis. In the "Procès-Verbaux" of the International Bureau of Weights and Measures for 1888, page 27, he gives the coefficient for nitrogen at a constant pressure of 1,000 millimeters as 0.003673364; and for a constant pressure of 1,387 millimeters he gives 0.00367816. But in the later "Rapports" of the Paris Congress (page 138) he gives 0.0036731 for nitrogen at a constant pressure of 1,000 millimeters, and 0.0036777 for a constant pressure of 1,386.8 millimeters, adding that the earlier values have since been recalculated and modified somewhat. The values given in the "Rapports" may therefore be accepted as his definitive results.

If we plot the experimental values of the coefficient of expansion of nitrogen at constant volume, and for various initial pressures, taking the initial pressures as abscissas and the observed coefficients as ordinates, we find that the following values may be reasonably adopted as the concluded values of the coefficient of expansion of that gas at constant volume, for the various initial pressures given:

Initial pressure.	Coefficient of Expansion of Nitrogen at Constant Volume.
1000 mm.	0.0036745
900 mm.	0.0036733
800 mm.	0.0036721
760 mm.	0.0036716
700 mm.	0.0036709
600 mm.	0.0036697

If we examine the coefficient of expansion of nitrogen at constant pressure in a similar manner, we shall find that the best obtainable value is 0.0036707 at a constant pressure of 760 millimeters, and 0.0036731 at a constant pressure of 1,000 millimeters.

Passing now to carbon dioxide gas, we will first consider the measures given by Chappuis in the sixth volume of the Travaux et Mémoires of the International Bureau of Weights and Measures. For an initial pressure of 995 millimeters of mercury he gives four determinations of the coefficient of expansion of carbon dioxide gas at constant volume, the mean of these four values being 0.00372477. In another series of five determinations for the same gas he finds the average value of the coefficient at constant volume, for an initial pressure of 870.3 millimeters, to be 0.00371634. In the "Procès-Verbaux" for 1890, page 21, he also gives, for this coefficient, the values 0.0037262 for an initial pressure of 998 millimeters, and 0.0036981 for an initial pressure of 518 millimeters. We also have the value 0.0037122 by Morley and Miller (see the issue of *Science* above cited).

A graphical study of these various values of the coefficient of expansion for carbon dioxide gives the following values, from a combination of all the data:

Initial Pressure.	Coefficient of Expansion at Constant Volume.
1000 mm.	0.0037258
760 mm.	0.0037106

For the coefficient of expansion of carbon dioxide gas at constant pressure ("Procès-Verbaux," 1890, p. 21), Chappuis gives 0.0037699 for the pressure 1,377 millimeters, 0.0037417 for the pressure 998 millimeters, and 0.0037074 for the pressure 518 millimeters. By comparing these by the graphical method, we may infer that the best value of the coefficient of expansion of carbon dioxide gas, at the constant pressure of 760 millimeters of mercury, is 0.0037247; though this value must be regarded as less certain than any of the other coefficients yet given.

Passing now to the consideration of the coefficients for air, we find, contrary to what might be expected, that they have not been determined as satisfactorily for that substance as for the other gases that have here been considered. Regnault made careful determinations of the coefficient of air at constant volume, and so also did Magnus. Jolly made determinations that are not usually considered (we believe) to be of equal value with those of Regnault and Magnus. The data given by these three experimenters have been recalculated by Mendeliéff (Reports of the Russian Chemical Society, 2/14 Dec., 1876), the conclusion of the Russian scholar being, that the experiments of the three, when combined in the most probable manner, show that the coefficient of expansion of air at constant volume, and for the initial pressure of 760 millimeters, is 0.0036699. Balfour Stewart (Phil. Trans., 1863, p. 425) gives fourteen determinations of the coefficient of expansion of air at constant volume, for the initial pressure of 760 millimeters of mercury; the mean of these fourteen determinations being 0.0036728. Chappuis gives two determinations of this coefficient for air ("Procès-Verbaux," 1888, p. 26), the mean of the two being 0.0036743. He does not distinctly state the initial pressure for which these coefficients are determined, but there is evidence in favor of the supposition that the initial pressure in this case was 1,000 millimeters. Weibe and Boettcher, of the Reichsanstalt (Zeit. Instr., vol. 10, p. 237), give eight values of the coefficient of expansion of air at constant volume, and for an initial pressure of 875 millimeters. The mean of these eight values is 0.0036706. For air at constant volume, Morley and Miller give 0.0036719 for an initial pressure of 760 millimeters. W. Hoffmann (Wied. Ann., vol. 66, 1898, p. 224) gives three determinations for an initial pressure of 730 millimeters, the mean of the three, to seven decimal places, being 0.0036696. If the various data here given are plotted as described in the earlier part of this article it becomes plain at once that Stewart's value is too large to be reconciled with the others. So far as the other determinations are concerned, it must be said that the agreement is far from satisfactory. The determination of Morley and Miller, and that due to Chappuis, are in good agreement with each other, and the remaining measures are also fairly consistent among themselves, though they do not agree with those obtained by Chappuis and by Morley and Miller. It does not appear to be possible, at the present time, to untangle this curious and unfortunate condition of affairs. The best that we can say at the present time is, that if Chappuis and Morley and Miller are right, then the coefficient of expansion of air at constant volume and for an initial pressure of 760 millimeters is about 0.0036716, and the corresponding coefficient for an initial pressure of

1,000 millimeters is 0.0036746; while if these experimenters are wrong and the others are right, then the coefficient at constant volume is 0.0036697 for an initial pressure of 760 millimeters, and 0.0036720 for an initial pressure of 1,000 millimeters.

The coefficient of expansion of air at constant pressure was determined by Regnault (Memoires, vol. 1, p. 59), the mean of his four results for the constant pressure 756 millimeters being 0.0036706. The "boiling point," in Regnault's work, was taken as the boiling point of water at Paris, under the pressure due to 760 millimeters of ice-cold mercury; whereas the "boiling point" as understood at the International Bureau of Weights and Measures is the boiling point of water at sea-level in latitude 45°, under a pressure due to 760 millimeters of ice-cold mercury. To reduce Regnault's result to the same standard as that adopted at the International Bureau, we must divide it by 100.01; and hence his corrected result is 0.0036702. Callendar and Griffiths (Phil. Trans., 1891 A, vol. 182, p. 119) give a determination of the coefficient of air at constant pressure, but it is so large that it can hardly be admitted as having the same weight as the others that we are considering. Hoffmann, in the paper cited above, gives a method for finding the coefficient of expansion of a gas at constant pressure, and quotes certain numerical results that he obtained, indicating that the coefficient of air at constant pressure is less than the corresponding coefficient at constant volume by 0.00000123, when the initial pressure is 894 millimeters; but he does not appear to think that this actual numerical result is of any particular value. A graphical study of the data for air at constant pressure indicates that the coefficient of expansion of air is 0.0036706 at the constant pressure of 760 millimeters, and 0.0036734 at the constant pressure of 1,000 millimeters.

Many other experiments might be cited, with reference to the coefficients of expansion of the gases considered above, but it is believed that the data here presented include everything that is of demonstrably great value.

Setting Boiler Tubes.

Various methods have been devised and various tools employed for setting tubes steam-and-water-tight in boilers and condensers. Probably the earliest tool used was a round, tapered plug, Fig. 1, small enough on the point to enter a short distance into the end of the tube, the plug being driven in with maul or hammer. This was found to be inefficient, for the reason that the plug was taper while the hole in the tube-sheet was straight, making the tube tight only on the outer edge of the hole. It was also liable to split the end of the tube on account of the excessive bearing surface.

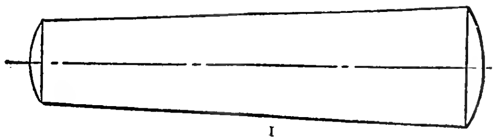

Fig. 1. — Simple Taper Plug.

An improvement on the tapered plug is the tool Fig. 2. This, a three-ribbed mandrel, presents less bearing and more gradually opens the end of the tube, its position being changed at each blow of the hammer. This also has the fault of being taper; to use these tools to good advantage the holes in the tube sheets should have a corresponding taper.

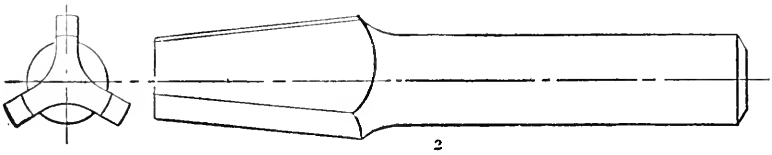

FIG. 2. — THREE-RIBBED MANDREL.

The Prosser tube expander, shown in Fig. 3, was among the earliest designed to tighten tubes by expanding them uniformly, and making a straight fit in straight tube sheet holes. It is a sectional tool, its parts being held together by a spring ring *b*. When assembled, these form a body with a tapered bore. A taper mandrel is provided, which, when driven in, distends the sections, increasing the diameter of the tool. With this tool the extending end of the tube is made bell-mouthed; the tool also forms an inside bead in the tube against the inner edge of the tube sheet while it expands the tube in the tube sheet hole.

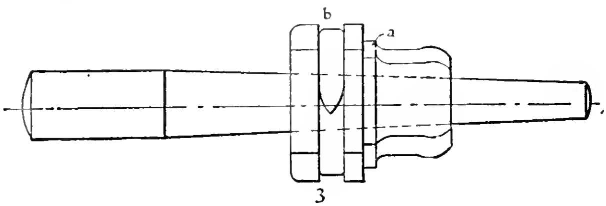

FIG. 3. — THE PROSSER EXPANDER.

The Dudgeon roller expander, Fig. 4, was the next to appear, and is still very extensively used. This tool, as its name implies, enlarges the tube by a rolling process. Three steel rollers are held in seats in a body, and are revolved and forced outward by a slightly tapered mandrel. A later design of the Dudgeon tool, shown in Fig. 5, has the seats for two of the three rollers set at an angle with the axis of the tool, which acts as a feed to draw in the mandrel instead of driving it in, as is necessary in the older style. The roller expander is a good, serviceable, and efficient tool in the hands of careful workmen who know when to stop rolling; but with it a tube can be rolled to a dangerous thinness, at the same time stretching the tube sheet and springing it out of shape. Hence care must be exercised in its use.

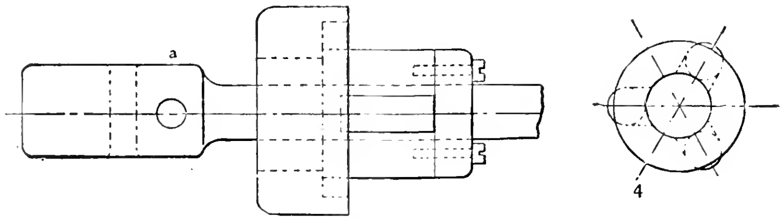

FIG. 4. — DUDGEON ROLLER EXPANDER.

The Dudgeon tool, when operated by hand, uses the mandrel as in Fig. 4; and when operated by pneumatic power it uses the mandrel shown in Fig. 5.

The next tool to be mentioned is the Deane tube expander, shown in Fig. 6. It consists of a cylindrical body having cut in it obliquely a groove which holds a small gib *a*, that is forced outward by a wedge *b*. The working face of the gib resembles in outline a section of the Prosser tool and is for the same purpose — *i. e.*, expanding the tube and raising an inside bead. In action the whole tool is rotated while being driven. This has been used successfully, but it is slow in operation, and the wear on the gib is excessive. It is also a dangerous

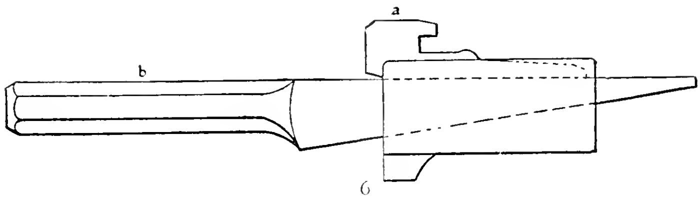

Fig. 6. — Deane Expander.

tool in unskilled hands, for if driven in the full amount in one place, it is liable to split the tube.

An improvement on the Prosser expander, made by the Pratt & Whitney Company, is illustrated in Fig. 7; it being used with a taper mandrel, which is not shown. This, it will be noticed, has an encircling, overhanging flange, which bears against the tube sheet, acting as a gauge to locate the beading end of the tool, and so bringing the bead against the inside end of the tube sheet. The inner shoulder used on the original Prosser tool (Fig. 3 *a*) for turning over the extending end of the tube is cut away, leaving a strong fillet (Fig. 7 *a*).

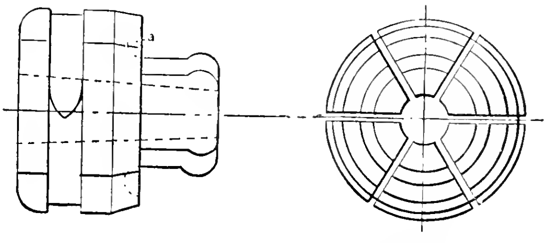

Fig. 7. — Improved Prosser Expander.

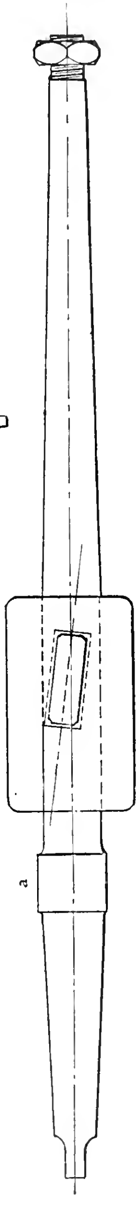

Fig. 5.

The latter-day method of tube end finishing proceeds as follows: The tube is first located in the tube sheet, allowing 3/16 to ¼ inch to protrude. Then with a Dudgeon roller tool the tube is rolled to a tight fit, after which the tool Fig. 8 is used to turn over and round up the end. This last is really a caulking operation, and is finished best with the tool Fig. 9, held in the hand and struck with a hammer, or the one Fig. 10, used in a

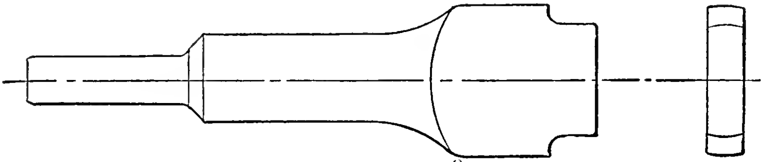

FIG. 8. — BEADING TOOL.

pneumatic hammer. On account of the metal being cold, this boot-shaped tool is best used, as it is necessary to very gradually draw the end of the tube down and around to make a smooth, tight job. This rounded end is shown at Fig. 11, *a*. After rounding the end, the improved sectional tool, Fig. 7, is inserted, and the inside bead shown at *b* in Fig. 11 is made, and at the same time the tube is still further tightened in the tube sheet. As the tube has been turned over on the

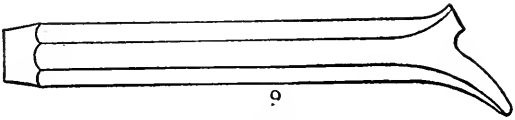

FIG. 9. — BEADING TOOL. (HAND.)

end by the boot tool, the shoulder, Fig. 3 *a*, on the old style Prosser expander is dispensed with, and the stiffening fillet, Fig. 7 *a*, is formed, which clears the finished end of the tube; otherwise it would be marred by its sharp corner. After the inside bead is made, the tube should be again rolled with the Dudgeon tool, for a final finish.

[The editor of THE LOCOMOTIVE desires to insert a parenthesis at this point, stating that the inside bead, shown at *b* in Fig. 11, does not appear to be of any great advantage to the tube, and there are, on the contrary, many cases in which it is a positive detriment. For example, in heating boilers where the temperature is often low, and in boilers of too great a capacity for the work to be done, and in

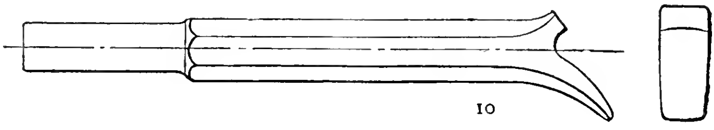

FIG. 10. — BEADING TOOL. (PNEUMATIC.)

which the circulation is correspondingly poor, the tube is often corroded at this internal bead, as a consequence of the disturbance of the superficial fibers of the metal in the formation of the bead. In places where the water contains a great deal of scale-forming matter, a protecting coating is likely to be formed over the metal of the tube, so that the corrosion is not liable to be troublesome; but where the water is pure, and the temperature is not always high, and the circulation is sluggish, the tube is likely to become corroded at the point in question.]

This method insures a good, tight job on both sides of the sheet, and inside the hole in the sheet. It does not damage the tube in the least [see, however, the preceding paragraph], and the work can be done rapidly, as the tools are all very simple in construction, and are easily and quickly operated.

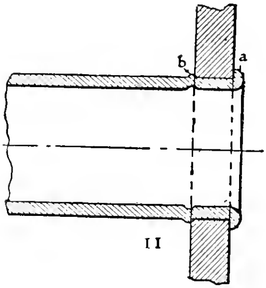

Fig. 11.

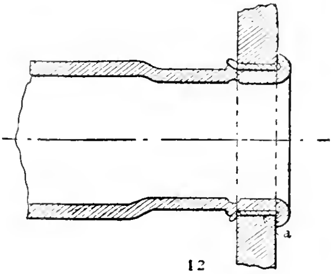

Fig. 12.

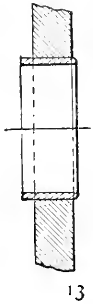

Fig. 13.

The following applies more particularly to the firebox ends of the tubes of locomotive boilers. Various styles of flue ends are made, depending generally on the water of the locality where the boilers are to be worked. The style most used for the firebox end is with this end of the tube swedged down ⅛ inch less in diameter, and a copper ferrule soldered on, as in Fig. 12; or, better, the ferrule may first be rolled in the tube sheet hole, as shown in Fig. 13, and the tube end then inserted and rolled. When finished, the copper lies between the tube and the sheet all the way round, as at *a* in Fig. 12, the purpose being to prevent corrosion.

The smokebox end is very often merely rolled and not turned over on the end, and seldom has an inside bead, though any combinations for the ends are used. Another style is with both ends plain, as in Fig. 11, where tube and sheet are metal to metal.

In locomotive practice it is necessary to put the tubes in from the front or smokebox end, and the front holes are made 1/32 inch larger than the nominal diameter of the tube to allow them to pass through freely. At the firebox end, which is the end requiring the most careful attention, the tube opening in the tube sheet is made 1/64 inch less than the nominal diameter of the tube, and this end of the tube is made 5/1000 inch full of this size, which makes a good, snug driving fit.

Since the advent of pneumatic tools for this service, the work of setting boiler tubes has been very much facilitated, and the life of the tools prolonged. — "H. E. B.," in *American Machinist.*

We desire to acknowledge the receipt of a copy of Professor Alexander Ziwet's "Elements of Theoretical Mechanics," which now appears in a single volume. We noticed the first edition at the time of its appearance in 1893-94, and in looking over the present revised edition we note that the book has been considerably changed in some of its parts. This work requires, for its comprehension, a knowledge of the simpler parts of the differential and integral calculus, and hence it is not adapted to the needs of engineers in general; but to those who are equipped with a sound knowledge of the principles of the calculus, it will certainly appeal as the best elementary work on theoretical mechanics that has yet been written in the English language. Professor Ziwet is thoroughly conversant with the subject, and he is familiar with all the important contributions to it that have appeared in any language, — even in the Russian tongue, with which he is quite familiar.

The Locomotive

Vol. XXV. HARTFORD, CONN., OCTOBER, 1904. No. 4.

Lyman B. Brainerd

President Lyman B. Brainerd.

President J. M. Allen, under whose guidance the Hartford Steam Boiler Inspection and Insurance Company has grown from the smallest imaginable beginnings to the proud position of being the largest company of its kind in the world, died on December 28, 1903, as recorded in the Memorial Number of The Locomotive, published in January, 1904; and in consequence the Directors of the Company were confronted with the sorrowful and difficult task of selecting a successor to him, who should be able, not only to maintain the high standard that Mr. Allen had established for the Company, but also to carry on the work of its development in the future as efficiently as Mr. Allen has carried it on in the past. After much earnest deliberation, the Board, on July 12, 1904, elected Mr. Lyman Bushnell Brainerd to the position, by a unanimous vote; paying him, at the same time, the compliment of requesting him to continue to serve the Company also in his previous capacity as Treasurer.

The Directors, in choosing Mr. Brainerd, based their decision upon his admittedly broad knowledge of finance and of insurance, and upon his ability as an executive officer. Of these qualifications, however, it is not necessary to speak further at the present time; for if the Board has chosen wisely, Mr. Brainerd will speedily demonstrate them for himself. By way of apology for the present article, however, it may be said that in his connection with the Company as its Assistant Treasurer and Treasurer Mr. Brainerd has not been brought in touch with the agents, inspectors, and other employees and friends of the Company as closely as the other officers have been, and hence it was thought by the management of The Locomotive that a biographical sketch, giving some account of his life and personality, might be acceptable as the best substitute at present available for the personal acquaintance that Mr. Brainerd would gladly extend to them all.

Lyman Bushnell Brainerd was born in the town of Westchester, New London county, Connecticut, on March 27, 1856. He was the son of Asa Brainerd and of Susan E. Brainerd, and was one of a family of children consisting of five sons and three daughters. After leaving the public schools Mr. Brainerd attended Wilbraham Academy, at Wilbraham, Massachusetts, and upon completing his studies there he began his career in the world by teaching school at Moodus, Connecticut. This school is reputed to have been one difficult to control. The pupils had taught the previous instructor some few simple physical exercises, which ended by his landing upon his native sod, just outside the window; and when they learned that a new candidate for similar honors had been discovered by the Committee, they formally notified him in advance that his life among them was in a fair way to be a strenuous one. The outcome was, that Mr. Brainerd had some valuable experience; but the executive faculties that he has since developed in larger measure were sufficient for the emergency, and after two or three test cases had been devised by the pupils and put into unsuccessful operation, the school was reduced to order, and the physical aspects of the education gradually gave way to more tranquil intellectual pursuits.

Although successful in teaching, Mr. Brainerd had no desire to make that his life work, and he followed it only for a short time. On March 27, 1876, he entered the employment of Mr. Anson F. Fowler of Middletown, Connecticut, who was agent for the Agricultural Insurance Company of Watertown, N. Y., and under whose tutelage Mr. Brainerd took his first practical lessons in the fire insurance business.

On May 14, 1878, he became a canvasser for the State Mutual Fire Insurance

Company of Hartford, Connecticut, remaining with this company until May 14, 1879, when he left it to accept a more advanced position with the Jersey City Fire Insurance Company of Jersey City, with which he continued for seven years. At the outset he was special agent for the Jersey City company, but after a time he was promoted to the positions of general agent and adjuster.

On August 16, 1886, Mr. Brainerd entered the service of the Equitable Mortgage Company of New York city, as negotiator of bonds and other securities. In 1887 he was made Secretary of this company, and in 1890 he became the manager of its bond department.

In the course of his connection with the Equitable Mortgage Company, Mr. Brainerd was often called to Hartford, and he met, here, the representatives of most of our leading insurance companies. A friendship with Mr. J. M. Allen, late the President of the Hartford Steam Boiler Inspection and Insurance Company, was one of the results of these visits, and from it came an invitation to Mr. Brainerd to connect himself permanently with this Company, as its Assistant Treasurer. The invitation was accepted, and Mr. Brainerd entered upon his new duties on March 2, 1894. In the following five years he became thoroughly familiar with the details of the Company's business, and the success of his administration was such that on February 7, 1899, he was elected by the Directors to the position of Treasurer. Four years later, on February 10, 1903, he was also elected a member of the Board of Directors itself; and on July 12, 1904, as is already recorded above, he was elected President.

Mr. Brainerd's influence has been widely felt in Hartford business circles, and his advice is very generally sought upon the most varied subjects in insurance and finance. In addition to his official connection with the Hartford Steam Boiler Inspection and Insurance Company, Mr. Brainerd is a Director of The Case, Lockwood & Brainard Company, a Director of The Security Company and a member of its Finance Committee, a Trustee of the Society for Savings and a member of its Loaning Committee, and a Trustee of the Hartford Theological Seminary and Chairman of its Executive Committee. He is a member of the Farmington Avenue Congregational Church.

Personally, Mr. Brainerd is a kind-hearted, fair-minded man, full of devotion to the Company's best interests, yet approachable by all, and considerate of all. In a word, the reins of management are in good hands, and there is every promise of the continued growth and prosperity, under his guidance, of the Hartford Steam Boiler Inspection and Insurance Company.

A. D. Risteen.

The total output of crude petroleum in the United States, since it was first discovered in quantity, in 1859, by Colonel Drake, on the waters of Oil Creek, near Titusville, Pa., to the end of 1902, amounted to 1,165,290,248 barrels. Allowing 5.6 cubic feet to each barrel, this quantity of oil would fill a tank whose base is one mile square to a height of 234 feet. It would likewise fill 38,843 tanks containing 30,000 barrels each. Allowing 90 feet for the diameter of tanks of this size, if they were placed so that their sides would touch, they would reach 662 miles; and if the barrels (estimated at 30 inches high) required to hold this oil were laid so that their heads would touch, they would encircle the earth 2.28 times. Considered as fuel, this oil is equivalent to about 330,000,000 tons of average coal. — *Report of the U. S. Naval Liquid Fuel Board.*

Report of the British Committee on Naval Boilers.

The Lords Commissioners of the British Admiralty appointed a Committee on Naval Boilers, in September, 1900, this Committee being instructed to make a thorough investigation of the relative merits of water-tube and cylindrical (*i. e.*, internal flue) boilers, for use in naval vessels. In 1902 a preliminary *Report* of this Committee was issued, copious extracts from which were printed in THE LOCOMOTIVE for November, 1902. The evidence that had then been obtained appeared to be unfavorable to the Belleville boiler in particular, — a circumstance of considerable interest, because the Belleville boiler has been very extensively installed in the British, French, Russian, and Japanese navies. (See THE LOCOMOTIVE for April, 1904.)

The final *Report* of the Committee is now at hand, the letter of transmittal accompanying it being dated June 12, 1904, and signed by Admiral Sir Compton Domvile, as President of the Committee. This letter will be of especial interest to the advocates of the Belleville boiler, for in it Admiral Domvile says: "I am compelled to say that my experience with the Belleville boilers on the Mediterranean station has been very favorable to them as a steam generator, and it is clear to me that the earlier boilers of this description were badly constructed and badly used. We have had no serious boiler defects in any of the ships out here, and the fact that two ships are about to be recommissioned with only the ordinary annual repairs being undertaken shows that their life is not so short as I originally supposed. However, the second commission of these ships will be a very good test of the staying capabilities of their boilers."

The final *Report* of the Committee is given in full in the issue of *Engineering* (London) for August 5, 1904; but owing to its length we shall here present only the major portion of it, including those parts which appear to us to be most important. The extracts that we give should be read in connection with the previous article on the Committee's work, as published in the issue of THE LOCOMOTIVE for November, because we have there given illustrations and brief descriptions of the chief types of boilers that are referred to.

Since 1902 the *Medea* has been refitted with Yarrow "large-tube" boilers, and the *Medusa* with Dürr boilers, and the new boilers of both of these ships have been thoroughly tested.

The *Report* of May, 1902, was intended to be final as regards the Belleville boiler, and the Committee now states that it sees no reason for modifying the opinion expressed in that *Report*, — the opinion, namely, that it is "undesirable to fit any more of this type in His Majesty's Navy." This conclusion, taken in connection with Admiral Domvile's statement in his letter of transmittal, leads us to believe that the sense of the Committee is, that while the Belleville boiler is adjudged to be less black than it has been painted, yet, in consideration of the large number of boilers of this type now in use in the British Navy (see THE LOCOMOTIVE for April, 1904), and of the apparent promise of certain other types of water-tube boilers, it is considered to be advisable to install some of these other types, so that all can be given a fair trial on the large scale.

The Committee had previously reported that in their judgment the Babcock & Wilcox, Niclausse, Dürr, and Yarrow "large-tube" boilers are sufficiently promising to justify their use in the British navy in combination with cylindrical boilers. Having concluded their investigations, the Committee is now satisfied that two of these four types, — namely, the Babcock & Wilcox similar to that tried on the *Hermes*, and the Yarrow "large-tube" similar to that tried on the

Medea, — are satisfactory, and that they are suitable for use in battleships and cruisers, not only *with*, but also *without* cylindrical boilers. Only long experience on general service can show which of these two is, on the whole, the better boiler; and for the present the Committee unanimously recommends both of these types as suitable for naval requirements.

The ships on which each type of boiler has been tried by the Committee are as follows: The cylindrical boiler on the *Minerva* and *Saxonia;* the Babcock & Wilcox on the *Sheldrake, Espiègle,* and *Hermes;* the Belleville on the *Diadem* and *Hyacinth;* the Niclausse on the *Seagull* and *Fantôme;* the Dürr on the *Medusa;* and the Yarrow "large-tube" on the *Medea.*

THERMAL EFFICIENCY OF BOILERS.

The best results (so far as thermal efficiency is concerned) that were obtained with the Babcock & Wilcox boilers of the *Hermes* were during the trials of furnace gas baffling. The boilers in the middle boiler room, with vertical baffles and a forced air-supply over the fires, then gave the high efficiency of 81 per cent. on a 30 hours' trial when 20 pounds of coal were being burned per square foot of grate per hour, and an efficiency of 77.8 per cent. on a 29 hours' trial when burning 27 pounds per square foot; these rates of combustion corresponding to the ordinary rate of steaming and to the full power of the boilers respectively. The boilers of the *Hermes* with the restricted up-take baffling, and without any special air-supply over the fires, had a maximum efficiency of 75.8 per cent. on a 12 hours' trial when burning 20.5 pounds per square foot per hour. On three trials of over 24 hours' duration each, and when 19 pounds were being burned per square foot per hour, the efficiency was in each case practically 71 per cent. When burning 29 pounds per square foot per hour for seven hours, the efficiency of these boilers was 66.3 per cent.; but the weather during this test was so bad that the trial, which was to have been of eight hours' duration, had to be stopped on this account after the seventh hour. During the baffling trials, however, in good weather, an efficiency of 70.3 per cent. was obtained on the 30 hours' trial, when burning 27 pounds per square foot per hour, or practically the full output.

The maximum efficiency of the Yarrow boilers of the *Medea* (namely, 75.7 per cent.) was obtained on a 26 hours' trial when burning 18 pounds per square foot per hour; their efficiency when burning at the maximum rate of combustion (namely, 40 pounds per square foot per hour for eight hours) was 69.5 per cent. On trials of over 24 hours' duration each, burning from 17 to 21 pounds per square foot per hour, the efficiency remained at or over 75 per cent.

The Belleville boilers of the *Hyacinth* had a maximum efficiency of 77.2 per cent., recorded on a 24½ hours' trial, when 16 pounds of coal were being burned per square foot of grate per hour. When burning 20 pounds per square foot per hour for 11 hours, the efficiency was 73.3 per cent., and when burning 17.4 pounds for 24 hours it was 71.8 per cent. The efficiency of these boilers on an eight hours' trial in fine weather, when burning 27 pounds per square foot per hour (corresponding to the full output of the boiler), was 65 per cent.

The maximum efficiency of the Dürr boilers of the *Medusa* was 64.8 per cent., obtained on an eight hours' trial, when burning 35 pounds per square foot per hour, this being the maximum rate of combustion for these boilers; the efficiency when burning 16 pounds per square foot per hour for 26 hours was 63.8. On trials of over 24 hours' duration each, and burning 18 and 21 pounds per square foot per hour, the efficiencies were 61.7 per cent., and 60.3 per cent., respectively.

Of the cylindrical boilers tried, those of the *Saxonia* on the only trial made, which was of 13 hours' duration, and on which 20 pounds per square foot per hour were burned, had the high efficiency of 82.3 per cent. The maximum efficiency obtained with the cylindrical boilers of the *Minerva* was 69.7 per cent., which was recorded on a 25 hours' trial when burning 14 pounds per square foot per hour. On a trial of 8½ hours' duration, with retarders in the plain tubes, the efficiency, in the case of the *Minerva*, was 68.4 per cent. In the smaller ships, the maximum efficiency of the Babcock & Wilcox boilers tried was 66 per cent. on a 12 hours' trial, burning 18 pounds per square foot per hour in the *Sheldrake*, and 73.2 per cent. on a nine hours' trial, burning 13 pounds per square foot, in the *Espiègle*. The maximum efficiency obtained by the Niclausse boilers of the *Seagull* was 66.9 per cent. on an eight hours' trial burning 13 pounds per square foot, and by those of the *Fantôme* 69.8 per cent. on a nine hours' trial, burning 14 pounds per square foot.

WETNESS OF STEAM.

The wetness of the steam was taken throughout the Committee's trials by means of a Carpenter calorimeter. Experience in the *Medusa* satisfied the Committee that the results registered by this instrument are trustworthy. As regards the production of dry steam at all rates of combustion, the Yarrow "large-tube" and the later Babcock & Wilcox boilers have given the best results.

LOSS OF WATER.

The loss of feed-water with each of the four types of boiler under consideration has been moderate throughout the Committee's trials. In the runs to Gibraltar and back, carried out with the *Medea* and *Medusa*, the loss of water was small, being at the rate of 1.6 and 1.8 tons per 1,000 horse power per day, respectively. On the 140 hours' endurance trial of the *Hermes* the loss was 3.8 tons per 1,000 horse power per day. The loss of water may be expected to be greater in boilers fitted with many doors than with those fitted with few, and to increase as the doors and joints become worn. In this respect the Yarrow boiler, having but three manhole doors, has an advantage.

EXAMINATION AND CLEANING OF INTERIORS OF TUBES.

Of the boilers tried by the Committee, the Yarrow boiler can be internally examined and cleaned in the shortest time and with the least amount of labor. To obtain access for such an examination and cleaning it is only necessary to remove three manhole doors. The Babcock & Wilcox type is less easily examined and cleaned, because two handhole plates have to be removed for each tube, and these have to be re-jointed after the examination and cleaning have been completed. In order to carry out a thorough examination of the tubes of the Dürr boiler, it is necessary to remove a handhole cover at the front of each tube, the diaphragm washer of the internal tube, the internal tube itself, and the cap-nut at the back end of the generating tube; and in order to carry out a thorough cleaning it is also necessary to remove the generator tubes from the boiler. These have to be replaced, and their manipulation, considered in its totality, is a long and tedious process. The work connected with the examination and cleaning of the tubes of Niclausse boilers is very similar to that necessary with the Dürr boiler. Further, the cap-nut at the back end of the Dürr boiler tube permits of each tube being readily emptied; but, since the back end of the Niclausse boiler is inaccessible, it is necessary to blow the water out of the tubes of this type either by a special pump and hose, or by some equivalent device.

EXTERNAL CLEANING OF TUBES.

In both the *Medea* and the *Hermes* it is possible to partially clean the tubes externally, when the fires are alight, by means of air-lances. The tubes in the *Medea* can be thoroughly cleaned externally when the fires are not alight, as they can be swept in three directions, — namely, from the furnace, from the smoke-box, and from the front of the boiler. The tubes of the Dürr and Niclausse boilers cannot be so thoroughly cleaned externally in place as those of the *Medea,* the number of rows being greater, and the overlapping of the baffles preventing portions of certain tubes from being touched. In the Babcock & Wilcox boilers the tubes can be swept horizontally through side doors fitted to the casings; but as the boilers in the *Hermes* were originally fitted, the sweeping in a vertical direction was difficult. Since the alteration of baffling, the sweeping vertically can be carried out, but this necessitates the removal of portions of the baffles. It is to be recognized that any system of baffling among the tubes, however it may improve the circulation of the gases, renders the cleaning of the tubes themselves more difficult.

BENDING OF TUBES.

After the *Medusa* had completed her preliminary runs, it was found that all the tubes of the bottom rows had curved upwards in the middle, the maximum bending being $1\frac{1}{16}$ in. These tubes were removed and straightened before starting on the Committee's trials. They had to be straightened again in August, 1903, and again at the conclusion of the Committee's trials in February, 1904. When the Committee visited H. M. S. *Berwick* in April, 1904, it was noticed that the tubes of the bottom rows of the boilers (Niclausse type) were bent upwards, and the Committee was informed that the maximum bending on March 22, 1904, was ⅝ in. The ship was new in 1903, and only commissioned in December of that year. With the Niclausse, and also with the Dürr boiler, considerable bending of the tubes of the bottom rows must be expected; and it will be necessary to straighten these tubes when the amount of bending exceeds ¾ in. This will entail a considerable amount of extra work with these types of boiler, and they will be off service for corresponding periods. The upward bend of the generator tube is often greater than the space between the inner and outer tubes; and as the inner tube, which is only supported at the two ends, remains straight, it is liable to touch the outer tube at some point, thus impeding the circulation between them. To prevent this it may be necessary to support the inner tube at the middle of its length as well as at the back end, so that it must bend with the outer tube.

In the case of the Yarrow boilers of the *Medea,* the Committee experimented in six of the boilers with the fire-rows purposely bent, with the object of overcoming some slight leakages of tube-ends, which showed themselves when working under forced draft. The Committee has suggested, concerning the Yarrow boilers proposed for H. M. S. *Warrior,* that the tubes of the fire-rows should be bent one inch from the straight, and this recommendation, in its opinion, should apply to future designs. In the Babcock & Wilcox boilers of the *Hermes,* although some of the tubes of the bottom rows have bent, no leakage of tube-ends has resulted, and it has not been necessary to remove any tubes for straightening or renewal.

CORROSION AND WEAR.

In none of the four types of water-tube boiler which were recommended for trial by the Committee has there been any considerable corrosive decay of tubes, and the ordinary wear has been very slight. On the conclusion of the Committee's trials the tubes of the boilers of the *Medea* and *Hermes* had not deteriorated to any appreciable extent. This applies also to the *Medusa,* save that the internal tubes have here shown signs of roughening. In the *Medusa* (Dürr boilers) there was some buckling of the side-casings of the boilers, but no serious trouble of this kind was had with any of the other types. The Committee found that the Yarrow boiler can be severely forced without danger, and that the Babcock & Wilcox can be forced to a lesser extent, but that the Dürr and Niclausse boilers should not be forced beyond the limits set by their designers and builders.

SKILLED FIRING REQUIRED.

The satisfactory stoking of water-tube boilers requires a higher degree of skill than that of cylindrical boilers, and this is more necessary with the large grates of the Dürr, Niclausse, and Babcock & Wilcox boilers than with the smaller grates and better shape of combustion chamber of the Yarrow. The stoking in the *Medea, Medusa,* and *Hermes* was good throughout the trials, and towards the end was excellent. Under ordinary service conditions, such good service can hardly be expected, at least until a vessel has been some time in commission. Good results can be obtained with Yarrow boilers, however, with engine-room complements that are new to the ship, as shown by the trials to Malta and back, which have been made by the *Medea* since the completion of the Committee's trials with that vessel. No trouble was found with the automatic feed apparatus, but the Committee was of the opinion that it is advisable to omit automatic apparatus of this kind, in types of boilers which, like the Yarrow "large-tube" and the Babcock & Wilcox, contain a fairly large reserve body of water.

Some experiments were tried with the Yarrow and Dürr boilers, to determine the effect of brackish water upon them. It was considered that neither type is likely to give trouble from this cause. In the case of the Yarrow boiler this result has been corroborated by the fact that on a recent voyage the *Medea* is reported to have had leaky condenser tubes, and a corresponding density in the boilers, without any bad effect.

Inspector's Reports.

On page 89 we present a general summary, by defects, of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company, during the months of May, June, July, and August, 1904. We also give, below, a summary of these months, showing the number of visits of inspection made, the total number of boilers examined, the total number inspected internally, the number tested by hydrostatic pressure, and the number of boilers condemned.

	MONTH (1904).			
	May.	June.	July.	August.
Visits of inspection,	13,001	13,693	13,458	12,350
Total number of boilers examined,	24,731	30,092	23,385	23,077
Number inspected internally,	11,772	9,947	12,341	10,220
Number of hydrostatic tests,	1,146	2,123	1,120	1,359
Number of boilers condemned,	122	83	71	71

Inspectors' Reports for May, June, July, and August, 1904.

Nature of Defects.	May.		June.		July.		August.	
	Total defects	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous	Total defects.	Dangerous.
Cases of deposit of sediment,	1,755	88	1,827	98	1,629	59	1,356	62
Cases of incrustation and scale	4,306	86	4,062	79	3,953	63	3,293	85
Cases of internal grooving,	365	45	305	23	349	26	220	17
Cases of internal corrosion,	1,310	53	1,519	55	1,705	45	1,436	56
Cases of external corrosion,	935	78	1,122	61	1,150	59	991	50
Defective braces and stays,	237	43	149	24	182	44	275	44
Settings defective,	684	57	696	60	659	54	454	40
Furnaces out of shape,	672	22	801	23	778	37	530	18
Fractured plates,	422	73	319	50	379	29	318	57
Burned plates,	585	45	565	44	529	54	397	47
Blistered plates,	139	39	141	5	143	0	74	7
Cases of defective riveting,	323	32	231	28	284	29	393	82
Defective heads,	141	21	122	12	183	16	174	17
Leakage around tubes,	1,009	91	930	77	740	93	766	82
Leakage at joints,	620	33	539	28	471	26	526	24
Water-gauges defective,	355	73	319	83	239	66	214	43
Blow-offs defective,	387	129	405	110	378	120	324	70
Cases of deficiency of water,	23	14	19	10	14	8	27	12
Safety-valves overloaded,	118	31	118	42	114	28	94	30
Safety-valves defective,	102	23	122	27	94	24	114	31
Pressure gauges defective,	708	57	656	40	603	20	565	36
Boilers without pressure gauges,	53	53	28	28	16	16	13	13
Unclassified defects,	319	65	226	44	295	60	348	239
Totals,	15,578	1,251	15,221	1,051	14,887	976	12,902	1,162

Concerning Tube Cleaners.

There are numerous forms of boiler-tube cleaners upon the market at the present time which are actuated by power. Some of these are designed to clean the inner surfaces of the tubes of water-tube boilers, some to remove sooty deposits from the fire side of the tubes of fire-tube boilers, and some to remove scale from the outer surfaces of the tubes of fire-tube boilers; these last acting by striking a succession of blows against the interior of the tube, and thus jarring the scale off from the outside. In the present article we shall not refer to those forms in which the deposits in fire-tubes are blown or sucked out by blasts of air or steam, nor to those by which the soot or scale is removed by the action of scrapers that are merely run through the tubes, except in so far as our remarks upon the danger of blowing steam through a cold boiler tube may be applicable to them. What we shall have to say will be mainly confined to those forms in which the apparatus employed communicates to the tube that is being cleaned a series of shocks of greater or less severity, either by directly hammering against the tube or the scale, or by the rapid rotation of a cutter or other revolving device which is corrugated or otherwise irregular in shape, and which strikes its blows in virtue of that irregular shape, the rotation, and the centrifugal force by which it is urged out against the tube.

Our inspectors have made numerous reports of serious damage being done to boilers by cleaners of these types, and as the use of such cleaners is becoming increasingly common, we have thought it our duty to call the attention of steam users to the dangers that are incident to them, when they are improperly handled. It should be understood that we have no intention of condemning these power cleaners wholesale, because many of them give very good results when used judiciously and intelligently. Our desire is to direct attention to the precautions that must be taken in the use of such appliances, in order that the good results that they are capable of yielding may be realized, while the bad results may be avoided with corresponding certainty.

The reality of the danger from power tube cleaners is sufficiently illustrated by Figs. 1, 2, and 3, which are taken from actual specimens removed from a boiler upon which a power cleaner had been used. The particular cleaner that was employed in this case is one that hammers against the inside of the tube of a fire-tube boiler, the jar that is thereby communicated to the tube being supposed to rattle the scale off from the outside of the tube. In the instance now under discussion, two boilers of a certain plant had been cleaned in this way, and when they were again put in service seven of the tubes collapsed in one of the boilers when the pressure reached 90 pounds. The inspector of the Hartford Steam Boiler Inspection and Insurance Company was summoned at once, and upon visiting the plant he found that in addition to the seven tubes which had collapsed four others were strongly oval in shape, so that they had to be removed. Fig. 1 shows a portion of one of the collapsed tubes, precisely as it was removed from the boiler; the flattened part extending to within nine inches of the end of the tube, or over the exact distance traversed by the cleaner. Fig. 2 is a photoengraving of a section of one of the other tubes, which had become oval from the action of the cleaner, but which had not collapsed. The cause of the distortion is plainly indicated in this engraving. The cleaner, instead of being constantly rotated and moved along the length of the tube, had been allowed to remain in one position for a short time, so that the hammer had pounded against the tube in one spot, which is indicated by the bright area on

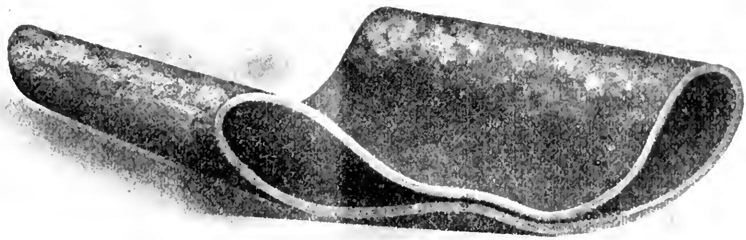

Fig. 1.—Section of a Tube Collapsed by the Action of a Tube Cleaner.

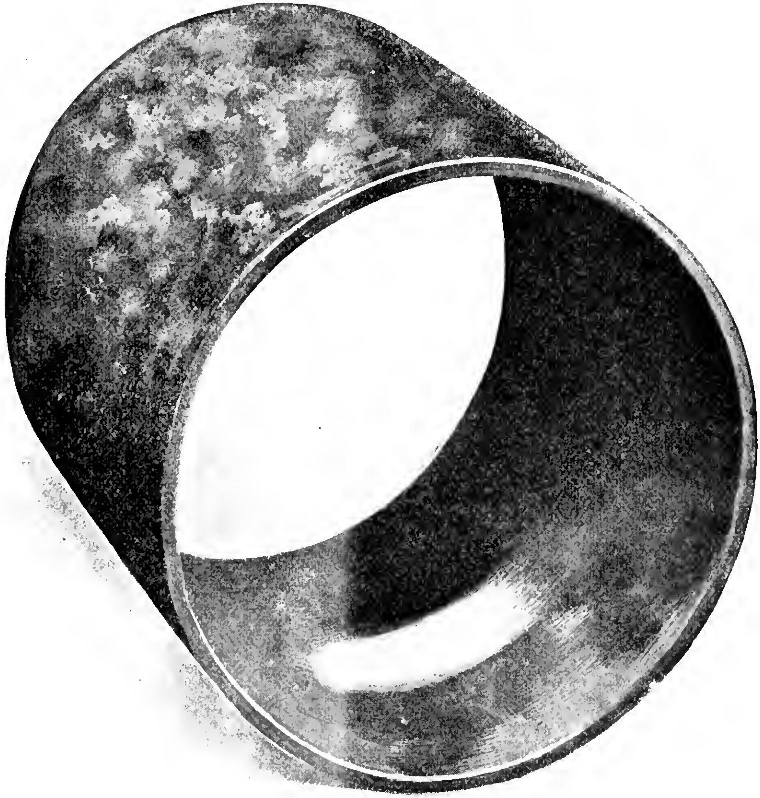

Fig. 2.—Section of a Tube Rendered Oval by the Action of a Tube Cleaner

the inside of the tube. The result was, that the tube was forced out into an oval shape, the greatest bulge coming opposite the bright spot. The actual deformation of the tube not being very evident to the eye in Fig 2, we present, in Fig. 3, an outline cut that exhibits it more clearly. The black outline in this cut was derived by placing the section of tube shown in Fig. 2 endwise against a sheet of paper, and drawing its inner and outer contours by a pencil; the space between the two lines so obtained being then filled in with ink, to represent the thickness of the tube. The actual, deformed contour being recorded in this way, dotted circles were next drawn, to show the original form from which the tube had been distorted by the action of the hammer. It is only fair to add that in this case micrometric measurements of the thickness of the affected tubes showed that they had been slightly thinned by the wear incident to ordinary use. The thin-

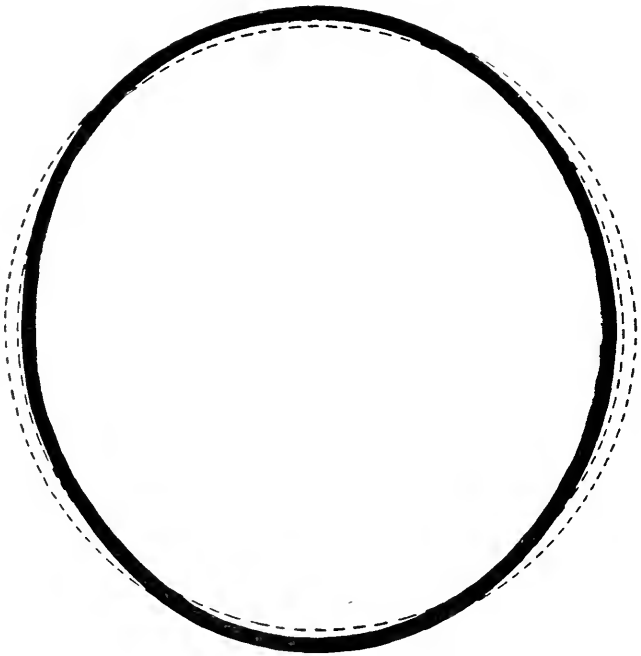

FIG. 3.— CROSS SECTION OF THE TUBE SHOWN IN FIG. 2.

ning was in no case great enough to render the tubes unserviceable, however, nor was it greater than would be found in the general run of boilers that have been a few years in service.

The cumulative effect of the blows of a power cleaner of this type, when the cleaner is permitted to remain stationary for a short time, is illustrated not only by the distortion of tubes, but also by their actual splitting, in severe cases. One of our inspectors, for example, has recently reported a case in which three tubes were split in this way in one boiler, from a single application of the tool. In this case the affected tubes were previously in excellent condition, and not sensibly thinned by wear nor by corrosion. The continued and severe action of a power tube cleaner may also actually stretch the tubes longitudinally, so as to loosen them in the heads, and cause leakage and loss of holding power. In one instance, for example, one of our inspectors found that a number of tubes in a boiler that he visited were projecting through the tube-sheet at one of the heads by as much as $\frac{1}{8}$ in. to $\frac{3}{16}$ in., although they had been originally well beaded down to the head. As these tubes were in good condition at the previous inspection, and there was no visible reason for their elongation, the inspector made inquiries for the purpose of discovering the cause of the trouble, and learned from the engineer that a power tube cleaner had been passed through all of the tubes, and that the extension of the tubes had immediately followed its application.

These defects are not confined to cleaners which strike against the inner surfaces of the tubes of fire-tube boilers, but are liable to be observed in any type of power cleaner which operates by repeated concussion upon the tube, or upon such scale as may be attached to the tube. Our inspectors have reported numerous cases, for example, in which water-tube boilers have been badly damaged by the action of cleaners that have been run through their tubes for the purpose of cutting out the scale upon their inner surfaces. In one such report that lies before us, the inspector says: "They had worked on ten tubes in the bottom row of boiler No. 1, but they soon found that one of the headers was cracked, and upon examination it was discovered that every tube into which the cleaner had been passed had crept forward through the front head by from $\frac{1}{32}$ in. to $\frac{1}{4}$ in. I could hardly believe this, but I saw it with my own eyes, and know it to be a fact. The cracking of the header had been due to this cause, and I did not think that it would be safe to proceed any further with such an apparatus. I suggested to the management that possibly they did not understand how to operate the machine, and I emphasized to them the necessity of taking extreme care if they were proposing to continue its use, as it would never do to put such a stress upon these headers as they had evidently been subjected to."

In another case of a similar sort, where a water-tube boiler was being cleaned, "the cleaner was being used under a steam pressure of 100 pounds, and every blow of the hammer left its impression by a dent in the tube." In this instance the pressure used to operate the tool was undoubtedly very excessive. The pressure should certainly not exceed 50 pounds, and we are of the opinion that 20 pounds is all that ought to be employed. If steam of this tension is not directly available, a reducing valve should be employed, so that the actual pressure furnished to the tool could not exceed a reasonable limit, such as 20 or 30 pounds. Any tube that is scaled so badly that it cannot be cleaned by a pressure of this magnitude should be removed and replaced by a new one. Leakage around the tube ends is a commonly reported result of the use of mechanical cleaners, the tubes being either actually elongated by the blows, as already pointed out, or merely loosened in the heads or headers by the constant succession of shocks to which they are subjected. The extension of the metal is sometimes made evident by the sagging of the tubes, and one report is before us which tells of a case in which the tubes were so stretched that when the boiler was again put into service, certain of them bent up or down until they came in contact with tubes in adjoining rows.

In the case of cleaners whose action involves the discharge of steam into or through the tubes, leakage around the tube-ends, or the actual extension of the tubes through the heads or headers, is liable to be caused by the direct expansion of the tubes, due to the heating effect of the steam. If the tubes and the shell were all heated at the same time and by the same amount, there would be no stresses introduced by the heating; the danger being, not from the heat itself, but from the stresses caused by the fact that the expansion is local, and practically confined to the tube that is being cleaned. It is easy to see that if one tube grows longer from thermal expansion, while the rest of the boiler retains the dimensions that correspond to its lower temperature, there must be a stress of some magnitude thrown upon the tube and upon the heads or headers into which it is secured. The rise of temperature of a tube that is being cleaned by such a device is often considerable, for if a tube is at all foul with scale, it may require twenty minutes or so to bring it into proper condition. We believe that some (and perhaps all) of the manufacturers of tools of this kind, being alive to the danger of starting the tubes by local heating, recommend that the boiler itself be heated up, before setting the cleaner at work, so that the effects of the subsequent warming from the action of the cleaner may be minimized. This practice appears to us to be of doubtful wisdom. In the case of a water-tube boiler the only method of heating the boiler that appears to be at all feasible is to build a light fire under it, while it is dry. If the fire is handled carefully and by a man of good judgment, the boiler may perhaps be warmed in this way sufficiently to prevent subsequent injury from unequal expansion, and yet without being itself injured by the direct action of the fire; but we should hesitate to recommend such a measure for general employment, because we should fear that the average attendant could not be depended upon to always strike the somewhat nice medium at which the warming of the boiler is effective, while the boiler itself is not overheated in any part by the fire. Moreover, the remedy would hardly be effective in any case, unless the slow fire were maintained during the entire time that the tubes are being cleaned. If the boiler were heated up only at the outset, for example, then it is evident that if from ten to twenty minutes are spent upon each tube, the majority of the tubes in the boiler would have ample time to cool down before the cleaner reached them. If, on the other hand, the slow fire were maintained during the entire time of cleaning, there would be a correspondingly greater danger that at some part of this period the fire would either become so light as to be ineffective, or so heavy as to overheat some part of the boiler. It will be observed that we do not assert that these things cannot be done, and done rightly; but our experience indicates that it is not well to recommend, for general adoption, any procedure whose safety and efficacy presuppose that the attendant will do everything with good judgment. We know too well that boiler attendants are human, and that they, like other mortals, do not always do things in the way they should. It is far better and safer to avoid the discharge of steam into a cold tube altogether, and to operate the cleaner with compressed air. This is sometimes inconvenient, but it is better to go to a little trouble and expense, rather than to take chances of injuring the boilers. Of course it is unnecessary to say that there is no objection to the use of steam in those forms of power cleaners which are operated by motors external to the tube, and in which the exhaust does not enter the tube.

In review of what has been said, let us state: (1) That when power tube cleaners are used, they should be kept in motion, so that they cannot strike a succession of blows against any one part of the tube; (2) they should be operated by a pressure not exceeding 20 pounds, or, at the most, 30 pounds per square inch; (3) steam should not be permitted to blow through the tubes of a cold boiler for a sufficient time to sensibly heat the tubes; (4) compressed air should be used to operate tube cleaners, unless the motive power is entirely external to the tube; (5) in any case the boiler should be carefully watched during and after the application of a power cleaner, especially around the ends of the tubes, and on the headers; and at the first sign of distress of any kind, the use of the cleaner should be promptly discontinued; (6) lastly, a power cleaner should never be put in charge of any attendant save one upon whose judgment and skill the owner of the boiler can implicitly rely.

Boiler Explosions.

June, 1904.

(164.)— On June 2d a cast-iron safety-valve broke off at the neck, in the Boonville Electric Light & Power Company's plant, at Boonville, Mo. Fireman Frank Crosby, who was trying to stop the valve from blowing at the time of the accident, was so badly scalded and otherwise injured that he died within a few hours.

(165.)— A tube ruptured, on June 6th, in a water-tube boiler at the Central Works of the American Cement Company, at Egypt, Pa. Daniel Shellhammer, fireman, and George Gill, ashman, were severely scalded.

(166.)— A flue collapsed, on June 6th, in a tubular boiler at the State Penitentiary at Columbus, Ohio. Nobody was injured, and the property loss was small.

(167.)— A small boiler exploded, on June 8th, at Boone, Iowa, while it was being tested by Mr. I. A. Griffee, in a small building in the rear of his jewelry store. The boiler was blown to pieces, and the roof of the building was demolished. We have not learned of any personal injuries, however. We infer, in view of the results, that the "test" was considered to show that the boiler was dangerous.

(168.)— On June 9th a tube burst in a water-tube boiler at the electric lighting plant of The Public Service Corporation of New Jersey, at Passaic, N. J. Nobody was injured, and the property loss was slight.

(169.)— A cast-iron header fractured, on June 9th, in a water-tube boiler in the Philadelphia Rapid Transit Company's power-house, at Thirteenth and Mt. Vernon Streets, Philadelphia, Pa. The property damage was small, and nobody was injured.

(170.)— A boiler exploded, on June 10th, in Jesse Cunningham's sawmill, at Tar Springs, near Cloverport, Ky. James Robards, James Richardson, Charles Simms and a five-year-old son of Mr. Simms were seriously injured. The boiler had been in use only one day.

(171.)— A flue failed, on June 12th, in a boiler on the steamer *Mary Bell*, belonging to the Lake Keuka Navigation Company, at Urbana Landing, Lake Keuka, N. Y. Frederick Maxfield, one of the firemen on the boat, was seriously and perhaps fatally scalded.

(172.)— A tube burst, on June 12th, in a water-tube boiler at the plant of the Mound City Ice & Cold Storage Company, at St. Louis, Mo. The property damage was small, and nobody was injured.

(173.)— A slight explosion occurred, on June 14th, in the plant of the Niagara Light, Heat & Power Company, at Tonawanda, N. Y. Frederick Miller, William Litz, and George Sicord were seriously burned and scalded. The explosion appears to have consisted in the failure of a plug which had been temporarily inserted in the boiler to take the place of a pipe which had been removed for repairs.

(174.)— A boiler exploded, on June 14th, in the Kincaid sawmill, at Hord, nine miles north of Louisville, Ill. Engineer Albert Coleman was killed outright, and James Simpson was scalded so badly that he died on the following day. David Cottrelson was also badly scalded, though at last accounts it was thought that he might recover.

(175.)— A small boiler exploded, on June 17th, while it was being "tested" in a shed on Grove Street, Milwaukee, Wis. Joseph Szywakowski was seriously injured, and Roman Jankowski and three brothers named Martin, Sylvester, and Clement Borczyzkowski were injured slightly. The shed in which the boiler stood was demolished, and an adjoining house was slightly damaged. The boiler was designed to carry a pressure of 175 pounds per square inch, and was being tested by steam pressure. It had stood a pressure of 175 pounds a week previously, but on the day of the explosion it failed at 140 pounds; and from the results, we judge that it was then considered to be unsafe. Water is so cheap and so safe that it seems as though everybody would prefer hydrostatic pressure for testing purposes; but the continual repetition of accidents of this kind shows that people will not always do what might reasonably be expected of them.

(176.)— On June 17th a tube burst in the plant of the American Sugar Refining Company, on Washington and Essex Streets, Jersey City, N. J. Fireman Thomas Smith was killed.

(177.)— A boiler exploded, on June 18th, in William M. Huff's sawmill, five miles east of Gadsden, Ala. Love Herring was scalded about the lower part of the body so badly that he cannot recover. Edward Dentore, Dell Huff, and William H. Huff were also severely injured. The mill, which was totally destroyed, was operated in Mr. Huff's name, but was owned by Mr. A. J. Bradley, of Keener, Ala.

(178.)— A slight boiler explosion occurred, on June 19th, in the plant of the Augusta Brewing Company, at Augusta, Ga. The property loss was small, and nobody was injured.

(179.)— A boiler exploded, on June 21st, on the Agnes plantation, on Bayou Vermilion, about eight miles south of Abbeville, La. Fireman James Harris and his assistant were badly injured, and the building in which the boiler stood was wrecked.

(180.)— A small boiler exploded, on June 21st, in Gray's renovating plant, on Howard Avenue, Utica, N. Y. Nobody was injured. The property loss amounted to only about $500.

(181.)— John Rutter was killed, on June 22d, by the explosion of a boiler on his brother's farm, two miles east of Millbury, Ohio. Henry Kalkhoff was also injured seriously, but not fatally.

(182.)— On June 24th a boiler exploded in the main pumping station at Riverside plantation, near Jennings, La. We have not learned of any personal injuries, though the engineer had a narrow escape from death.

(183.)— Two tubes burst, on June 24th, in a water-tube boiler at the Mahoning Valley Works of the Republic Iron & Steel Company, at Youngstown. Ohio. Fireman Patrick Harrington and helper Michael Lynch were scalded.

(184.)— On June 26th a tube burst in a water-tube boiler in the plant of the Public Service Corporation of New Jersey, at Passaic, N. J.

(185.)— On June 27th two flues failed in the boiler of the steam yacht *New-*

ark, near Milton on the Hudson, N. Y. Engineer William Cone and Steward Joseph Handy were badly scalded, and were taken to Vassar Hospital. The *Newark* is owned by Mr. William Steinwald, an architect in Liberty Street, New York. A part of her cabin was blown out by the explosion.

(186.)— The boiler of a sawmill exploded, on June 28th, at Buck Hollow, near Beaver, Ohio. Engineer Samuel Westfall was instantly killed, and Alexander Clements was fatally injured.

(187.)— The boiler of freight locomotive No. 177, of the Pennsylvania railroad, exploded, on June 30th, at Ehrenfeld, nine miles east of Johnstown, Pa. Engineer J. B. Wissinger, Fireman Daniel Crouch, and Flagman Charles Ross were instantly killed, and Conductor A. G. Boyle and Brakeman J. B. Smith were seriously injured. (The explosion here recorded occurred only fifty yards west of the site of a similar one which took place on February 22d of the present year, and which is recorded in the issue of The Locomotive for July, 1904, as No. 71.)

(188.)— On June 30th there was a slight explosion of a water-tube boiler in the dry goods store of Gross & Strauss, in Boston, Mass. The damage to property was trifling.

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(189.)— On July 5th a boiler exploded in the sawmill of Peters & Cairns, about seven miles from Haliburton, Ont. William Duncan was instantly killed, and William Winn was fatally injured. Several other persons were also injured to a lesser degree. The mill and machinery, valued at about $8,000, were totally wrecked.

(190.)— Four headers were fractured, on July 5th, in a water-tube boiler in the Bound Brook Woolen Mills, at Bound Brook, N. J. The damage to property was trifling.

(191.)— A tube ruptured, on July 5th, in a water-tube boiler at the electric light and power plant of The Public Service Corporation of New Jersey, Jersey City, N. J., injuring Patrick Reiley.

(192.)— Four tubes ruptured, on July 5th, in a water-tube boiler in the Consolidated Gas Company's plant, in New York city. Fireman James Walsh was scalded. The property loss was small.

(193.)— A boiler exploded, on July 7th, in Pfeifler & Burch's sawmill, at Wabmene, five miles south of Petoskey, Mich. William Reed, William Franks, and Thomas Dickerson were killed, and John Fortune was scalded so badly that at last accounts it was thought that he might die. Orange Judd was also thrown forty feet and slightly injured. The damage to the mill is estimated at from $3,000 to $5,000.

(194.)— Several tubes failed, on July 8th, in a water-tube boiler at the Union Ice Company's plant, at Newark, N. J. Fireman Robert Martin was scalded.

(195.)— On July 8th a slight boiler explosion in the Pittsburg Machine Tool Company's plant, at Allegheny, Pa. The damage was small.

(196.)— A tube burst, on July 8th, in a water-tube boiler at the plant of the Little Rock Railway & Electric Company, Little Rock, Ark. Cory Betts, a coal passer, was injured.

(197.)— The elbow of a blow-off pipe failed, on July 11th, at the Southern Engine & Boiler Works, Jackson, Tenn. Engineer O. C. Kelsoe was slightly injured.

(198.)— A tube ruptured, on July 12th, in a water-tube boiler at the plant of The Colorado Springs Electric Company, Colorado Springs, Colo. John Johnston was severely injured.

(199.)— On July 12th a tube burst in a water-tube boiler in the office building of the Ellicott Square Company, at Buffalo, N. Y. The property loss was small.

(200.)— A locomotive boiler exploded, on July 13th, at the Caswell Creek Coal & Coke Company's plant, at Simmons, W. Va. The accident consisted in the stripping of the stays in the crown sheet, from low water and consequent overheating.

(201.)— On July 13th a tube ruptured in a water-tube boiler in the Armour Elevator Company's grain elevator "Minnesota," at Chicago, Ill. Considerable damage to property resulted.

(202.)— On July 14th a boiler, used for operating a steam drill, exploded near the residence of H. G. Perry, on Moyer Street, Canajoharie, N. Y. Luigi Daksandri, who was running a steam drill over 100 feet from the boiler, was struck by a piece of the firebox and injured so badly that he died a few hours later. José Paranuchi and Engineer Frederick L. Beard were also injured severely, but not fatally.

(203.)— A tube ruptured, on July 16th, in a water-tube boiler at the Susquehanna Coal Company's plant, at Nanticoke, Pa., doing considerable damage, but fortunately injuring nobody.

(204.)— On July 17th a locomotive boiler exploded at C. D. Smith's sawmill, at Pinola, Miss. The property damage was small, and there were no personal injuries.

(205.)— On July 17th a boiler exploded in J. W. Broce's sawmill, at Shady Valley, Johnson county, Tenn. Columbus Stout, John Lowdy, and William Hamilton were seriously injured, but at last accounts it was believed that all three would recover. A large fragment of the boiler was thrown ninety feet up the mountain. We have seen no estimate of the property loss.

(206.)— A boiler exploded during the course of a fire, on July 18th, in the new power house of the East St. Louis & Suburban Electric Company, at East St. Louis, Ill. The loss, which was due to the fire rather than to the incidental explosion, was about $50,000. The boiler room in which the explosion occurred is 500 feet long, and is said to house the greatest system of boilers in southern Illinois.

(207.)— A hot-water boiler exploded, on July 22d, in the engine room of Ewing Hall, a building belonging to the Ohio University, at Athens, Ohio. The property loss was estimated at from $1,000 to $2,000. It does not appear that there were any personal injuries.

(208.)— On July 22d a boiler exploded in the Canadian Pacific railroad shops, at Toronto, Ont. Nobody was injured, but a great many men were thrown out of work.

(209.)— A hot-water boiler exploded, on July 23d, in the basement of the

Suburban Club, on Park Heights Avenue, near Pikesville, Baltimore, Md. Nobody was injured, but the building was damaged to the extent of about $400.

(210.)— On July 26th a boiler used for operating a traction engine exploded on Mr. J. L. Moody's place, at Russiaville, Ind. Walter Michael was badly scalded.

(211.)— A boiler exploded, on July 27th, in Inman Bros.' sawmill, near Minnowford, Giles county, Tenn. Engineer Bud Durham was killed, and the two Inmans who owned the mill were seriously and perhaps fatally injured.

(212.)— A tube burst, on July 27th, in a water-tube boiler in the Mound City Ice & Cold Storage Company's plant, at St. Louis, Mo. Nobody was injured, and the property loss was small.

(213.)— A slight boiler explosion occurred, on July 27th, in the Standard Ice & Fuel Company's plant, at Pittsburg, Kans.

(214.)— On July 27th a water-tube boiler ruptured at the plant of the American Glue Company, Boston, Mass. The boiler was considerably damaged, but nobody was hurt.

(215.)— A boiler exploded, on July 28th, on the steamer *Rhocean*, just after she had tied up to the dock at Boyne City, Mich. The passengers and crew had left the steamer, and hence there were no personal injuries. The end of the cabin next to the boiler room was smashed, and the cabin itself was showered with ashes and débris.

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(216.)— On August 1st a tube burst in a water-tube boiler in the Norfolk Cold Storage & Ice Company's plant, at Norfolk, Va. The property loss was small.

(217.)— A tube ruptured, and five headers fractured, on August 1st, in a water-tube boiler in Studebaker Bros.' plant, at South Bend, Ind. Nobody was injured.

(218.)— Mr. F. M. Leforgee was seriously injured, on August 2d, by the explosion of the boiler of a traction engine, at Germantown, near Willows, Cal. It is said that Mr. Leforgee was "testing" the boiler at the time. Since he was blown into a tree, and received a fracture of the skull and of one of his legs, we presume, as is usual in such cases, that the boiler was considered to be dangerous. Accidents of this nature frequently attend the testing of boilers by steam pressure, instead of the perfectly safe and equally effective hydrostatic test.

(219.)— On August 2d a boiler exploded in James Starks' sawmill, three miles north of Newpoint, near Batesville, Ind. Webster Smith, Charles Moulton, Frank Starks, and Edward Damaree were painfully but not fatally injured. The entire plant was totally destroyed. One portion of the boiler was thrown 500 feet eastward, and the rest was thrown 300 feet to the southwestward.

(220.)— The boiler of a threshing machine outfit exploded, on August 2d, at Wagner, near Inola, some thirty miles northwest of Muskogee, I. T. A. J. Austin was fatally injured, and two other men, one of whom was a Mr. Olmstead, who owned the outfit, were injured.

(221.)— On August 2d a rag-bleaching boiler exploded in the San Rafael paper mills, near Mexico City, Mex. It is reported that the cover to one of the stock openings became loosened, and that the second foreman of the department attempted to tighten up the bolts that held it, while the boiler was under pressure. An explosion followed, and three men were killed, and six others were badly injured. We have often tried to impress upon our readers the extreme danger of tightening bolts or making repairs upon boilers of any kind while they are under pressure; and accidents like this one demonstrate the soundness of our oft-repeated advice.

(222.)— A boiler exploded, on August 3d, in the enameled iron works of the Ingram & Richardson Manufacturing Company, at College Hill, near Beaver, Pa. The boiler house was somewhat damaged, but fortunately nobody was injured.

(223.)— Thomas McGee, a tool dresser, was instantly killed, on August 4th, by the explosion of a boiler at the Ashcroft oil well, at Fairmont, W. Va. The well was being drilled by the Hope Natural Gas Company.

(224.)— On August 7th a boiler blew up in the city stone-crushing plant, about five miles west of Ishpeming, Mich. The explosion took place at about eleven o'clock at night, when nobody was about. The report that we have received states that the explosion was due to dynamite, introduced into the boiler by some malicious person; but as we have often investigated reports of this character before, and found them without any adequate foundation in fact, we have but little hesitation in classifying this as a true boiler explosion, occurring under banked fires. It is so hard for an inexperienced person to realize the enormous damage that a boiler explosion can do, that it is by no means uncommon to attribute such explosions to dynamite.

(225.)— The boiler of locomotive No. 771, on the Lake Shore railroad, exploded, on August 8th, at Amboy, near Ashtabula, Ohio. Fireman Guy W. Amsden was fatally injured, and lived but a short time. Engineer Patrick Griffin was also seriously injured. The explosion consisted in the failure of the crown sheet.

(226.)— The elbow of a blow-off pipe failed, on August 8th, in the plant of the Pennsylvania Stave Company, at Cross Forks, Pa. Fireman M. W. Whittier was scalded.

(227.)— A boiler exploded, on August 8th, on the Kurtz farm, near Findlay, Ohio. William Thompson was seriously injured, but at the last reports it was thought that he would recover.

(228.)— On August 9th a boiler exploded in the plant of the Guthrie-Tuck Manufacturing Company, at Homer City, Indiana county, Pa. C. W. McGee was injured. The boiler house and blacksmith shop were completely wrecked, and the main building was considerably injured. The property loss was estimated at from $4,000 to $6,000.

(229.)— A tube burst, on August 11th, in a water-tube boiler at the Algonquin Hotel, Dayton, Ohio. Nobody was injured, but the damage to property was considerable.

(230.)— A boiler exploded, on August 11th, in Smith's sawmill, Walsingham Township, near Langton, Ont. Isaac Leworg and Norman Wingrove were killed, and John Leivorage was injured. The mill was wrecked, and the ruins took fire.

(231.)—The boiler of a threshing machine outfit belonging to Michael Collins exploded, on August 11th, on William Grant's farm, three miles east of Hudson, Wis. Henry Cushman and John Jensen were injured, and the threshing machine was totally wrecked.

(232.)—On August 12th a boiler used for pulping rags exploded in the plant of the Kinleith Paper Mills, on the old Welland Canal, in the western part of St. Catherines, Ont. Edward Hudson was injured, but nobody was killed. The explosion entirely demolished the western wing of the mills, three stories high, in which the boilers were situated, scattering brick and timbers in all directions. The property loss is estimated at from $15,000 to $20,000.

(233.)—The boiler of a locomotive on the Colorado Springs & Cripple Creek District railroad exploded, on August 13th, near South Cheyenne canyon, some sixteen miles from Colorado Springs, Colo. Engineer D. O. D. Everett, fireman E. W. Gowans, and head brakeman Nathan Alexander were seriously injured. The explosion consisted in the failure of the crown sheet of the locomotive.

(234.)—On August 13th the boiler of a locomotive exploded in the middle yard at Packerton, near Mauch Chunk, Pa. Engineer Harry Xander was terribly and perhaps fatally scalded. The explosion appears to have consisted in the failure of the staybolts about the furnace.

(235.)—The crown sheet of a locomotive blew out, on August 15th, on the Great Northern railroad, three miles west of Wellington, near Everett, Wash. Fireman O. F. Stand was fatally scalded.

(236.)—The boiler of a threshing machine outfit exploded, on August 15th, at Spring Prairie, near Burlington, Wis. Gilbert Vaughn, who was in charge of the engine, was seriously injured, and another man, whose name we have not learned, was injured in a lesser degree.

(237.)—On August 15th a boiler exploded in J. F. Arnold's sawmill, some five miles from Senoia, Ga. J. F. Arnold, Buford Arnold, J. S. Carden, N. L. Carden, and two other men, whose names we have not learned, were killed. Alton Shipp and Oscar Gresham were seriously injured.

(238.)—A small boiler used for roasting peanuts exploded, on August 16th, at Warsaw, N. Y. John Frank was severely and propably fatally injured. The property loss is estimated at $1,200.

(239.)—A cast-iron section of a water-tube boiler exploded, on August 16th, in the plant of the Tremont Nail Company, at West Wareham, Mass. John Gosenski was injured.

(240.)—A boiler belonging to Charles Little exploded, on August 17th, at Batson, Texas. One man was severely scalded, and the boiler was thrown seventy-five yards.

(241.)—On August 19th a boiler exploded in the factory of the Wright Wire Company, at Palmer, Mass. There were no personal injuries, but the boiler house was considerably damaged.

(242.)—A boiler exploded, on August 20th, in the Franklin Iron Works, at Port Carbon, near Pottsville, Pa. Jesse Turner was seriously scalded, and the plant was disabled.

(243.)—The boiler of a traction engine exploded, on August 20th, at Glenwood, near Rushville, Ind. John Daubenspeck was fatally injured, and John Herschel and Sherrod Daubenspeck were injured seriously, but not fatally.

(244.)—The boiler of a threshing machine outfit exploded, on August 21st, on the Richard Correll farm, three miles northeast of Media, Ill.

(245.)—A tube burst on August 22d, in a water-tube boiler in the plant of the Norfolk Ice Corporation, at Norfolk, W. Va. Nobody was injured.

(246.)—On August 23d a boiler exploded on the Thorp oil lease, near Oil City, Pa. Nobody was injured.

(247.)—A boiler exploded, on August 24th, in one of V. R. Harris' heading mills, at Erin, Tenn. James O'Guine, Samuel Baler, Gilbert French, Luke French, John Cook, and a man named Morgan were more or less seriously injured. It is thought that Gilbert French and John Cook may not recover.

(248.)—On August 24th a boiler exploded in J. Baumback cheese factory, at Bloomfield, near Titusville, Pa. Robert Stanton was quite badly injured.

(249.)—A boiler exploded, on August 25th, at the plant of the Green Bay Phosphate Company, at Green Bay, near Lakeland, Fla. George Davis, Mack Waters, Simon Stanley, and Andrew Reed were killed. John Johnson, Joseph Davis, John Stakely, John Harris, and one other man, whose name we have not learned, were more or less seriously injured. The property loss is estimated at $10,000.

(250.)—The boiler of a threshing machine outfit exploded on August 30th, on George Hirschmann's farm, at Centerville, near Manitowoc, Wis. Mr. Hirschmann's nine-year-old son received injuries which, at last accounts, were believed to be fatal.

(251.)—On August 30th a boiler exploded in William Gaynor's sawmill, on White Fish Lake, near Spooner, Wis. Mr. Gaynor was badly injured, and the mill was damaged to the extent of about $600.

Human Fallibility.

The fact that the human mind cannot be reduced to a mathematical basis, and that human nature cannot be depended upon, unvaryingly, to do what it should, makes the human element in engineering practice something to be conjured with. We see this in all departments of engineering. Men of previously irreproachable standing, and to whom important duties have been assigned in all confidence that these duties will be faithfully and correctly performed, will occasionally fail at a critical moment to do what is reasonably expected of them, even when the failure involves the most serious consequences, not only to others, but also to the offender himself. A temporary mental stress, or a slight disturbance in physical condition, and the trusted man will occasionally do the last thing that would be expected of him.

Mr. Victor Hugo, Chief Inspector for the Hartford Steam Boiler Inspection and Insurance Company in its Southwestern Department, has made a brief but interesting analysis of the railroad accidents that have occurred in the United States during the first half of the present year, for the purpose of exhibiting the importance of the element of human fallibility in railroad engineering, and his results are given in the accompanying table. The accidents tabulated resulted in the death of 31 persons, in the injury of 164 others, and in the destruction of property valued at something like $300,000. From this table it appears that 68 per cent. of the accidents were due entirely to the mental or physical state of the human agent. This does not mean, of course, that the efficiency of railroad employees is only 32 per cent., for we are taking no account of the thousands of cases in which he does *not* fail. The table shows, however, that when there *is* an accident, the odds are two to one that the man is at the bottom of it.

It would be highly interesting to have a similar table for the accidents that occur in boiler practice, since a tabulation of this sort would have a closer bearing upon our business. It does not appear to be possible, however, to obtain equally clear evidence as to the causes of boiler accidents.

CAUSES OF RAILROAD ACCIDENTS.

Nature of cause.	Percentage of accidents due to the cause assigned.	Remarks and Explanations.
"Mistake," . .	28	Mostly mistakes in receiving or giving signals, or in writing or reading orders.
"Forgot," . . .	24	Just "forgot to carry out orders."
"Confused," . .	8	Properly classifiable as mistakes, but separated here because attributable to excitement.
Physically incapacitated.	8	Men fell asleep, presumably on account of previous exposure or exhaustion.
Malice, ...	4	Malicious interference from persons not employed by the railroad.
Elements, . . .	12	Fog; snow-storm; heat of the sun.
Defective equipment, .	16	Failure of air-brakes and of car-wheels.

We have received, from the publishers, a copy of the first part of Professor William Ledyard Cathcart's treatise on *Machine Design*. The present volume is entitled *Fastenings*, and it is devoted to the consideration of shrinkage and pressure joints, screw threads, riveted joints, and keyed and pin joints. The work is well illustrated, and will be a welcome addition to the library of any engineer who has to deal with the subjects of which it treats. The preface states that "the main purpose of this book is to present, in compact form for the use of the student and designer, modern American data from the best practice in the branch of machine design to which the work refers." The text itself appears to bear out in a satisfactory manner this somewhat ambitious purpose, and we recommend the volume to the consideration of our readers, very sincerely. (The D. Van Nostrand Company, 23 Murray St., New York. Cloth, $3.00.)

The title page and index to the volume of The Locomotive that is completed with this number may be had upon application to the Hartford office of this company.

The Locomotive.

FOUNDED BY J. M. ALLEN, A.M., M.E.

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THE LOCOMOTIVE *can be obtained free by calling at any of the company's agencies.*
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MR. CHARLES SPAFFORD BLAKE, who was elected to the position of Supervising General Agent of the Hartford Steam Boiler Inspection and Insurance Company, by its Directors, on July 12, 1904, has had a wide and somewhat varied experience in steam engineering. He was born at Windsor Locks, Connecticut, on October 25, 1860, and at an early age entered the employ of the Central Iron Works at Jersey City, where he served an apprenticeship of about three years, and where he had extensive experience, both in construction and in repair work, upon marine boilers and engines. Before he was twenty-one years of age he was granted a special license as a marine engineer by the United States Steamboat Inspection Service, afterwards receiving a license as chief engineer. His work then alternated between stationary and marine engineering until September, 1884, when he accepted a position as inspector of boilers for an insurance company, being subsequently advanced to the position of chief inspector and adjuster. On June 1, 1898, he entered the service of the Hartford Steam Boiler Inspection and Insurance Company as its general agent. His present advancement to the office of supervising general agent has been earned by faithful service, and the appointment has proved to be a very popular one among Mr. Blake's friends and business associates.

A. D. RISTEEN.

"Report" of the U. S. Naval Liquid Fuel Board.

The *Report* of the Board appointed by the United States Navy Department for investigating the subject of liquid fuel is at hand, and inspection shows, as was to be expected, that it is filled with information of great variety and value. It forms a large volume of 450 pages, and any review of it that would be at all adequate would be quite too long to be printed in the pages of THE LOCOMOTIVE. Hence we can only present a few remarks concerning its contents, and an extract giving the general conclusions to which the Board has been led by its investigations. We may say, however, that the *Report* is one of the most valuable recent contributions to engineering literature, and that it is indispensable to any engineer who has to deal with oil fuel.

The tests that are here described were carried on practically without intermission for more than two years. A Hohenstein water-tube boiler was employed throughout the trials, and a series of tests was conducted with Pocahontas and New River coal, before beginning the work with the oil, in order that a fair comparison might be made between oil and coal. Analyses were made of each kind of coal and oil that was used; the moisture of the steam was determined by a Barrus throttling calorimeter; and, in fact, every care appears to have been taken to obtain results that would be really accurate and valuable.

The *Report* is well illustrated, and, beginning with page 338, it gives an exceedingly interesting and instructive classification of the various forms of burners that have been used or proposed. It could not be expected that every form of burner would be shown, for the patent offices of the world are known to have several thousand designs on file, and it has been well said that the oil-fuel burner has received almost as much attention from inventors as the car-coupler. The classification is perforce of the broadest kind, and all burners are divided into five general classes, which are subsequently considered in further detail. Beginning with page 374, the various forms of furnaces which have been tried or suggested are also considered in like manner. Special forms of burners, which were actually used in the trials, are illustrated in the *Report*. Some of these were illustrated in the issue of The Locomotive for January, 1903.

The oil that was used was from the Texas and California fields, for the reason that the output of these fields is not entirely absorbed for illuminating and commercial reduction. No attempt was made to determine the evaporative efficiency of either the Pennsylvania or the Ohio crude petroleum product, since practically the bulk of the supply of these districts, pumped through the pipe-line to the Atlantic coast, is used for illuminating purposes. The Beaumont (Texas) oil is "said to have been subjected to an inexpensive treatment which removed the sulphur and some of the more volatile hydro-carbons." The chemical compositions, and the estimated calorific values of the oils were determined, and the results are given in the *Report*, beginning with page 68. The Beaumont oil was mainly used in the trials.

The *Report* states that the generally received opinion that the use of oil as fuel will be certain to do away with the smoke nuisance is erroneous. Thus on page 398 we read: "One of the principal reasons heretofore advanced for the general use of oil rather than coal, as a fuel for naval purposes, was the advantage that would accrue from the abolition of smoke. It seemed to be regarded as a matter of certainty that with the use of oil, complete combustion of the fuel could be secured before the gases reached the base of the funnel. And yet on shore the burning of oil, as fuel, in large quantities, has been carried on only with extreme difficulty as regards smoke, particularly when there has been an attempt made to force the fires. An examination of the remarks made in connection with the different oil-fuel tests of the Board will show that whenever an attempt was made, under severe forced-draft conditions, to secure an exceedingly large evaporative capacity, the smoke nuisance was encountered.

"Careful and long-continued observations upon the question of preventing smoke convinced the Board that with the use of water-tube boilers, as compared with the fire-tube boilers, the difficulty of effecting complete combustion before the gases reached the base of the stack had enormously increased."

On the subject of the available supply of fuel oil, the *Report* says (page 416): "Careful consideration has been given the question as to the supply of crude petroleum in the United States available for fuel purposes. This matter has been specially investigated by Prof. Arthur L. Williston, of the Pratt Institute, Brooklyn, N. Y., who reports as follows: 'The supply of oil which is available for fuel in the United States, therefore is (1st) the small percentage (probably not over 2 or 3 per cent.) of the total production of the Pennsylvania and Ohio oil which constitutes the residuum from the process of refining; (2d) crude oil from the Ohio and Indiana fields, wherever the price of coal makes the burning of oil at 95 cents or one dollar per barrel (plus freight) profitable; (3d) those portions of the California oil which are not best suited for refining; and (4th) practically the entire output of the Texas field.' The demands for the better grades of oil for refining purposes will probably keep pace with its production; consequently we can never expect to see such grades of oil compete with coal to any large extent. On the other hand, the refining value of the Texas oil and much of the California oil is so low that its value will probably always be largely controlled by the demand for it for fuel purposes. It is inconceivable that a fuel that has so many distinct advantages, and which is not unlimited in its supply, should sell in all markets at a price which would make it cheaper to burn than coal. Any great demand for such a fuel would bring up its price at once. On the other hand, so long as there is an assured supply of Texas and California fuel oil, the price of such oil as has little intrinsic value for refining will probably remain low enough to enable it to compete successfully with coal, in those regions where coal is scarce in quantity and poor in quality. And the area in which this condition exists is sufficiently wide to create a demand for the fuel oil that will soon equal the supply, unless further stores of oil are found as the demand for it increases. The fact should be remembered that in every oil region there is, with each succeeding year, a progressive proportionate increase in the percentage of the yield consumed for illuminating purposes."

Following are the general results which the Board considers that its experiments with oil fuel have established:

CONCLUSIONS DERIVED FROM A COMPARATIVE STUDY OF THE COAL AND OIL TESTS.

In view of the cost incurred and the labor involved in conducting these experiments, the manufacturing as well as the maritime world will be most interested in noting the practical conclusions reached. It is hoped that the engineering profession will find much interest in and attach proportionate value to the data collected.

As a result of the extended series of tests, the following conclusions have been drawn:

1. That no difficulty should be experienced by an intelligent fireroom force in burning oil in a uniform manner. It need likewise require but little experience upon the part of skilled water tenders to be able to detect, either from the character of the roar or hissing noise or by the color of the flame at different points an approximate idea both as to evaporative output and efficiency conditions.

2. For general purposes on shore, high-pressure steam is a more satisfactory spraying medium than air. The use of steam, however, as an atomizing agent for naval purposes will undoubtedly require a considerable increase in the size of the evaporating plant, and this must be considered of importance. The necessary increase of the evaporating plant is practically the main objection to the employment of steam as the spraying medium for liquid fuel on board naval and merchant vessels.

3. While the use of steam as a spraying medium will undoubtedly prove most satisfactory for general purposes, the results of the tests show that the consumption of fuel oil cannot be forced to as great an extent with steam as the atomizing agent as when highly heated compressed air is used for this purpose. As the warship is designed to be operated at short notice under the severest forced-draft conditions, the question will have to be considered whether it is not more advisable to fit air burners that would be found most efficient for

the day of battle, rather than effect an installation of steam burners that are most desirable for general cruising. The advantages of air as the best spraying medium for severe forced-draft conditions is due to the fact that this atomizing agent, after entering the furnace, is a supporter of combustion. With the use of steam as the atomizing agent, the rarefied vapor simply displaces a certain portion of air that is requisite for complete combustion. If it were not for the fact that air compressors necessary for supplying an atomizing agent are very bulky and heavy, and require considerable room for their installation, the question might be considered, whether for warship purposes it would not be advantageous to effect an installation whereby either air or steam could be used at will.

4. That in every oil-fuel installation special provision should be made for the removal of the water that will collect from various sources at the bottom of the supply tanks. Even a small amount of water pumped to the burners will interfere with the efficient and satisfactory work of an oil-fuel installation. As it is essential with every boiler plant to secure a uniform if not large output, the annoyance and evil of occasionally pumping water rather than oil to the burners cannot be overestimated.

5. That the evaporative efficiency of crude and refined oil is practically the same, no matter from what locality the oil may come. The danger of using crude oil, however, is much greater. As it should not be an expensive matter to build refineries near one of the terminal points of a pipe line, the expense of such refining should not increase to a perceptible degree the cost of such fuel, since the sale of the by-products of crude oil would often pay in great part the expense of distillation.

6. The great benefit of heating the air necessary for effecting combustion cannot be doubted.

7. In order to provide a uniform supply of oil to the burners the oil should be heated by some simple means. It can be expected that the burners will be operated much more satisfactorily when oil is thus heated. It being understood that the heating has been carried only to a point well below the temperature of the deposition of the hydro-carbons.

8. Where the use of a liquid-fuel installation is projected, there should be a reserve of burners installed, and these burners should be of a design that would permit rapid examination, thorough overhauling, and easy renewal of special parts by the fireroom force. Careful experiment as well as extended experience have shown that by increasing the number of burners there is not only a more uniform but a more efficient distribution of flame. There is also a minimizing of the blowpipe effect, as well as a marked reduction in the amount of noise in the furnace.

9. That the hygrometric state of the atmosphere has a noticeable influence upon the efficiency and capacity output of boilers.

10. In order to secure in oil-fuel installations more uniformity of conditions in the furnace, and to decrease the noise where air is used as a spraying medium, an air-cushion tank for the oil-supply pump should be installed. Such a tank would break the pulsations of the pump and serve a similar purpose as the regulating air chamber of an ordinary feed pump.

11. In view of the liability of every form of burner to clog, the necessity of making special provision for straining the oil was emphatically shown. It would be extremely advisable to install a strainer both on the suction and discharge pipes of the oil-feed supply. These strainers should be of a design that would permit rapid examination and renewal, and one patterned after the Macomb type would meet all general requirements.

12. Extended experience in the burning of crude oil will confirm the opinion that the simpler the furnace the greater its efficiency. The erection of brick arches only tends, in many cases, to reduce the volume of space necessary for effecting complete combustion. In Scotch boilers there should be a simple vertical brick lining of the back combustion-chamber wall and a lining of the front end of furnace for about a third of its length.

13. That no design of oil-fuel installation should be permitted for marine purposes which would not permit the renewal within twenty-four hours of all grate and bearing bars, so that a return to coal could be accomplished within a reasonable time in case of failure of oil supply.

14. Where oil is used as a fuel in a Scotch boiler the introduction of retarders in the tubes will undoubtedly increase the evaporative efficiency of the boilers. The use of retarders will prove beneficial by reason of the fact that such devices not only prevent the heated products of combustion from passing too freely through the tubes, but likewise cause a more uniform distribution of these gases in their passage through the tubes to the base of the stack. In thus causing a more uniform and effective heating of the tubes the liability of the end of the tube to be burned is undoubtedly diminished. With oil as a fuel, but little soot forms on the heating surfaces of the tubes. Where retarders are not used in large tubes in an oil-fuel installation it is reasonable to presume that a certain portion of the gases of combustion reaches the smokestack without coming into contact with any of the boiler surfaces. Where coal, however, is used as a fuel in a Scotch boiler the resulting coating of the tubes by soot generally reduces their sectional area to a degree sufficient to materially impede the flow of the gases of combustion, and therefore under such conditions the gases reach the base of the stack at a comparatively low temperature. Where oil is properly burned it can be regarded as a fact that the velocity of the flow of the gases is greater than where coal is used, and therefore retarders should be used in the case of fire-tube boilers and increased baffling in the case of water-tube boilers.

15. An important point established has been that the calorimeter openings of water-tube boilers should be less than in the case of the Scotch boiler, whether oil or coal be used as a fuel.

16. That marine firemen are not ill-disposed toward the use of oil. It will be essential, however, particularly for marine work, to secure intelligent men for the operation of the burners. It will be found that resulting financial economy will ensue by intrusting the management of oil-fuel installations to men of skill and judgment. Cheap labor cannot be employed in this work; there will be resulting damage, annoyance, and danger if the operation of oil-fuel burners is assigned to unskilled labor.

17. That the efficiency of oil plants will be primarily dependent upon the character of the installation of fittings and auxiliaries. The form of the burner, so long as it is manufactured in accordance with general well-known principles and all its parts are accessible for overhauling, will play a very small part in extending the use of crude petroleum. The method and character of the installation, however, are all important, and therefore the work of designing and constructing such a plant should only be intrusted to those who have given careful study to the matter and who have had extended practical experience in burning the crude product. Consumers should take special care that they neither purchase appliances that have been untried nor permit the installation to be effected by persons who have had but limited experience in such work.

18. Where crude petroleum has undergone a light refining or distillation no ill effects result to modern steel boilers. From the standpoint of endurance of the boiler, the advantage, if any, is with oil. Crude oil, however, by reason of its searching and corrosive effects, has a greater tendency than refined oil to attack the seams and tubes of modern boilers. For marine work, therefore, no crude petroleum should be used, and particularly for ships making long voyages, the fuel oil should undergo some mild distillation before being placed in the tanks.

19. That in the stowing of liquid fuel on board vessels, whether taken on board for fuel purposes or for transportation in bulk, the compartments containing the crude product should be as few as possible, both for reasons of safety and for facility of delivery and discharge.

20. That with the use of oil the forcing of a marine boiler should be much more readily accomplished than with the use of coal.

21. That under severe forced-draft conditions and with water-tube boilers and with the use of oil as a fuel the solution of the smoke question is nearly as remote as ever. Where a limited quantity of oil is burned in a Scotch boiler, however, and retarders are used in the tubes the burning crude petroleum should be smokeless.

22. The value and necessity of installing a series of draft gauges between the ash pan and the base of the stack were conclusively shown. As a result of the study of the draft conditions at different points there were changes made in baffling the gases which were of decided benefit. It is therefore recommended that for experimental purposes a series of draft gauges be fitted to the boilers of several large ships, since the board is of the opinion that marked gain as to both the efficiency and capacity of naval boilers would be secured by a careful observation and study of the draft condition at various points between ashpan and smokestack.

23. In order to secure for the day of battle increased speed for warships, naval administrators are justified in demanding of manufacturers of water-tube boilers increased coal consumption per square foot of grate surface. The weight thus saved in the reduction of the number of boilers should be exclusively applied to giving the machinery greater endurance by using heavier boiler linings and casings and more substantial auxiliaries. The space gained in the reduction in the number of boilers should be assigned to providing increased sized firerooms, evaporator rooms, and passageways in the boiler compartments. The fireroom conditions on board the modern battleship could not be much worse, whether viewed from the standpoint of providing for sanitary stokeholds or for an arrangement of firerooms where not only efficient stoking can be carried on, but an installation should be made in which there are adequate facilities for rapidly effecting routine examination and repairs. It is not surprising that there is excessive expenditure as regards cost of repairs, as well as rapid and excessive depreciation, and that the boiler endurance is exceedingly limited when marine steam generators are crowded in the manner in which they are now installed. Under existing fireroom conditions, auxiliary feed and bilge pumps are likewise installed directly in the firerooms and even in niches cut out of the bunker compartments. As now arranged, the character of the installation of these appliances not only interferes with efficient stoking and repairs to the boilers, but the pumps themselves are constantly under either repairs or examination, due to the dust and grit which settle upon their working parts and thus cause their early renewal. There can be no satisfactory installation of either coal or oil-burning appliances

until an increase of space is allowed for the operation and preservation of boiler installation.

24. The absolute lack of endurance of both Scotch and mica water-gauge glasses for installation in boilers carrying over 250 pounds pressure and subject to forced-draft usage was conclusively established. Reflex water-gauge glasses should alone be used on boilers which are subject to heavy forced-draft conditions.

25. Practically every form of commercial firebrick that was used in the boiler for the purpose of forming a deflecting arch disintegrated either under the action of the intense heat generated, or due to the action of the acids in the oil or coal. In case any form of arch or bridge wall is essential to the efficient or forced burning of liquid fuel, then special experiments should be conducted to secure a refractory brick that would possess endurance under the severest of forced-draft conditions.

26. For naval installations there should be supplied a fuel oil that will not flash under 175° F. The higher flash point required for naval than for merchant vessels is essential for the following reasons:

(*a*) The war vessel must be kept in readiness to proceed to the tropics at immediate notice, and the firing of the guns subjects the naval ship to danger conditions to which other types of vessels are not exposed.

(*b*) The fitting of numerous transverse bulkheads and a protective deck in a naval installation, combined with the fact that both machinery and boilers are exceedingly crowded, makes it extremely difficult to properly ventilate certain compartments, and therefore in warships it will be necessary to use special precautions both in the stowing and in the handling of oil fuel.

(*c*) The fact that a large number of men must be permanently housed beneath decks on the naval ships will make it difficult to prevent the use of open lights in some of the lower compartments, and thus the danger of using oil as a fuel from this cause will always be greatest in naval vessels.

27. There should be no attempt made to use oil as auxiliary or supplementary to coal. Such an installation is certain to prove unsatisfactory, and the solution of the oil-fuel problem for naval purposes is only delayed by any attempt to inject a limited supply of oil fuel over a bed of incandescent coal. The mechanical feature of the problem having been satisfactorily met, the good of the service requires that any installation attempted should depend alone upon oil as a fuel and not any combination with coal.

28. In maritime construction no oil fuel should be carried in compartments directly beneath the boilers. In case such compartments should ever be used as oil reservoirs, there might be danger of radiated heat from the boilers volatilizing and exploding some of the hydro-carbons of the fuel oil. In case, also, there was any puncturing of the inner bottom, the hot ashes might reach the oil. The possibility of oil also reaching the bilges through improper manipulation of the valves of the manifold boxes is especially liable to happen.

29. The importance and necessity of always possessing a reserve supply of superior fuel were strikingly impressed upon the board, for during both the coal and oil experiments there was resulting delay due to the non-delivery of fuel. Special effort was taken at all times to maintain a reserve supply of coal, but from causes beyond the control of the board shipments of such fuel would be delayed. Particularly was it found difficult to secure hand-picked coal of superior quality, and in one instance such fuel could only be secured within reasonable time by having it shipped at express rates to the experimental plant. The

necessity of maintaining at every naval station a large invoice of hand-picked coal of the very best quality, to be utilized for emergency and experimental purposes, was repeatedly emphasized. As for a reserve of coal for war purposes, it is highly probable that in a contest for the command of the sea an adequate reserve of fuel may be only one remove in importance from the possession of a reserve of ships.

30. In view of the fact that 48 per cent. of the world's output of crude petroleum is produced in the United States, and that practically our entire yield is secured from fields which are in pipe-line communication with important maritime and strategic ports, the board considers that a joint commission, representing commercial, manufacturing, maritime, and naval interests, should be authorized by the Congress, whose province it would be to formulate such rules and regulations as would provide for an economical, efficient, enduring, and safe oil-fuel installation. Heretofore the oil-fuel problem has been principally investigated by various individual interests which have sought to secure information along certain lines. As a result there has not been obtained that knowledge of the subject which would give to the country at large such development of the use of crude oil as a fuel as would be warranted, considering the natural advantages possessed by the United States in having at its command near great seaports such a large proportionate supply of the world's production of the crude product. Particularly for the development of our commercial interests in the Gulf of Mexico and on the Pacific coast should the work of such a commission have an important influence in extending our prestige and power, whether viewed from a commercial, maritime, or naval standpoint.

31. The board regards the engineering or mechanical feature of the liquid-fuel problem as having been practically and satisfactorily solved. For manufacturing purposes the financial and supply features are the only hindrances to the use of crude petroleum as a standard fuel. For mercantile purposes the commercial and transportation features of the problem are existing bars which limit the use of oil fuel in merchant ships. For naval purposes there is the additional and serious difficulty to be overcome of providing a satisfactory and safe structural arrangement for carrying an adequate bunker supply.

32. That in the consideration of the problem of attempting to use oil as a fuel for either marine or naval purposes it should be particularly remembered that, by reason of the economic and commercial demands for crude oil for illuminating, lubricating, and other purposes, the available supply of the world's production of crude petroleum that could be used as a fuel would not meet over 3 per cent. of the world's demand for coal and other combustibles. For a time, therefore, the effort should be made to use oil fuel only for special purposes in particular localities.

33. The board considers that what will eventually be recognized as the most important result of these extended experiments is the collection of a great mass of trustworthy data concerning the comparative value of coal and oil as a fuel under various conditions. It should be observed that this data was secured with painstaking care and checked at the earliest practicable time after each test. Wherever it was found that discrepancies existed in any experiment, the test was repeated, in order to discover if possible the cause of the inconsistency. There have also been secured very complete and trustworthy data in regard to boiler efficiency and capacity.

The Locomotive

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Rascality in Bolts.

The illustrations that we present in connection with this article show very clearly that a boiler inspector needs to be exceedingly careful in passing judgment even upon new work. The bolt which is shown in Fig. 1 is one of several which were ordered removed from a new system of piping erected in a large steam plant, subject to examination and approval by an inspector of the Hartford Steam Boiler Inspection and Insurance Company. These bolts were used to join pipe flanges, and it was found that quite a number of them were too short, so that it was impossible to screw up the nuts upon them sufficiently to make the bolts enter more than from one-half to two thirds of their depth. When this defect was observed by our inspector, and notice of it was given to the contractors, a workman was sent to replace the short bolts with others of proper length. The piping ran across the upper part of the boiler room, and the air about it was exceedingly hot and uncomfortable, so that the task of replacing the bolts was a very unpleasant one. The workman bought the required number of

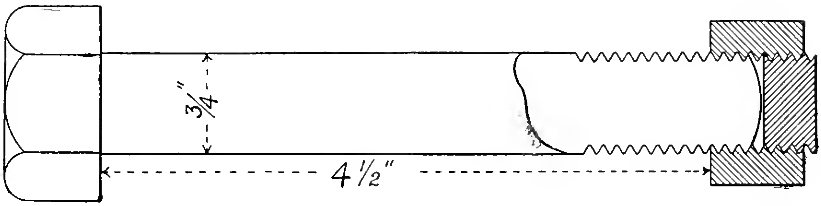

FIG. 1. — SHOWING "STUB END" OF BOLT IN POSITION.

bolts, but not liking the task of putting them in properly, he sawed off stub ends from them, and ran these stub ends into the nuts that were already on the pipe, so that the stubs projected one or two threads. To a casual observer it would appear, after this operation, that the old bolts had been replaced by others of proper length, and our inspection department was notified that this had been done. Our inspector, accompanied by the chief engineer, then made a further examination of the piping, so that he could certify, from his own personal knowledge, that everything had been put into proper condition. Upon close examination, it was observed by the inspector that the projecting ends of the bolts showed marks as though a hack-saw had been used upon them. There would be no objections to the bolts projecting a little too far through the nuts, and as the air was very hot and uncomfortable (as we have already said) about the pipe line, it was impossible to understand why the workman should have taken the trouble to cut off any such projection that might have been left. A still closer examination followed, and it was found that all of the short bolts, to which we had objected, still remained in the pipe flanges, with these stub ends made into the nuts.

Fig. 1, when taken in connection with the description already given, will make the nature of the difficulty perfectly plain. In Fig. 2 we present a view, which is practically full size, of one of the stub ends that were removed. The marks of the hack-saw are visible upon the end of it, though they are somewhat indistinct.

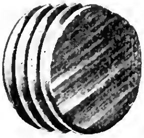

FIG. 2.

It is needless to say that the contractors, upon being notified of the state of affairs, immediately had the work done right, and we have no doubt that they dealt properly and justly with the workman who did the rascally job, and who had preferred to take chances of serious accident, destructive alike to life and property, rather than to subject himself to the temporary discomfort involved in doing the work as he knew it should be done.

Boiler Explosion in an Ice Plant.

We present, herewith, three photographic views illustrating a recent boiler explosion in an ice factory. The boiler house contained four horizontal tubular boilers, set side by side, the one which exploded being the third, counting from the left hand end. It was 60 in. in diameter and 19 ft. 3 in. long, with 56 four-

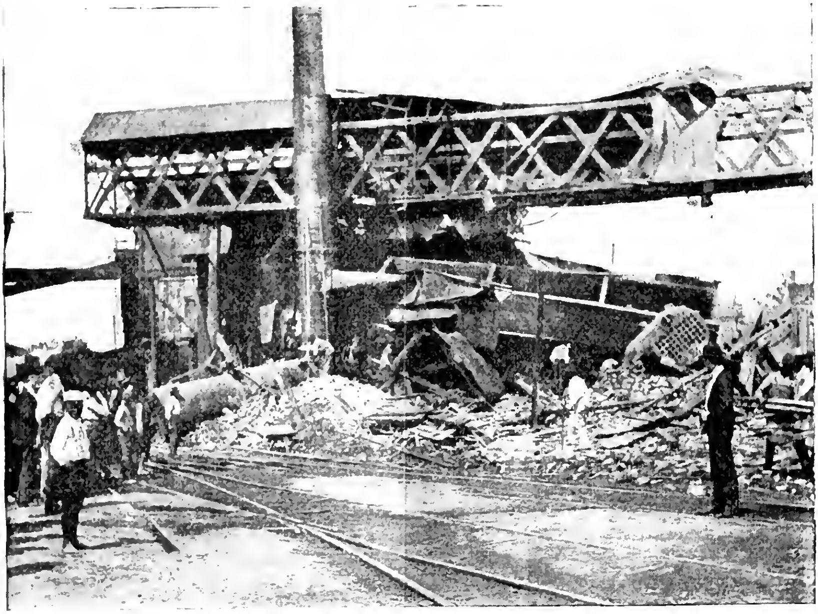

FIG. 1. — GENERAL VIEW OF RUINS.

inch tubes, 18 ft. long. The shell was 11/32 in. in thickness. The initial rupture took place in the center course of the boiler, along the horizontal joint, each course being composed of a single plate. After the explosion, unmistakable evidence could be seen of an old fracture, which lay between the rivet holes and the edge of the lap of the joint, and which extended along the joint for a dis-

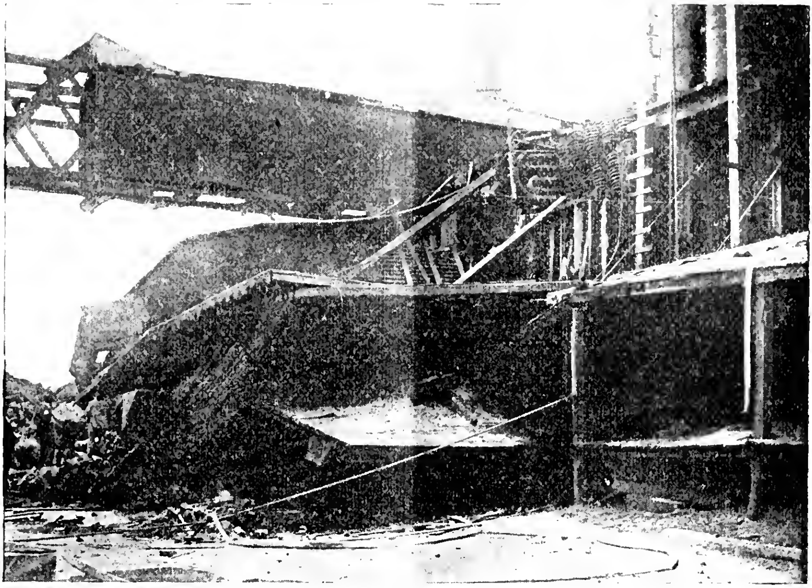

Fig. 2. — General View of Ruins.

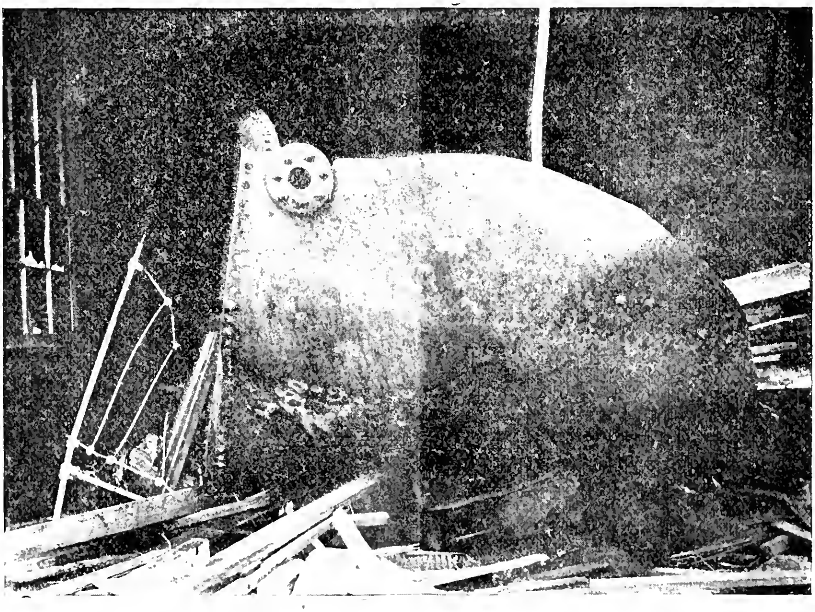

Fig. 3. — Portion of Rear Sheet of Boiler.

tance of about five feet, not actually entering the rivet holes at any point save at the very end.

One man was killed by the explosion, and five other persons were seriously injured. The property loss, from the explosion alone, was something like $7,000; but the wrecked building caught fire, and further damage resulted before the flames could be extinguished. General views of the ruins are presented in Figs. 1 and 2, while Fig. 3 shows a fragment of the rear sheet of the boiler.

Inspectors' Reports.

On page 117 we present a general summary, by defects, of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company during the months of September, October, and November, 1904. We also give, below, a summary for these months, showing the number of visits of inspection made, the total number of boilers examined, the total number inspected internally, the number tested by hydrostatic pressure, and the number of boilers condemned.

	MONTH (1904).		
	September	October	November
Number of visits of inspection,	13,441	13,901	15,831
Total number of boilers examined,	24,357	27,781	24,118
Number inspected internally,	9,360	10,090	8,951
Number of hydrostatic tests,	1,137	1,113	1,031
Number of boilers condemned,	70	40	42

Boiler Explosions.

SEPTEMBER, 1904.

(252.) — A boiler exploded, on September 1st, in John Biggs' cotton gin and sawmill, at Paragould, Ark. Alonzo Biggs was instantly killed, and Luther Biggs, Louis Jackson, and Richard Seay were more or less seriously scalded and bruised.

(253.) — On September 5th the boiler of a threshing machine outfit exploded on George Halverson's farm, three miles north of Bricelyn, Minn. Christopher Sunde, James Seymour, Abraham Foster, Willard Gallyon, and Peter Daley (the owner of the outfit) were killed, and George Halverson was badly injured.

(254.) — James Cunningham was killed, on September 7th, by the explosion of a threshing machine boiler, near Fingal, N. D. The separator man was somewhat bruised also, but not seriously hurt.

(255.) — The boiler of a Lake Shore locomotive exploded, on September 8th, at Silver Creek, near Dunkirk, Pa. Fireman John Gress was instantly killed, and engineer George Mansfield was painfully but not fatally scalded.

(256.) — A boiler exploded, on September 14th, in the plant of the Toronto Bolt & Forge Company, at Sunnyside, near Toronto, Ont. Frederick Jones and William Dixon were fatally injured, dying after being removed to the Toronto Emergency Hospital. Alexander Watson, George Woods, Albert Durnford, James Hall, and Charles Jolley were also seriously but not fatally injured. The property loss was estimated at about $3,000.

Inspectors' Reports for September, October, and November, 1904.

Nature of Defects.	September.		October.		November.	
	Total defects	Dangerous.	Total defects.	Dangerous	Total defects	Dangerous.
Cases of deposit of sediment,	1,368	87	1,363	78	1,396	102
Cases of incrustation and scale,	3,185	89	3,690	82	3,255	114
Cases of internal grooving,	188	17	182	26	175	24
Cases of internal corrosion,	975	46	1,009	47	859	50
Cases of external corrosion,	883	65	854	88	698	74
Defective braces and stays,	138	38	203	40	164	46
Settings defective,	453	33	502	33	479	49
Furnaces out of shape,	534	22	539	15	529	26
Fractured plates,	240	35	369	39	317	54
Burned plates,	464	43	434	36	458	46
Blistered plates,	88	9	90	8	80	7
Cases of defective riveting,	326	47	354	83	265	63
Defective heads,	146	26	170	14	106	21
Leakage around tubes,	794	114	953	167	782	119
Leakage at joints,	627	37	521	55	754	57
Water-gauges defective,	422	38	286	77	346	49
Blow-offs defective,	368	96	392	102	371	108
Cases of deficiency of water,	31	17	39	16	27	10
Safety-valves overloaded,	126	37	130	41	155	49
Safety-valves defective,	118	33	121	37	132	28
Pressure gauges defective,	625	35	573	23	536	63
Boilers without pressure gauges,	23	23	47	47	17	17
Unclassified defects,	71	17	147	43	175	61
Totals,	12,193	1,004	12,968	1,197	12,076	1,237

(257.) — On September 15th a boiler exploded in Wall & Murphy's sawmill, at Hawley, Pa. Peter Hass was instantly killed, and Charles Whitmore was seriously injured. The boiler was hurled through the Schlager Knitting Mill, which was at the time unoccupied.

(258.) — A boiler exploded, on September 15th, in V. P. Moore's planing mill, at Adairville, Ky. An elderly man named Phelps was seriously injured, and Mr. Moore was himself injured in a lesser degree. The mill was wrecked.

(259.) — A boiler exploded, on September 16th, on the Tuttle ranch, near Miller, S. D. S. J. Wakely, government inspector of cattle dipping, was scalded, together with three of his assistants. The coals from the firebox were scattered broadcast and started a prairie fire, which the injured men, by heroic work, finally succeeded in extinguishing.

(260.) — Joseph Linhart was killed, and Edward Wund seriously injured, on September 16th, by a boiler explosion in the Herancourt brewery, at Cincinnati, Ohio.

(261.) — A boiler exploded, on September 17th, in James Wise's sawmill, near Aiken, S. C. David Fagan's skull was crushed, and Mr. Wise and his fireman were also injured, though less seriously.

(262.) — On September 17th a boiler exploded in the plant of the Philadelphia Canning Company, at Howard Center, Pa. Frank Paul was injured so badly that he died, later, in the hospital.

(263.) — A manhole plate failed, on September 20th, on the boiler of the steam launch of the United States cruiser *Marblehead*, at San Francisco, Cal. Three of the five men on board the launch at the time were rendered unconscious, but none of them was seriously injured.

(264.) — On September 21st a boiler exploded in the Texas oilfields, at Batson, Tex. Mr. Swayne, who owns the outfit, was not present at the time. Fireman Frank Loper was at the derrick and so escaped injury. The boiler was used in drilling an oil well.

(265.) — A boiler exploded, on September 23d, in the Ellis cotton gin, at Raleigh, N. C. Henry C. Fowler, Lee Hurst, H. G. Braswell, and George McLean were killed, and one other man was fatally scalded. Several other men were also injured to a lesser degree, and the engine room was partially wrecked.

(266.) — On September 23d a boiler exploded in the steel plant at Ensley, near Birmingham, Ala. Cyrus Leck and John Thomas were killed.

(267.) — On September 24th the boiler of a threshing machine outfit exploded near Kimball, Minn. The engineer was killed instantly, and a farmer named John Kramer was seriously injured.

(268.) — A boiler exploded, on September 27th, in the pumping station of the Yazoo & Mississippi Valley Railroad, at Yazoo City, Miss. The engine house was completely wrecked, but fortunately nobody was injured.

(269.) — A small boiler, used for heating frankfurters, exploded, on September 29th, at the corner of Penn and Lackawanna avenues, Scranton, Pa. There were no personal injuries, but the frankfurter business was suspended for a time.

(270.) — Two boilers exploded, on September 30th, in the Carrie Furnace division of the Carnegie Steel Company, at McKeesport, Pa. Michael Mason and Thomas Towner were injured, and the plant was damaged to an amount estimated at about $20,000.

October, 1904.

(271.) — A boiler exploded, on October 2d, in the Franklin Iron Works, at Port Carbon, near Pottsville, Pa. Engineer William Kane was instantly killed, and the entire plant was blown almost to atoms, the machine shop, boiler house, engine house, and every building of the plant except the office and a small storehouse being leveled. One end of the boiler was thrown, passed out through the side of the boiler house and landed in a meadow 500 feet away, after cutting a tree in two in its passage.

(272.) — Ames Schubert and Walter Schumacher were killed, on October 3d, by the explosion of a boiler in the Schubert sawmill, three miles east of Coulterville, Ill. Seven other men were seriously injured, and the mill was wrecked.

(273.) — The boiler of the Lyons cheese factory exploded, on October 4th, at Aylmer, Ont. Nobody was hurt, but the engine house and other outbuildings were wrecked.

(274.) — The boiler of a threshing machine outfit exploded, on October 4th, at Glenwood, Minn. Clark Haight was instantly killed.

(275.) — The boiler of a locomotive on the Moriah & Lake Champlain Railroad exploded, on October 5th, at Mineville, N. Y. Engineer Frank Twilliger and fireman Archie Heslin were instantly killed.

(276.) — A boiler exploded, on October 6th, in the slaughter house of John Heil, at Bellaire, Ohio. George and Herman Heil, sons of the proprietor, were seriously injured.

(277.) — On October 6th a boiler exploded at the Stratton Ice Works, Pensacola, Fla. Fireman Bingham was killed, and Louis Vann, B. M. Hatton, Susan Adams, and Mr. and Mrs. George Parks were more or less seriously injured. The power plant of the works was wrecked, and a cottage near by was damaged. The property loss from the explosion was about $6,800.

(278.) — A boiler exploded, on October 7th, in the Leonard mill at Cherryville, three miles southeast of Seelyville, Ind. The roof was torn from the boiler house, but nobody was present at the time, so that there are no personal injuries to record.

(279.) — On October 7th a boiler exploded in Edward L. Huntt's saw and grist mill, at Mattawoman, near La Plata, Md. A boy who was playing about the place was killed, and a companion of his received injuries which will probably prove fatal. Joseph L. Huntt, a son of the owner of the mill, was also terribly scalded.

(280.) — A boiler exploded, on October 8th, in Thomas Fisher's sawmill, at Westover, near Hamilton, Ont. James Van Every and Mr. Fisher (the owner of the mill) were killed.

(281.) — On October 8th a boiler exploded in Edward Ryal, Sr.'s, cotton gin, at Covington, Ga. The fireman, whose name we have not learned, was fatally injured, and a boy also received injuries of a serious nature.

(282.) — On October 8th a boiler exploded in the Lake Shore electric power house, at Fremont, Ohio. William Miller and Frank W. Sting were injured so badly that they died next morning. The explosion appears to have consisted in the failure of a tube or header in a water-tube boiler.

(283.) — The boiler of a switching locomotive exploded, on October 9th, on the Chicago, Lake Shore & Eastern Railroad, Chicago, Ill. Thomas Marrs was fatally injured.

(284.) — A boiler exploded, on October 10th, in John Magness' cotton gin, at Newark, near Little Rock, Ark. Mr. Magness, who was about fifty yards away at the time, was seriously injured. Three other men were also injured to a lesser extent.

(285.) — The head blew out of a mud drum, on October 10th, in the plant of the Jackson Ice & Fuel Company, at Jackson, Ohio. Nobody was injured, and the property loss was small.

(286.) — On October 11th a boiler exploded in the machine shop of Alton Hopkins, at Denver, Colo. Three men were present at the time, but nobody was seriously injured, though all were greatly shocked. The building was practically wrecked. The doors and windows were blown out, the walls were shattered, and the boiler went out through the roof.

(287.) — The boiler of a threshing machine outfit exploded, on October 17th, on the Hewitt farm, about one mile from Eau Claire, Wis. Frederick Sauer, Jr., was badly injured.

(288.) — A boiler used for heating by hot water exploded, on October 19th, in the residence of Alden G. Bray of Winthrop, Mass. Mrs. Bray had a narrow escape from serious injury. One side of the house was blown out, and considerable other damage was done. The property loss is estimated at $1,000.

(289.) — A boiler exploded, on October 19th, in Clark's mill, on the Wabash, near Huntington, Ind. Russell Palmer was slightly injured.

(290.) — The boiler of a dipping plant exploded, on October 19th, on the Hileman ranch, twenty miles southwest of Colby, Kan. Albert Hileman and Frederick Desmond were seriously injured.

(291.) — A boiler exploded, on October 20th, on the famous Chatsworth dairy farm, near Richmond, Va. The boiler passed up through the roof of the building and went fully 100 feet into the air. Nobody was injured.

(292.) — The Union Oil Mill, a branch of the Southern Cotton Oil Company situated at Union, S. C., was the scene of a boiler explosion on October 22d. Some idea of the violence of the explosion may be had from the fact that an eight-foot piece of piping was blown through a twelve-inch wall, and subsequently through a frame building, finally bringing up against a heavy post, which it partially splintered.

(293.) — The boiler of a threshing machine outfit exploded, on October 23d, near McHenry, N. D. Henry Eiller was struck by flying wreckage and killed, and John Dundeen was badly injured.

(294.) — On October 24th William Blasius was calking the flues of a locomotive boiler in the roundhouse of the Monon railroad, at New Albany, Ind., while the boiler was under steam. One or more of the flues failed, and steam and hot water were discharged upon the unfortunate man, scalding him so severely that he died on the following day. He was able to crawl out of the firebox alone, but he was frightfully scalded from head to foot. This accident affords one more terrible proof of the folly of attempting repairs of any kind upon a boiler while under steam, a folly against which we have preached continually for many years.

(295.) — The elbow of a blowoff pipe failed, on October 24th, in the basement of the New Lexington Hotel, on Boylston Street, Boston, Mass. Four men were more or less seriously scalded. The damage to the building probably did not exceed $400.

(296.) — A boiler connected with a steam sawmill, and owned by Mr. J. E. Wilber, exploded, on October 25th, at Union, Conn. Fortunately nobody was hurt.

(297.) — On October 27th a boiler exploded in David Wells' cotton gin at MacRae, a small village about fourteen miles northeast of Bonham, Texas. Engineer Alton Fain was instantly killed, and A. Ballard and one other man whose name we have not learned were badly injured. At last accounts it was thought that Mr. Ballard might die.

(298.) — A boiler exploded, on October 28th, at the plant of the Hilton & Dodge Lumber Company, at Satilla Bluff, about forty miles from Brunswick, Ga. Three men were killed outright, and several others were slightly injured. The property loss was about $3,000.

(299.) — A boiler exploded, on October 30th, in a planing mill at Dale, Spencer County, Ind. The building and machinery were wrecked, but nobody was injured.

November, 1904.

(300.) — The boiler of a traction engine belonging to Curtis Johnson exploded, on November 1st, on Mrs. Anna Keys' farm, half a mile from Beason, Ill. James Felter and Mr. Johnson, owner of the outfit, were scalded and burned. The boiler was being repaired at the time of the explosion, — a very dangerous practice under all circumstances, when a boiler is under pressure. (Compare explosion No. 294, above.)

(301.) — A hot-water boiler exploded, on November 2d, in the kitchen of the Central Hotel at Tazewell, near Roanoke, Va. W. C. Henderson was painfully burned, and wreckage was scattered about over a radius of hundreds of yards. Fire followed the explosion, and added largely to the damage.

(302.) — A boiler exploded, on November 3d, in the Hon. A. J. Bell's sawmill, near Bradford, White County, Ark. The mill was blown to pieces, but nobody was injured.

(303.) — A heating boiler exploded, on November 5th, in the basement of Roberts Hall, of Chesbrough Seminary, at North Chili, near Rochester, N. Y.

Miss Dora Schall, a student in the seminary, was painfully injured. The damage to the building probably did not exceed $200.

(304.) — The boiler of switch engine No. 6, of the Indianapolis Union Railway Company, exploded, on November 7th, at Indianapolis, Ind. Engineer Harry Nichols and fireman Edward Bell were severely but not fatally injured. The locomotive was wrecked, together with a freight car that was attached to it.

(305.) — One of the boilers of the Gulf-Cypress Lumber Company exploded, on November 7th, at Ehren, Fla. Two night watchmen were killed, and another man was badly wounded. The plant was not greatly damaged.

(306.) — A flue failed, on November 7th, in the boiler of a west-bound passenger train at Greens Farms, Conn. Fireman James Foster was killed, and engineer Angus was slightly injured.

(307.) — A boiler exploded, on November 8th, in the Klemp-Blake Furniture Factory, at Leavenworth, Kans. Fireman Green Nichols was injured so badly that he died shortly after being removed to the Mitchell Hospital. Willa B. Roady also died from his injuries on the 9th, and George Kellerman died at Cushing Hospital on the 22d. Thomas Norris and several other employees received minor injuries. The building was badly wrecked, and the property loss was estimated at $20,000.

(308.) — On November 8th the crown sheet of the boiler of the tug *Warnick* failed at Detroit, Mich. Clarence Correy was instantly killed, and George Morris and Louis Verno received injuries that were considered to be probably fatal. The tug is owned by Breyman & Rooney of Toledo.

(309.) — A boiler exploded, on November 9th, in the New England shipyard mill, at Bath, Me. Nobody was injured, and the damage to property was small.

(310.) — On November 9th a boiler used to operate a corn shredder exploded on the William Schmidt farm, near Clinton, Wis. William Zick and Frank Pratt were seriously injured.

(311.) — A flue failed, on November 11th, in one of the boilers of the New England Building, at Cleveland, Ohio. Fireman Charles Jackson was scalded so severely that he died in a short time, and engineer Thomas English was badly burned and scalded while endeavoring to draw the fires. About two weeks previously a steam pipe burst in this same boiler room, and engineer English was quite severely scalded while closing a stop valve.

(312.) — On November 11th a boiler used for operating a corn shredder exploded on the Samuel Kaufman farm, four miles east of Elkhart, Ind. John Boltenhouse and Warren Bassett were killed instantly, and Floyd Kaufman, a son of the owner of the farm, was scalded and bruised so badly that he died about an hour later. Guy Brusman, Charles Dills, and Norman Shigley were injured painfully but not seriously. The engine was blown to a distance of over 300 feet.

(313.) — The boiler of a threshing machine outfit exploded, on November 11th, on the John Wilcox farm, near Sault Ste. Marie, Mich. John Page and a man named Williams were seriously injured, but at last accounts it was believed that both would recover: Fire followed the explosion, and the total property loss amounted to about $4,000.

(314.) — A small vertical boiler exploded, on November 12th, in the basement of a building on Market Street, St. Louis, occupied as a hotel, restaurant, and saloon. Nobody was injured. The property loss amounted to about $1,400.

(315.) — On November 12th a heating boiler was installed, for temporary use, in the Queens County Court House, Long Island City, N. Y., and on the same night two of its tubes failed. No serious damage was done, and the boiler was again put into service on the 14th. Soon after the courts opened on that day, however, ten more of the tubes failed, again with no serious results beyond forcing an adjournment on account of the cold.

(316.) — A boiler belonging to R. J. Banfield of Rumsey, Ky., and used for steaming timber, exploded on November 12th. Nobody was seriously hurt.

(317.) — A boiler used to cook feed at the Ideal Poultry Farm of Louis Pierron, near Silver Springs, Wis., exploded on November 15th, demolishing a portion of the building in which it stood. Nobody was injured.

(318.) — A slight boiler explosion occurred, on November 16th, in the plant of the Standard Wheel Works, at Terre Haute, Ind. Nobody was injured, and the property loss was small.

(319.) — On November 17th a boiler exploded in Simon Czernicky's abattoir at Shenandoah, Pa. The damage to the building was about $1,000, and an adjoining building owned by August Knas was also damaged to the extent of about $300. Nobody was injured. The local authorities believed that the explosion was due to dynamite, but we have little hesitation in classifying it as a true boiler explosion.

(320.) — A small boiler exploded, on November 17th, in M. H. Lucas' bicycle repair shop, at Eugene, Ore. We have not learned further particulars.

(321.) — A portable boiler exploded, on November 19th, on the Dubach farm, about three miles west of Ashtabula, Ohio. Gottlieb Dubach was severely burned and bruised. Samuel Loomis, William Brooks, and Charles and John Dubach also received minor injuries.

(322.) — The boiler of locomotive No. 995, of the Grand Trunk Railroad, exploded, on November 20th, four miles east of Haskell, Ind. Fireman Edward A. Cloney was scalded and burned so badly that he died in a short time. Engineer Connerly was also badly injured, but will recover.

(323.) — A boiler exploded, on November 21st, in the Buttercup Creamery, seven miles west of Beloit, Wis. Fire followed the explosion, and the total property loss, from explosion and fire, was estimated at $4,000.

(324.) — On November 21st a boiler exploded in Jeremiah Hubers' sawmill, on Davies' Run, near New Haven, Ky. Nobody was seriously injured.

(325.) —A boiler exploded, on November 22d, in Cyrus Culver's sawmill, five miles southeast of Oblong, Ill. Orris Bond and Cyrus Culver were instantly killed, and Otto Imboden was fatally injured. One other man, whose name we have not learned, was also injured seriously but not fatally.

(326.) — A boiler exploded, on November 24th, in D. R. Middleton's cotton gin, at Walters, near Vicksburg, Miss. Henry Hebron and West Smith were killed, and Luther Hebron and Andrew Bland were very seriously injured. Mrs. John Sanders and two of Mr. Middleton's little daughters also received slight injuries. The property loss is estimated at $10,000.

(327.) — On November 24th a sawmill boiler exploded near Churchville, Augusta County, Va. George Hanger was injured so badly that he died about three hours later.

(328.) — A boiler exploded on November 24th during the course of a fire in the shops of the St. Louis & San Francisco Railroad, at South Memphis, Tenn. Samuel Massey and a man named Briggs were injured by the explosion.

(329.) — A boiler exploded, on November 25th, on the Hutchings oil lease, in the eastern part of Delaware County, Ind. Nobody was injured.

(330.) — On November 25th a boiler exploded in the basement of Factory A of the United States Glass Company, Pittsburg, Pa. William Hollis was scalded and burned so badly that he died on the following day in the hospital. Thomas Hutchinson also received minor injuries. The boiler was blown to pieces, but the damage to surrounding property was small.

(331.) — A flue failed, on November 26th, in a boiler in the Pittsburg, Fort Wayne & Chicago Railroad shops, at Allegheny, Pa. James Alexander was scalded to death, and Thomas Rudan was burned very seriously, but probably not fatally.

(332.) — The boiler of a freight locomotive on the Santa Fé Railroad exploded, on November 27th, at Pontoosuc, thirty miles west of Galesburg, Ill. Brakeman William Forsythe and fireman William Harvey were instantly killed, and engineer Joseph Milton was fatally injured. The force of the explosion was so great that the locomotive was stripped of its equipment and turned around. Several cars were also wrecked.

(333.) — On November 28th a boiler exploded in George T. Fielding's sawmill, near Manhattan, Kans. Arthur Foltz was killed.

(334.) — A boiler exploded, on November 28th, at the Indian Spring Woolen Mill, near Madison, Me. Nobody was present at the time, and hence there were no personal injuries. There was also but little damage to property.

(335.) — A steam heating boiler exploded, on November 28th, in the railroad station at Campbell Hall Junction, N. Y. The building, which belongs to the Ontario & Western Railroad, was partially wrecked. Edward Kuhl, Mrs. Henry Lamey, and a young woman, whose name we have not learned, were more or less seriously injured.

(336.) — A boiler used for steam heating purposes exploded, on November 28th, in the residence of F. L. Sturtevant, on Elm Street, Worcester, Mass. Nobody was injured, but the house was damaged to the extent of about $1,500.

THE little book entitled *The Metric System*, which was published by this company under the editorship of the late President J. M. Allen, continues to hold its place in the favor of those who have to do with metric measures. It is mailed, postpaid to any address, upon receipt of $1.25 per copy. (An edition printed on bond paper may also be had, at $1.50 per copy.)

The Locomotive.

FOUNDED BY J. M. ALLEN, A.M., M.E.

HARTFORD, JANUARY 15, 1905.

THE LOCOMOTIVE *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each. (*Any volume can be supplied.*)

Obituary.

FRANCIS BUELL COOLEY.

We record with profound regret the death of Mr. Francis Buell Cooley, which occurred on November 25, 1904, at his home in Hartford, Connecticut. Mr. Cooley was born at Granville, Massachusetts, on June 21, 1822, and graduated in succession from the Granville Academy, the Westfield Academy, and the Albany Academy. He began his business career at Granville, in the country store owned by his father, Noah Cooley. In 1847, at the age of twenty-five, Mr. Cooley went to Chicago, where he established the wholesale dry-goods house known at first as Cooley, Wadsworth & Company, and subsequently as Cooley, Farwell & Company. This was the beginning of the large dry-goods trade that now exists in that city, and the firm of Marshall Field & Company, and many other large dry-goods houses now in Chicago, practically started from the house that Mr. Cooley founded. In 1865, after having amassed a handsome fortune, Mr. Cooley came to Hartford, where he has since lived, recognized by everybody as a man of great financial ability, firm integrity, and keen business acumen. During his life he exerted a profound influence upon business enterprises of all kinds, and his counsel was widely sought and highly prized. At the time of his death he was president of the Society for Savings and of the American School at Hartford for the Deaf, and vice-president of the National Exchange Bank of Hartford, and of Landers, Frary & Clark of New Britain. He was also a director of the Phœnix Mutual Life Insurance Company, the Ætna Insurance Company, the Hartford County Mutual Fire Insurance Company, and the Hartford Steam Boiler Inspection and Insurance Company; being elected to his position on the directorate of the last-named company in 1886. In 1865 Mr. Cooley was elected president of the National Exchange Bank, a position which he held for twenty-one years until, in 1886, he resigned it to accept the vice-presidency, which he held up to the time of his death, as noted above. Upon resigning the presidency of the National Exchange Bank, Mr. Cooley retired from active business, thereafter devoting his time to the management of his own large interests, and to acting in an advisory capacity towards the institutions with which he was connected. He was an influential member of the Center Church (Congregational) of Hartford, and was in all respects a generous, lovable, Christian gentleman.

The following minute was adopted, on November 28, by the directors of the Hartford Steam Boiler Inspection and Insurance Company: "He became a citizen of Hartford, and, in due time, became connected with its business enterprises, and carried into them the same quiet energy and cheerfulness which he had shown in his youthful life. He was trusted because he was always trustworthy, grasped neither power nor place, and was contented to let others obtain success. In mid-life he became a member of the First Congregational Church, and was active and efficient in Christian work. He used his powers and his property for the benefit of his fellow men, and his memory will live in the universal respect of the people of Hartford.

"By the death of Mr. Francis B. Cooley, who has been for the past eighteen years a member of this Board, this Corporation and many other corporations of Hartford have suffered a great loss. In his early manhood he emigrated from New England to Chicago, where he entered upon an extensive mercantile business with great energy, and achieved marked success. His cheerful temperament, his equanimity, and his courage in emergencies enabled him to extend the details of his business until he had laid the foundations of great commercial enterprises in Chicago, when he returned to the East with a measure of prosperity with which he was content."

For 1905.

Mr. Theodore H. Babcock has tendered to this company his resignation as Manager of the New York Department, to take effect December 31, 1904. By this act Mr. Babcock closes a long term of highly-valued service rendered to the company. In 1869 he was appointed Secretary of the company, and in February, 1873, he resigned the secretaryship to accept the position of Manager of the New York Department, which office he has filled for almost thirty-two years, the business of the Department having grown, under his administration, from almost the smallest beginnings to its present large proportions.

Mr. Curtis C. Gardiner, Jr., for several years Manager of the Southwestern Department of the company, succeeds Mr. Babcock as Manager of the New York Department, and we are confident that he will receive the same generous and loyal support that has been accorded, for so long a time, to his predecessor and to the company.

Mr. Victor Hugo, who has been associated with Mr. Gardiner for some years, succeeds him as Manager of the Southwestern Department; this change, like the one just noted, taking effect from January 1, 1905. The office will continue in the Security Building, No. 319 North Fourth street, St. Louis, Missouri. For Mr. Hugo also we bespeak the same consideration and cordial coöperation that have been extended to previous Managers of that Department.

Mr. Charles P. Cooley, treasurer of The Fidelity Company of Hartford, Connecticut, was elected a Director of the company, on December 15, 1904, to fill the vacancy caused by the death of Mr Francis B. Cooley.

OWING to the fact that THE LOCOMOTIVE is now a quarterly instead of a monthly, it has been thought best to include *two* years in each volume. Hence no index will be issued for the year 1904, and no bound volumes for that year will be issued in separate form. At the close of the year 1905 an index will be issued covering both 1904 and 1905, and the issues for these years will be bound together and sold as one volume.

Explosion of a Horizontal Tubular Boiler.

The accompanying illustration gives a general view of the wreckage produced by the explosion of a 48-in. horizontal tubular boiler, which blew up recently in the middle West. The boiler was built of ¼-in. iron, but the plates, when afterwards examined by one of our inspectors, showed no brands. The rivets were 11/16 in. in diameter, pitched 2 in. from center to center, the joints being single riveted. The heads were 7/16 in. thick, and there were forty 3-in. tubes. Two 10-in. × 15-in. manholes were located in each head, these being reënforced by strips 2 in. wide and ½ in. thick. There were no braces below the tubes, and above the tubes there were two through rods, each 1-⅛ in. in diameter, with rivets inside and outside. In addition to the rods there was a single strip of

RUIN WROUGHT BY THE EXPLOSION OF A HORIZONTAL TUBULAR BOILER.

angle iron, 3 in. × 3 in. × ⅜ in., riveted across the head, a stiffening piece of plate being attached to this, which was 6 in. wide at the middle, and tapered towards the ends. There were two boilers in the nest, these being connected by means of steam and mud drums which were located near the middle of the boilers and attached to them by means of wrought-iron legs, 8 in. in diameter and about 12 in. long. The safety-valve was 3 in. in diameter, it is said, and was located on the steam drum. Although there were three gage cocks on each boiler only one of each set appears to have been in order. Apparently the glass gages were in disuse, as their valves were found closed. The steam gage and safety valve could not be found after the explosion. The boilers were fed into the mud drum direct from the city mains, in which the pressure is usually maintained at 130 pounds. The boilers were not insured at the time of the explosion, although they had been insured in the past.

The east boiler of the nest exploded, killing the fireman and fatally injuring two other men. The west boiler was apparently uninjured, save that the steam drum was pulled from its shell. About one-half of the mud drum remained on this boiler. The front half of the exploded boiler was broken into fragments, the principal points of separation being along the middle girth seam and along the seam of the front head. The fractures at these places extended completely around the circumference, and failure was through the rivet holes. Nearly all the rivets in these seams remained in place, and the front head was completely separated from the shell. All the tubes pulled out of both heads, and the braces were broken close to the inside rivets.

These boilers had seen too much service, and the explosion was doubtless due to this fact. The material was worn out, and the boiler that exploded had been repeatedly patched with half sheets without removing the old holes. Corrosion and grooving had occurred along the old seams where the new patches were attached. Cold feed water and over pressure doubtless contributed their share to hasten the explosion, it being conceded by the owners that the working pressure was sometimes pushed to 100 or 110 pounds.

The lesson of this explosion would appear to be that a boiler which in its early days may be quite safe for a reasonable pressure is certainly not safe, in its old age, for an unreasonable pressure. The repeated signs of distress that the boiler had shown (as is evidenced by the patches that had been placed upon it) should have taught the owner that he was straining it beyond the point of safety. We may say that after insurance upon it had been discontinued the boiler was sold, and we lost track of it for a time. When it was again proposed that we insure it at a pressure that we did not consider safe, our inspector recognized the boiler in its new location, as he had repeatedly examined it in its old home, and knew its every peculiarity. He made certain suggestions with regard to pressure, and especially with regard to a certain modification of the safety valve which he considered essential to safety; and the owner (as the inspector reported to us) "emphatically declined, with the remark that if we did not feel inclined to accept things as they were, we were at liberty to retire." We did retire, and our impression is that the engineer at the plant did likewise on the following day.

We do not mean to imply that the owner of this boiler was consciously indifferent to the safety of lives and property; but the impression sometimes holds among boiler owners that insurance companies are altogether too anxious to have repairs and other changes made, and that they are not willing to insure boilers unless those boilers are manifestly able to carry with safety a far higher pressure than it is proposed to carry. In reply to this criticism we would say that we have always taken the position that the hazards that are inherent in the use of steam, and inseparable from it, are quite sufficient; and we do not consider that it is justifiable, on the part either of an owner or of an insurer, to continue a boiler in service when there is any reason whatever to doubt its safety. Our experience indicates that boilers that are believed to be safe have exploded quite often enough, from causes that could have been foreseen (or which, at all events, *were not* foreseen). In putting this principle into practice, it may well be that we sometimes call for changes the necessity for which is not apparent to the assured, even though we endeavor to explain it to him to his satisfaction; but we are never intentionally unreasonable in our demands. According to our lights, it is the man who insists upon our "accepting things as they are" who is unreasonable.

Concerning Pipe Threads.

In the issues of The Locomotive for September, 1896, and January, 1902, we discussed the subject of pipe threads at some considerable length; the first of these articles being devoted to a description of the Briggs standard system of threads, while the second was mainly devoted to a discussion of the notorious fact that the pipe threads that are met with in actual practice do not always conform to this standard. In the present article we desire to touch upon certain further facts in relation to pipe threads; but, in order to make the present article more complete and intelligible, we shall first give somewhat extensive extracts from the two earlier ones, concluding with the new matter to which we wish to draw attention, and which is presented in connection with Figs. 10 to 15, inclusive.

First, as to the standard proportions of pipe and pipe threads. At the sixth annual meeting of the American Society of Mechanical Engineers, held at Boston in November, 1885, a committee was appointed by the president of the society, to confer with manufacturers of pipe, pipe dies, and pipe fittings, for the purpose of establishing a series of standard gauges for pipes and pipe threads, so that a uniform system might prevail throughout the country. The committee so appointed did its work thoroughly and well, and it is to their labors that we owe the system now in general use.

Upon the introduction of wrought-iron pipe with the taper thread, the veteran engineer Robert Briggs adopted and published a table of thicknesses

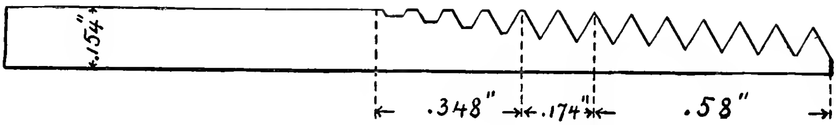

Fig. 1. — Section through a Two-inch Pipe.

and threads for various sizes of pipe, and his proportions became known as the "Briggs standard," and were adopted by most manufacturers of pipe and fittings. Its use was not universal, however, and as the pipe industry had grown to immense proportions a uniform standard had become not only desirable, but necessary.

The committee of the American Society of Mechanical Engineers met in Hartford in February, 1886, and its first extended report was presented at the

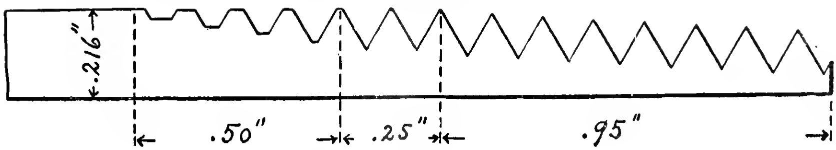

Fig. 2. — Section through a Three-inch Pipe.

seventh annual meeting of the society, which was held at New York in November, 1886. "The opinion of this committee is," says the report, "that the Briggs standard, which nearly all, if not all, of the pipe manufacturers once adopted, is the proper standard to be adhered to, and that it only requires definite co-operation on the part of pipe manufacturers with the committee in order to bring their product strictly to that standard, and to adopt means of strictly adhering to it within practical limits." Such co-operation was heartily given by the Manufacturers of Wrought Iron Pipe and Boiler Tubes, the Cast Iron Fittings Association, the Manufacturers of Brass and Iron Steam, Gas, and Water Work, and others. A joint conference was held in June, 1886, with a committee of pipe manufacturers, and it was decided to ask each manufacturer to send to the Pratt & Whitney Company of Hartford sample pieces of all sizes of pipe from six inches down, threaded on one end, to be tested by the Pratt & Whitney Company, and compared with the Briggs standard gauges. Thirteen manufacturers complied with the request and furnished the desired samples, which were then carefully tested; the results of the tests were tabulated, and submitted to the Pipe Manufacturers' Association, at its regular convention held at Philadelphia in August, 1886. The variations from the Briggs standard, as shown by the tests, were small except in the cases of the three-quarters and one inch sizes. Another conference of committees was then held, and finally, in October, 1886, the Briggs standard was definitely adopted by the Manufacturers of Wrought Iron Pipe

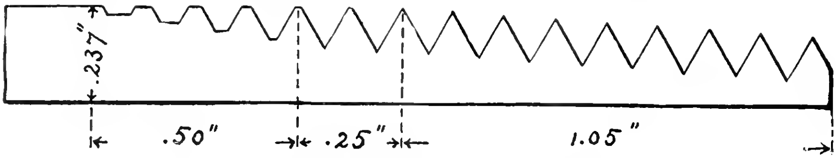

FIG. 3. — SECTION THROUGH A FOUR-INCH PIPE.

and Boiler Tubes, and in December of the same year it was also adopted by the Manufacturers' Association of Brass and Iron Steam, Gas, and Water Work; so that now it may be regarded as a national standard.

The Briggs standard thread may be described, in general terms, somewhat as follows: The threads have an angle of 60°, but are rounded off slightly at top and bottom, so that the depth of the thread is only four-fifths as great as it would be if the threads were sharp; the outside surface of the tube is tapered to a certain distance from the end, the standard taper being such that the tube-surface inclines toward the axis of the tube by 1 in 32. This makes the *total* taper, as measured by the variation in outside diameter, equal to 1 in 16, or ¾ of an inch to the foot. The total *length* of the tapered part is given by the empirical formula

$$\textit{Length of taper} = (4.80'' + \tfrac{4}{5} D) \div n,$$

where D is the actual external diameter of the tube in the straight part, in inches,

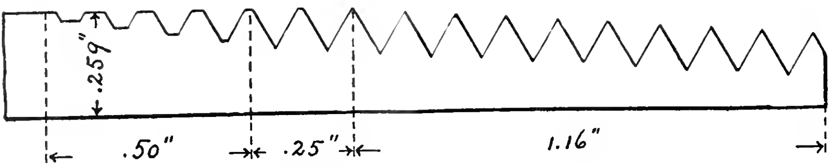

FIG. 4. — SECTION THROUGH A FIVE-INCH PIPE.

and n is the number of threads per inch. For example, the actual outside diameter of a 5-inch pipe is 5.563", so that to find the length of the tapered part we proceed as follows: $\frac{4}{5} \times 5.563'' = 4.450''$, and $4.450'' + 4.80'' = 9.250''$. There are 8 threads to the inch on pipe of this size, and hence we have, finally, 9.250″ ÷ 8 = 1.156″, which is the length of the taper. The tapered part of the pipe is threaded with threads that are perfect at both top and bottom. Further back, beyond the perfect threads, come two threads that have the same taper at the bottom, but which are imperfect at the top. The remaining part of the screw, which consists of four threads that are imperfect at both top and bottom, is not essential to the Briggs system, but is "simply incidental to the process of cutting the thread at a single operation."

The accompanying table gives the nominal or commercial inside diameter

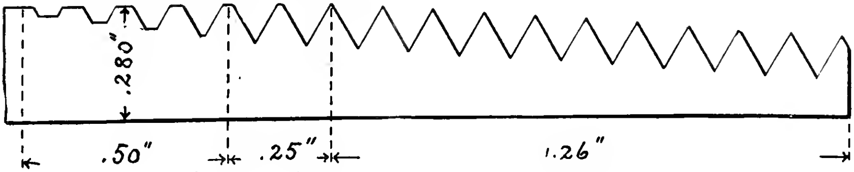

Fig. 5. — Section through a Six-inch Pipe.

of pipe up to 10 inches in diameter, with the actual inside and outside diameters, the thickness of metal in the body of the pipe, the length of the taper and perfect screw, the outside diameter of the thread at the end of the pipe, and the diameter at the bottom of the thread at the end of the pipe. These dimensions are all according to the Briggs standard, with one exception. At a meeting of the Manufacturers of Wrought Iron Pipe and Boiler Tubes, held at New York in May, 1889, action was taken regarding the outside diameter of 9″ pipe, and the

Standard Proportions of Pipe and Pipe Threads.

Diameter of Tube.			Thickness of Metal.	Screwed Ends.		Diameter at End of Pipe.	
Nominal inside.	Actual inside.	Actual outside.		Number of threads per inch.	Length of taper and perfect screw	Outside.	At bottom of thread.
1/8″	0.270″	0.405″	0.068″	27	0.19″	0.393″	0.342″
1/4	.364	.540	.088	18	.29	.522	.445
3/8	.494	.675	.091	18	.30	.656	.579
1/2	.623	.840	.109	14	.39	.816	.717
3/4	.824	1.050	.113	14	.40	1.025	.926
1	1.048	1.315	.134	11 1/2	.51	1.283	1.162
1 1/4	1.380	1.660	.140	11 1/2	.54	1.626	1.505
1 1/2	1.610	1.900	.145	11 1/2	.55	1.866	1.745
2	2.067	2.375	.154	11 1/2	.58	2.339	2.218
2 1/2	2.468	2.875	.204	8	.89	2.819	2.646
3	3.067	3.500	.216	8	.95	3.441	3.268
3 1/2	3.548	4.000	.226	8	1.00	3.938	3.765
4	4.026	4.500	.237	8	1.05	4.434	4.261
4 1/2	4.508	5.000	.246	8	1.10	4.931	4.758
5	5.045	5.563	.259	8	1.16	5.491	5.318
6	6.065	6.625	.280	8	1.26	6.546	6.373
7	7.023	7.625	.301	8	1.36	7.540	7.367
8	7.982	8.625	.322	8	1.46	8.534	8.361
9	9.000	9.625	.312	8	1.57	9.527	9.354
10	10.019	10.750	.366	8	1.68	10.645	10.472

standard for this dimension was made 9.625″ instead of 9.688″, as had been recommended by Briggs. Aside from this change the proportions here given agree with those adopted in 1886.

The taper thread for pipes and fittings is an American invention. It was first used about 1840 by Walworth & Nason of Boston, with whom Mr. Robert Briggs was associated for many years.

The engravings show the standard proportions of pipe threads for several sizes of pipe, except that the *taper* has been slightly exaggerated for greater clearness. Two threads, it will be seen, are perfect at the bottom but flat on top, and four are imperfect at both top and bottom.

The dimensions and proportions indicated above having been adopted (as we have already indicated) by the Manufacturers of Wrought Iron Pipe and Boiler Tubes, and also by the Manufacturers' Association of Brass and Iron Steam, Gas, and Water Work, may be regarded as a national standard, and all pipe that is threaded at the mills of the manufacturers is supposed to be threaded according to this standard. But in the shops where the pipe is cut into commercial lengths, in installing new systems of piping or in repairing old ones, the standard proportions of thread are not always followed. This, in fact, is but a very mild and temperate way of stating the case; for we often find that the threads that are cut in such shops are so far from the standard of the fittings that they have to enter that it is impossible to make a good joint in erecting the pipe; and the result is that many lines of pipe that are now running under heavy pressure are in a condition that can be fairly described as positively dangerous. The justice of this statement is abundantly proved by the failures that are constantly occurring at threaded joints; and if further evidence were required, a mere inspection of some of the threads that are to be found on pipes that are being made ready in these shops to go into important work, or that are taken out of such work in the course of repairs, would furnish it abundantly enough to satisfy the most incredulous.

As an example of the kind of thing that may be expected to occur, let us consider a medium size of pipe, — say a four-inch one. The standard calls for eight perfect threads, then two that are perfect at the bottom and slightly flat on the top, and then four that are imperfect on both the top and the bottom; the total length that is scored by the die on the pipe being 1.80″. This is what the standard calls for, as we have said; but when we come to look at the threads that are actually turned out in the shops, we find, not uncommonly, that the total length of thread on a four-inch pipe is only 1.25″, and often this is all the thread there is even on a *six-inch pipe*, where the standard calls for a total length of 2.01″. Now when a pipe is threaded in such a careless manner as that, it cannot possibly be made up into a standard fitting to the full number of threads that are called for in this system, and which are essential in order to secure the requisite strength of the joint; and we regret to say that we are constantly finding pipe connections to boilers made with only two, three, or four threads properly made up. We cannot speak too strongly against such a practice, for it shows an indifference to the safety of life and the security of property that is little short of criminal. There is no excuse for it whatever, for it is easy to tell, upon looking at a pipe before the joint is made up, whether the thread upon it conforms to the standard for that size or not; and no pipe ought to be accepted that does not so conform. If a pipe has been threaded short, and then made up snug against the fitting, it is often difficult to tell, in the finished job, whether it was threaded to standard or not; but the man who puts it in has every chance to inspect it before it is made up, and there can be no excuse whatever for his passing it if it is not right.

In order to illustrate as clearly as possible the points that we are making with regard to piping, we present, in Figs. 6 to 9, four half-tone engravings that were made from photographs, which will show how real are the dangers to which we refer. These pieces of pipe had been in actual use, and we may add that we have not tried to select specimens that would represent extreme cases of departure from the standard, because we have thought that it would be much more useful and instructive to take specimens that would fairly represent what would be

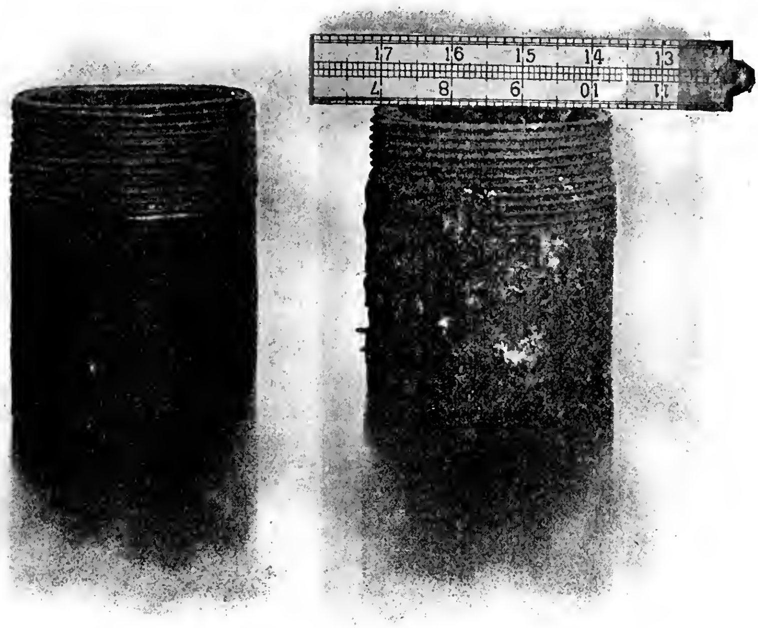

FIG. 6. — THREE-INCH PIPES. (THE ONE ON THE RIGHT COULD BE MADE UP ONLY SIX THREADS. THE OTHER WAS STANDARD, OR NEARLY SO.)

found in actual practice. In the case shown in Fig 7, the pipe was threaded, at its upper end, for a length of 2¼ in., when the standard (for four-inch pipe) only calls for a total length of thread, over all, of 1.80 in.; yet, notwithstanding the great length of the thread, it had been found impossible to make the pipe up into the fitting to a greater distance than four threads, because the thread was almost perfectly straight, and had hardly any sensible taper at all. The slips of paper that are attached to the pipes in Figs. 7 and 8 were adjusted before taking the photographs, so that their ends show the distance to which the threads on the respective specimens had been made up into their fittings. In the specimen shown in Fig. 9, the threads were not clean and sharp, and, moreover, were not of standard shape. In making up this piece of pipe, it had been found impossible to force it into the fitting more than about three threads; and it had been in use, for how long or under what pressure we do not know, with only these three threads to take the entire strain.

It is almost impossible to preserve, in a photo-engraving, all the little indications that tell the story, to the eye, of what the pipe is, and how it has been threaded; but when the specimens that we have illustrated are examined at first hand, they show almost every kind of a departure from the standard that they

FIG. 7. — FOUR-INCH PIPE. THREAD WITHOUT SUFFICIENT TAPER; MADE UP ONLY FOUR THREADS.

are supposed to conform to. Some are threaded too short, some do not have clean threads at all, some have threads that are wrong in shape, and some do not have the proper taper. The fact that these specimens are not extreme in any sense, being selected almost at random from pipe shops, shows how grave this matter is; and we want to say again, that we can hardly find words strong enough to express our condemnation of pipe work that is done in any such bungling and reckless fashion. Too much care cannot be exercised in making pipe connections, particularly in steam pipe and boiler work, when failure is liable to cause loss of life. There is no reason whatever why a workman cannot determine at once, in fitting up piping, whether or not a joint is properly put together, and whether or not it is of the strength intended for standard fittings and pipe. Some of the specimens here illustrated show evidence that calking has been resorted to, in order to make them tight. This is all wrong, for if the joint is properly made up, calking will not be necessary. Calking to obtain tight work is proof of an imperfect joint. The *peening* of a pipe, however, is a very different matter, and the Hartford Steam Boiler Inspection and Insurance Company recommends the peening of pipe ends, when the piping is to be used in connection with pressures of over a hundred pounds. For this purpose a recess is formed in the face of the flange into which the pipe is screwed, and the end of the pipe (which is made a trifle long for this purpose) is peened solidly into this recess, as indicated in Fig. 10; the end of the pipe being afterwards faced off. The object of this peening, however, is not to make the pipe tight, but to increase its holding power in the flange; the pipe being supposed to be made up so that there is no leakage whatever, before the peening is begun.

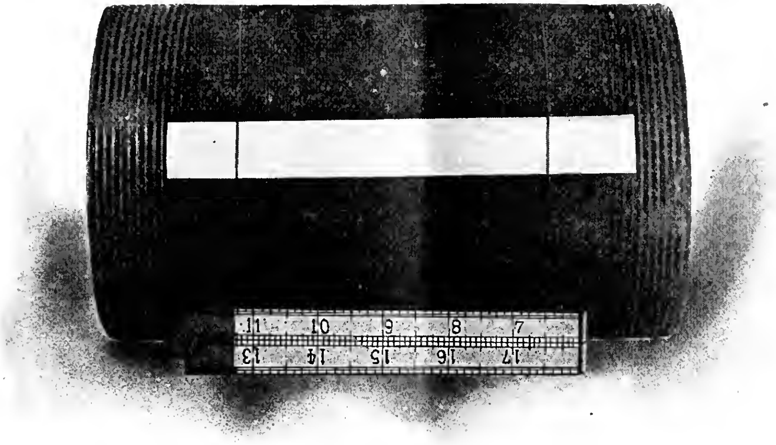

Fig. 8. — Five-inch Pipe; Standard (or Nearly So) at One End, but Not at the Other.

We have before us, as we write, a fitting and a piece of pipe which illustrate still another important defect in pipe joints, — a defect which is becoming increasingly common, and which should receive careful consideration by steam fitters and pipe cutters, particularly in connection with high pressures. In high pressure work a great many constructors increase the length of the thread on the pipe, to correspond with the extra heavy fittings and flanges that are then used. This is most commendable, and in many cases it is really necessary. It is highly important, however, that the work should be free from defects and weakness, as there is nothing gained from the extra length of thread if the joint is improperly made, and in some cases the extra length is in reality a source of weakness, as will be understood by reference to Figs. 11 to 15, which are presently to be explained. In order for the extra length of thread to be of value it is necessary that the threaded part of the pipe shall be everywhere in solid contact with the fitting; and this condition is not even approximately fulfilled by the specimen of pipe that lies before us. The first nine threads of this pipe (counting from the end) are straight, or so nearly so that no taper can be detected by calipering. Following these nine threads are eight others that *are* in taper. It is impossible to get a good (or even a passable) joint under these circumstances. The cause of the defect, and the danger that arises from it, will be understood by reference to the diagrams.

Fig. 11 is supposed to represent a section of pipe which has been threaded to the usual length, by a die of the usual thickness. (The taper of the thread is exaggerated, in these sketches, in the interest of clearness.) The thread, when the die is in the position shown in Fig. 11, is just completed; the pipe coming through the die so as to be just flush with its outer surface. Now if it were

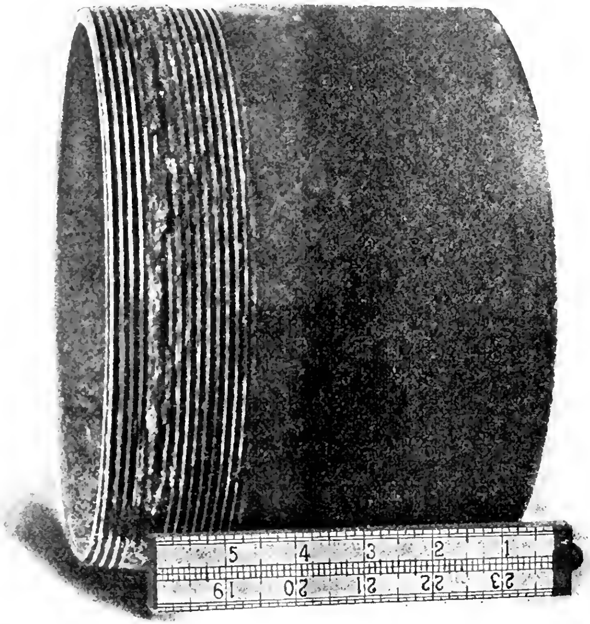

FIG. 9. — EIGHT-INCH PIPE, WHICH COULD BE MADE UP ONLY THREE THREADS.

desired to cut a longer thread on the pipe than is shown in Fig. 11, it would be necessary either to use a die of greater length, or to run the present die further onto the pipe. The latter expedient is the one that is altogether too often adopted, the die that is used for a thread of ordinary length being merely run along the pipe until the thread is as long as desired. This method of procedure is illustrated in Fig. 12. Now it is evident that the threads that project through the die in Fig. 12 cannot have any taper. They must necessarily be straight, and of a diameter equal to the smallest diameter of the die. This fact must be carefully borne in mind in considering the sketches which follow; and to assist the eye, these straight threads have been indicated, in Figs. 12 to 15, by dotted lines.

We not infrequently find that the thread on a pipe is considerably longer than

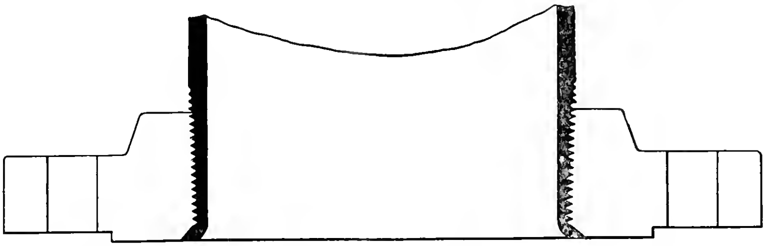

Fig. 10. — Illustrating a Peened Pipe.

that on the fitting into which the pipe is to be made up. In this case there is neither an advantage nor a disadvantage (so far as holding power is concerned) in having the end threads of the pipe straight, provided the rest of the thread is standard, and the straight part is small enough in diameter to pass through the fitting, as indicated in Fig. 13. More often, however, we find that the thread on the pipe has been made long because the thread in the fitting is long, and it is desired by the piper to have the thread in the pipe engage that in the fitting throughout its whole length. This excellent purpose can readily be achieved,

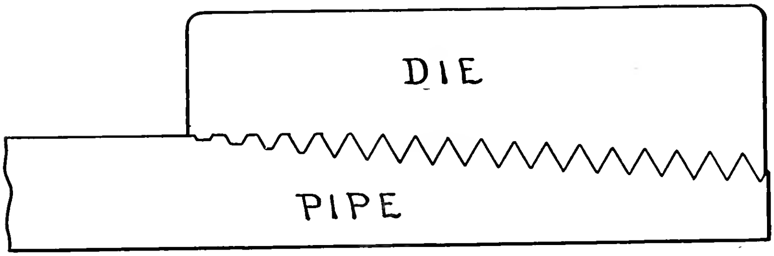

Fig 11. — Illustrating a Completed Pipe Thread.

if the die used in threading the pipe is long enough and made with the standard taper; but when (as in the case now on the writer's desk) the thread on the pipe has been made long by running an ordinary die further up the pipe than usual, as is shown in Fig. 12, so that there is a straight part at the end, the pipe will necessarily "make up" into the flange or fitting somewhat as represented in Fig. 14. It is here supposed that the straight part of the pipe thread (indicated by the dotted line) is just of a size to fit the small end of the fitting perfectly. In that event, and assuming also that the taper on the pipe and the fitting is the

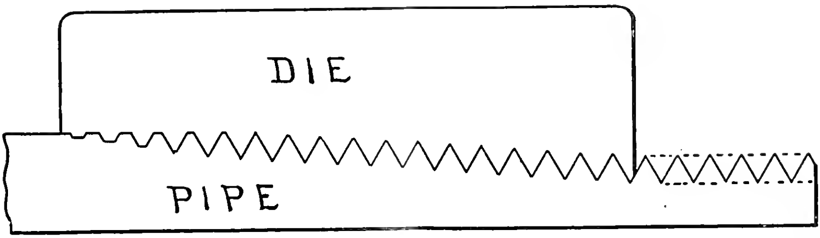

Fig. 12. — Illustrating the Effect of Running the Die too far up the Pipe.

same, it is manifestly impossible for the threads in pipe and fitting to fit one another properly, anywhere except for a couple of threads at the small end of the fitting. Owing to the fact that the last threads on the pipe are imperfect (or should be), it is quite possible that one or two of the perfect threads at the large end of the fitting will touch the pipe in the manner indicated on the left of Fig. 14; but it is plain that a contact of this kind adds nothing to the holding power of the joint. In fact, in a case such as is shown in Fig. 14, the strength of the joint consists of nothing whatever save the few threads that bind where the straight part of the pipe thread makes into the smallest part of the fitting. The theory of the taper thread in pipe work is, that in making up the joints there

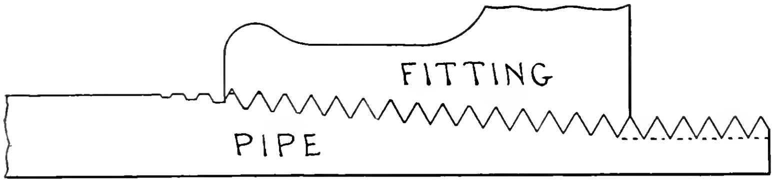

FIG. 13. — ILLUSTRATING THE PIPE PROJECTING THROUGH THE FITTING.

is just enough difference in the gauges of the fitting and the pipe to permit of the joint coming together so as to bring all the threads into good, compressive contact, throughout the whole length of the joint. In this manner a uniform strength and holding power is obtained, through every thread in the fitting; and with a heavy fitting and an extra length of *standard* thread, the joint becomes correspondingly stronger. But when the pipe thread is straight for a certain distance at the end, so that the condition of joint shown in Fig. 14 is inevitable, and only two or three or (at most) four threads are in good contact in the entire length of pipe, the conditions are very different. The joint is deficient in holding power, and the threads that are in contact, being insufficient to

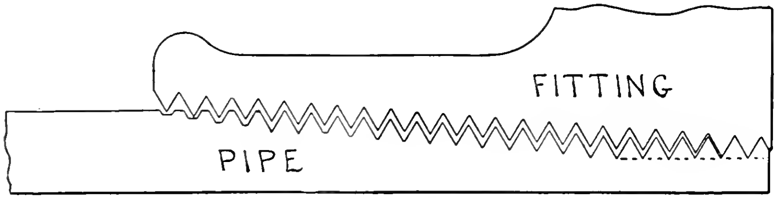

FIG. 14. — ILLUSTRATING AN IMPERFECT PIPE JOINT.

hold the strain, are very likely to strip and withdraw, the load being thus thrown upon the next few threads; and these, since they will fit each other very poorly, are less strong than the original ones, and the joint presently fails, very likely with disastrous consequences. This action is greatly facilitated by the vibration which is universal in pipe lines and boiler connections, this vibration causing the threads to abrade and loosen. The dangers that we are pointing out are not imaginary in the least; for we have met with many cases of pipe failure, in the past few years, from the very causes here explained; and we cannot emphasize too strongly the fact that in threaded joints for high pressure work the greatest care should be taken to see that there is a uniform and standard taper, both in the pipe and in the fitting, and that both are cut to gauge, so that when the joint is made up the threads of the pipe will all be forced into, and bottomed into, the threads in the fitting.

Sometimes pipe is threaded in such a manner that its end threads are straight for the reason illustrated in Fig. 12, while its tapered part makes a greater angle with the center line of the pipe than the standard calls for. In this case the pipe may fit the fitting at each end, while departing from it materially in the middle, as is illustrated in Fig. 15. A hold such as is shown in Fig. 15, while undoubtedly wretched and dangerous, is nevertheless slightly better than that shown in Fig. 14, since more of its threads are properly bottomed, and it is also more solid, and therefore less liable to suffer from vibration.

In conclusion, let us say that all pipe that is to be used in steam, water, and gas fitting should be of standard size, standard thickness, and standard thread, and should be round and straight. All fittings (unless made of malleable iron or steel, which would be preferable but more expensive) should be of heavy gray iron castings, with heavy beads, and with clean, full threads, tapped to standard gauge; and for high pressure service (100 pounds and over), the fittings should be extra heavy fittings, of the standard adopted by the American Society of Mechanical Engineers; the threads being cut actually and accurately by the Briggs standard in taper and gauge, but of the increased length required by the

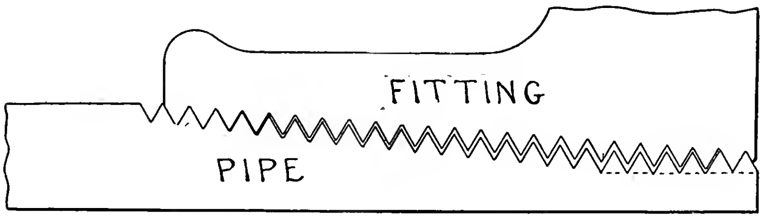

Fig. 15. — Illustrating an Imperfect Pipe Joint.

heavier fittings and flanges. The depth of thread in the fittings should also receive the consideration that it requires, in order that the extra length of thread on the pipe itself may be engaged throughout its entire length.

In handling large, heavy pipe, the threads sometimes become bruised so as to prevent the proper making up of the joint; and for this reason the precaution of examining both the fitting and the pipe before making the joint should never be neglected. In the best practice a thread guard is used in shipping and handling heavy pipe, and we are glad to say that this practice is now followed by a considerable and increasing number of contractors.

Often, in connecting to boilers and tanks, no reinforcing piece is used, and we frequently find that the opening in the shell of a boiler, where the blow-off is reinforced, is cut large, so that only the reinforcing piece is threaded. This is all wrong. To obtain a proper strength or holding power, both the reinforcing piece and the shell should be threaded. (This matter of the threading of both the shell and the reinforcing piece, where blow-off pipes enter a boiler, is more fully discussed in the issue of The Locomotive for March, 1903.)

Finally, we desire to repeat that at the present time, when there are so many pipe attachments to boilers, carrying full boiler pressure and perhaps subjected to an intense heat also, and often endangered by corrosion, it appears to us just and proper that manufacturers of such pipes should brand their products in the same way that boiler plates are branded, giving the name of the manufacturer, the quality of the material, and the pressure to which the pipe has been tested, as a guarantee of good faith. In the present state of affairs we have to take these things on trust, for there is no certain way of demonstrating from what plant a given sample of pipe came, unless the plant is known within a limited number of places. In this latter case the character of the marks left by the welding clamps will sometimes serve to determine from which plant it came; but it should not be necessary to trust to such an uncertain and often inapplicable method of identifying the source from which it came. There is nothing unreasonable about this suggestion, and we should think that all well-intentioned makers of pipe would be glad to adopt such a plan, in order to protect themselves from unjust suspicion when an inferior piece of pipe, from some less scrupulous maker, comes to light.

A Peculiar Steam Pipe Failure.

The steam pipe failure which is illustrated in the accompanying cuts occurred recently in the South, and it was thought to be well worth describing in THE LOCOMOTIVE, on account of the singular course that the broken pipe must have taken. The engravings themselves tell the story pretty well. The pipe which failed was a twelve-inch steam main, which received the output of six horizontal tubular boilers. The initial rupture occurred at a cast-iron tee,

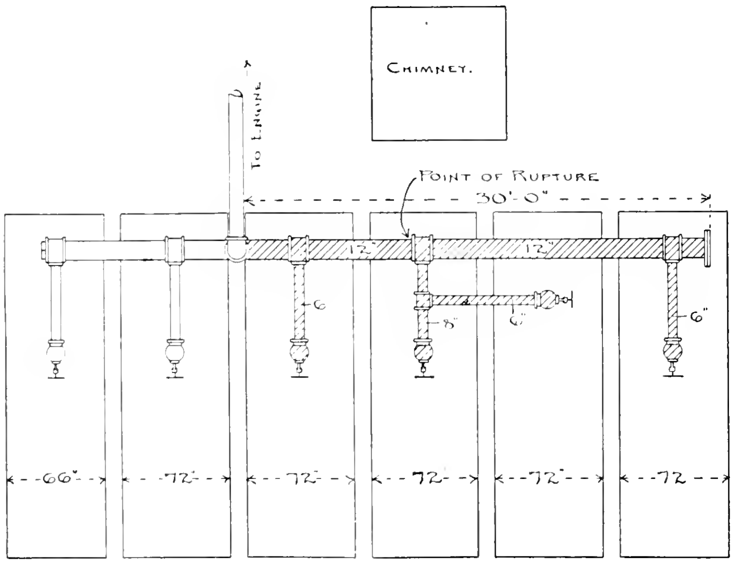

FIG. 1. — PLAN VIEW OF BOILER PLANT.

12 in. × 12 in. × 8 in., and it was afterwards found that the accident was due to the fact that owing to the threads not being standard, the steam main had been "made into" the fitting only three threads. The boiler carried a pressure of 120 pounds, and these three threads stripped in the tee, releasing the pipe entirely. The risers from the several boilers broke off at the steam nozzles, and the entire length of pipe that is shown shaded in Fig. 1 was thrown forward over the fronts of the

boilers, passing, in its course, between the smoke flue and the roof of the boiler house. As will be seen from Fig. 2, the space between the flue and the roof is only five feet high; and the singular fact about the accident is, that the broken main, together with its attached risers, passed through this space without hitting

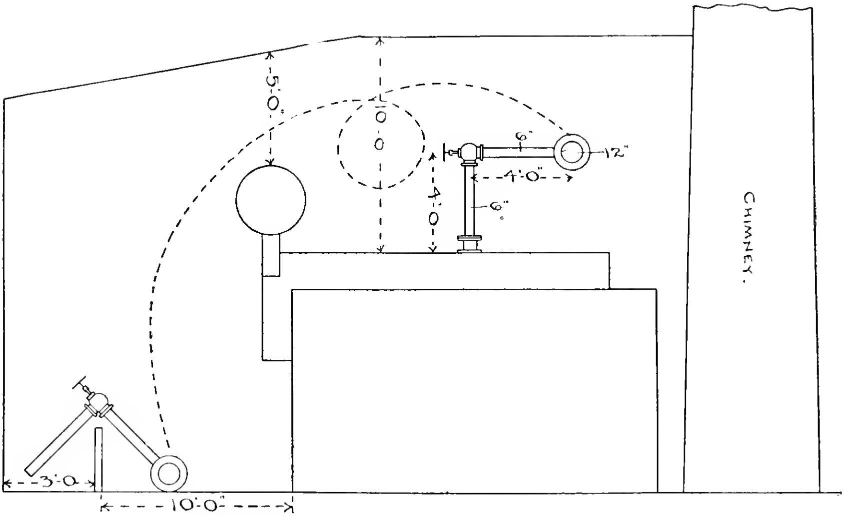

FIG. 2. — ELEVATION OF BOILER PLANT.

anything, landing eventually in the position shown on the left of Fig. 2. We presume that such a thing would not happen again, once in a million times. Nobody was injured.

Steam Pressures at Low Temperatures.

It is sometimes necessary, or desirable, in steam engineering practice, to know the pressure of saturated steam, corresponding to some definite temperature that is materially below 212° Fahr. All engineers are familiar with the fact that a definite pressure corresponds to each temperature, at temperatures higher than 212° Fahr., and all who have had to do with condensing engines should also know that the same holds true also at temperatures below 212°. The only difference is, that below 212° the pressure corresponding to any given temperature is less than the pressure of the atmosphere, and hence it cannot be observed except in condensers, or other similar vessels, from which the air is more or less perfectly excluded.

The diagram that is presented herewith is intended to facilitate the approximate estimation of the pressure of saturated steam, at any temperature between 32° Fahr. and 140° Fahr. As these small pressures are mostly observed by means of mercury gauges, or by other forms of vacuum gauges which are graduated so as to give their readings in inches of mercury, our diagram is drawn with this as the unit of pressure; the small horizontal subdivisions that are indicated at the top and bottom corresponding to tenths of an inch of mercury. The Fahrenheit thermometric scale is also used, and a horizontal line is drawn across the diagram for every even 10°, while the fine subdivisions that are indicated on the vertical lines at the left and right of the diagram are drawn for every 2°.

The diagram may be used either to find the temperature corresponding to a given pressure, or the pressure corresponding to a given temperature. For example, suppose we wish the temperature corresponding to a pressure (above a vacuum, of course,) of 0.5 in. of mercury. We look along the bottom graduated line of the diagram until we find the point corresponding to this pressure, and we then find the point that lies directly over this, on the curved line of the diagram. The height of the point so located on the curve gives the temperature desired. In the case of a pressure of 0.5 in., the temperature is almost exactly 60° Fahr. To take another case, suppose we wish to know the pressure corresponding to a temperature of 130° Fahr. We first find the point where the horizontal line through 130° intersects the curve, and we then determine the position of this point of intersection with respect to the horizontal scale. In the case of a temperature of 130° Fahr., the pressure is thus found to be approximately 4.6 in. of mercury, above an absolute vacuum.

A single illustration of the applicability of this diagram to practical matters may also be useful. Suppose that the average temperature of the condensing water in a given condenser is 115° Fahr., and we wish to know what is the highest vacuum that can possibly be attained in the condenser under these circumstances. There is no graduation mark on the diagram corresponding precisely to 115° Fahr., but there are marks corresponding to 114° and 116°, and, guided by these, we easily find that the pressure corresponding to 115° Fahr. is almost precisely 3.0 in. of mercury. This means that since water, at 115°, gives off vapor having a pressure of 3.0 in. of mercury, the condenser, no matter how perfect its action, cannot possibly give a vacuum that is within 3.0 in. of perfection; for even if the vacuum were perfect at a given instant, the water that is present would at once evaporate until the pressure became 3.0 in., absolute. In order to know where the vacuum gauge should stand, when the condenser water has a temperature of 115°, we must also know the height of the barometer at the time; that is, we must know what height of mercury the atmosphere will sustain at the given time, when the vacuum over the mercury column is perfect. If we suppose that the barometer reads 29.7 in., then it is apparent that the gauge on the condenser cannot possibly indicate (if it is correct) a vacuum higher than 26.7 in. If, therefore, the gauge on the condenser stands close to 26.7, when the temperature of the condensing water is 115° Fahr. and the barometer reads 29.7 in., we know that the condenser is working as perfectly as it possibly can, under the given conditions of temperature and barometric pressure.

EVERY once in a while we learn something brand new and interesting from the daily papers, about boilers and steam and other cognate subjects. This time it relates to the discovery of the power that can be had from steam. In connection with the description of a boiler explosion, one of our contemporaries says: "Sir Isaac Newton more than a century ago discovered the power of steam, when he noticed the vapor from his teakettle lift the lid." Now anything that Sir Isaac did *must* have been done "more than a century ago," because the gentleman died in 1727. The story about the teakettle lid may possibly have been true of James Watt, but we guess there is nothing in it so far as Newton is concerned.

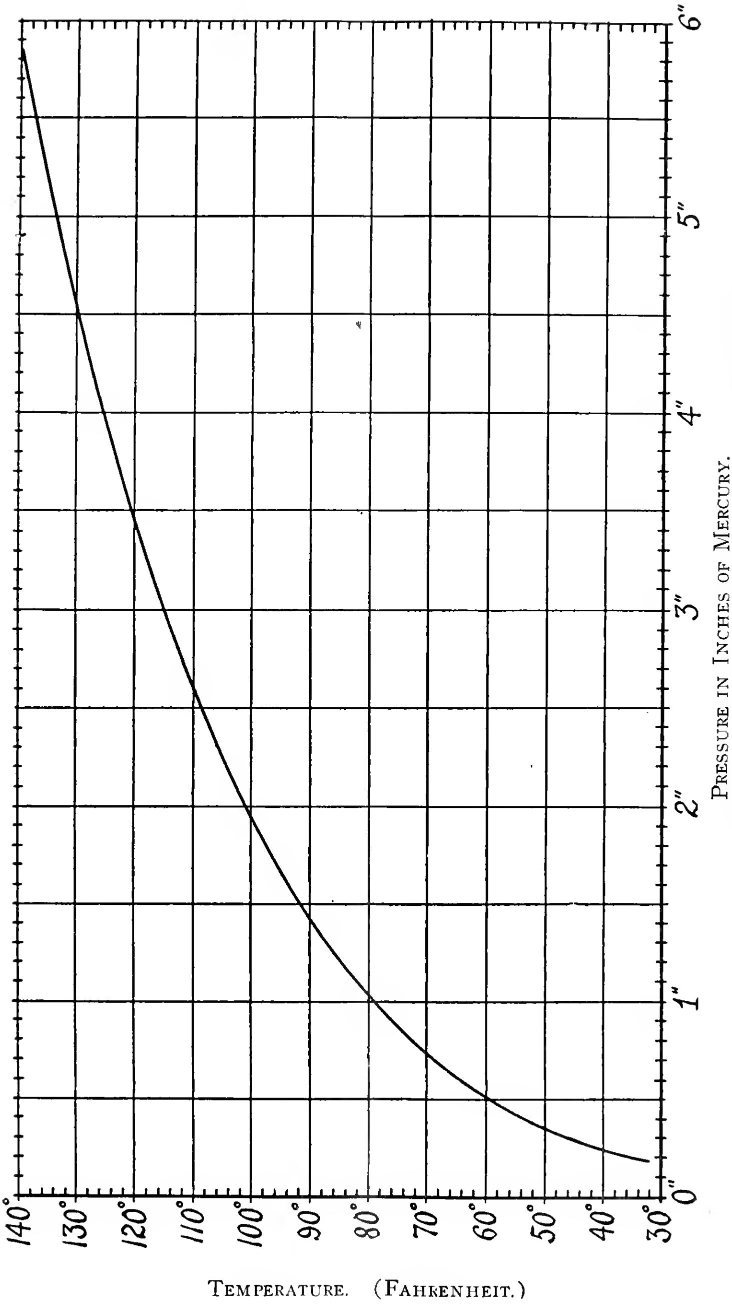

Diagram Giving Absolute Pressure of Saturated Steam at Low Temperatures.

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The Locomotive

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The Brockton Boiler Explosion.

At a few minutes before eight o'clock, on the morning of March 20, 1905, a terrible boiler explosion occurred at Brockton, Mass., in the factory of R. B. Grover & Company, manufacturers of the Emerson shoe. The explosion and its effects were awful, beyond all description. The entire country was profoundly shocked, and Brockton itself was overwhelmed with horror and grief.

The Grover factory (which was located in that part of Brockton known as

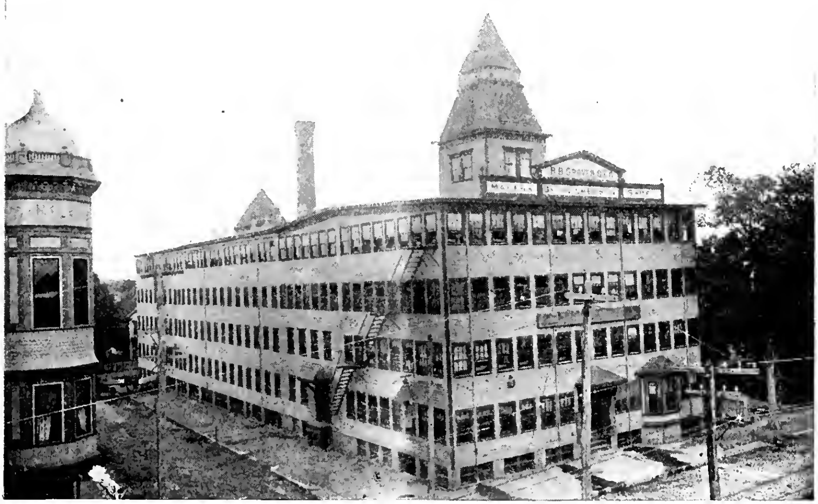


Fig. 1.—The R. B. Grover Company Plant before the Explosion.

Campello) was a four-story wooden structure, bounded by Denton, Calmar, and Main Streets. It extended along Calmar Street for a distance of nearly 200 feet, and it had wings extending down Denton and Main Streets for a distances of about 125 feet and 60 feet, respectively; the offices being in the Main Street wing. In Fig. 1 we present a general view of the office wing, taken some time before the explosion; the street in the foreground on the right being Main Street. This wing, being newer than the rest of the factory, was known as the "new building,"

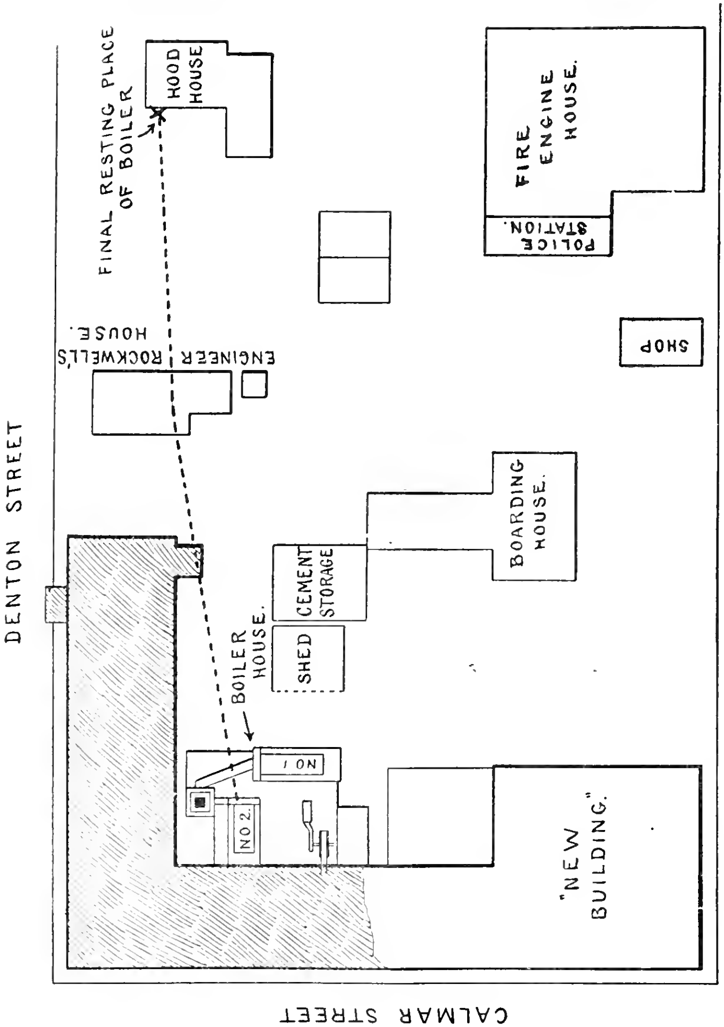


Fig. 2.— Plan of the Buildings.

The dotted line shows the course of the boiler, and the shaded area shows the part of the main building that was immediately thrown down by the explosion.

although it was continuous with the older part of the structure. The general plan of arrangement of the buildings will be understood by reference to Figs. 2 and 3. The boiler house was separate from the main building, but abutted against the central part of it, close to the Denton Street wing. It contained two boilers, known respectively as "No. 1" and "No. 2". No. 1 was the newer of the two, and it was also somewhat larger, and was run at a higher pressure. No. 2 was the boiler that exploded. As will be seen from Fig. 2, the setting of No. 2 boiler abutted directly against the Calmar Street section of the building, and it was parallel to the Denton Street wing, and only about ten feet distant from it.

On Monday morning, March 20, without the slightest warning, boiler No. 2 exploded with extreme violence, destroying the boiler house, and also blowing down, instantly, the entire Denton Street wing of the main building, and a considerable part of the Calmar Street section. (The portion of the main building which collapsed immediately is indicated by the shaded area in Fig. 2.) Fire broke out within a few minutes of the explosion, it being caused, in our opinion, by the open gas jets which were necessarily used in the process of shoe manufacturing. The ruins burned fiercely, partly because the wood work was very dry, partly because of the escape of the gas, and of the naphtha that was used in the manufacturing processes, and partly (we are informed) because the floors were more or less saturated with oily matters. We do not desire to give the impression that the factory was regarded as a poor fire risk, however, for we understand that it was insured by the fire companies at a rather low rate, indicating that they did not anticipate any very serious fire. The building was also furnished with automatic sprinkling apparatus, but this, of course, was rendered useless by the breaking of the pipes, when the building fell. The entire building was quickly destroyed by the flames, including the "new building," which remained standing, as well

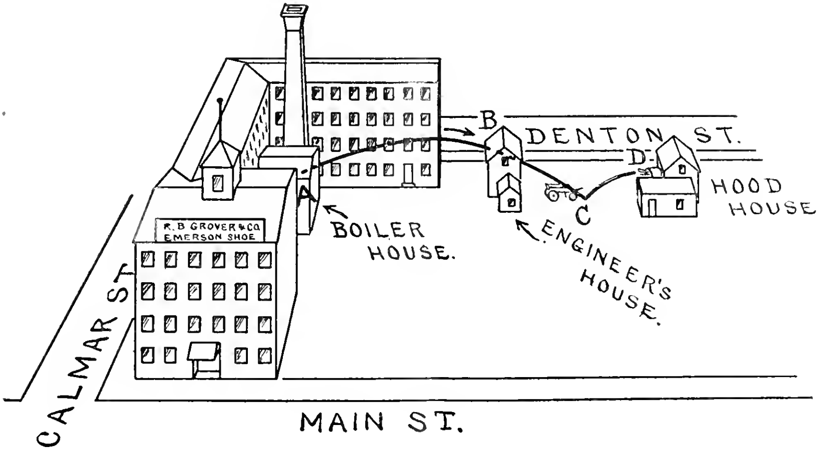


Fig. 3.— Perspective View of the Buildings.
The curved line, A B C D, shows the course of the boiler.

as the part that was thrown down by the explosion. The fire also spread to neighboring buildings, and among those destroyed were the Dahlborg block, across Calmar Street, the Iola House, and the dwellings of John A. Peterson, Oscar Peterson, Sylvester Wright, August Berger, and John Taft. The houses of engineer David W. Rockwell and Mrs. Effie Hood were damaged by the boiler itself, and the Rockwell house was afterwards further damaged by fire.

At the time of the explosion there were about 400 persons working in the factory, 200 of whom were in the part of the building which collapsed. Many of the 200 who were thrown down with the ruins were imprisoned by the wreckage, and were killed by the flames, before they could be extricated by the rescuing party. The scenes at the ruins were heartrending, and beggar description. Let us pass them over reverently. We should like to record the fact, however, that there were many notable exhibitions of heroism, both on the part of the dying and of the rescue party. It is not on the battlefield alone that heroism is seen. The flames were roaring fiercely, and the time that the work of rescue could be continued was all too short. Numbers of those who were badly hurt begged the rescuers to pass them by, and save others. Many who could not be reached cried out messages of love and remembrance for their friends that would shortly know them no more. Concerning the deeds of the rescue party, we desire particularly to mention those of the Rev. Father J. M. Kelcher, pastor of St. Margaret's Church, and of his curate, Rev. Father James O'Rourke. The former risked his life repeatedly in aiding in the rescue, while many of his parishioners were burned to death before him. Father O'Rourke was among the first at the scene. He rescued seven persons, and continued at work until he was overcome by the smoke and the exertion, and was physically unable to do more.

Of the 200 persons in the collapsed part of the building, no less than 58 died, either in the ruins or after being removed, and 117 others were injured. Most of the bodies in the ruins were burned beyond recognition, and identification had to be effected, in many cases, by the aid of buttons or trinkets, after the fire had been controlled. Even by these means it was found to be impossible to identify more than 17 or 18 of the bodies, and the remainder were buried by the city of Brockton, public burial services being held on the day of the funeral at five different places simultaneously, including the churches and the City Theater. No less than 108 families were thrown into mourning by the disaster. Public subscriptions were at once opened for the relief of the needy, and in a few days a fund of over $45,000 was collected.

The property loss, in a catastrophe of this kind, is hard to fix with precision, and in stating it we shall have to rely upon estimates which, while they may not be entirely correct, are apparently reasonable. The loss to R. B. Grover & Company is estimated at $200,000 That due to the destruction of the Dahlborg block is estimated at $25,000, and the loss from the destruction of the other buildings is also estimated at $25,000. The immediate property loss, due to the destruction caused by the explosion before the fire gained headway, is estimated at $80,000. It is said that the Grover company carried a total insurance of $195,000; $10,000 of this being boiler insurance with the Hartford Steam Boiler Inspection and Insurance Company.

It is easy, after a great disaster of this sort, to discover and point out errors of various kinds, whose correction or avoidance would have lessened the loss of life and property, even though such errors may not have been known or observed before attention was directed to them in such a terrible way. We realize this keenly, and it is therefore in no critical spirit that we suggest that the catastrophe would have been far less appalling if the factory had been more substantially built. The construction should have been such that the explosion of a boiler, external to the building, could not possibly have blown down half of the structure. Had the building been more substantial, it is probable that there would have been not more than two or three deaths to record, instead of 58.

The exploded boiler was of the horizontal tubular type, was built in 1891 by E. Kendall & Sons of Cambridgeport, Mass., and had been inspected and insured by the Hartford Steam Boiler Inspection and Insurance Company during this entire period. It was first inspected in the boiler-maker's shop on October 10, 1891, when it was thoroughly examined in every respect, and was also subjected to a hydrostatic test of 150 pounds to the square inch. It was 72 in. in diameter and 17 feet long, and was built of four courses of plates, the plates being 3/8 in. thick, one plate to a course. The heads were 1/2 in. thick, and there were 140 three-inch tubes. The seams were double-riveted lap seams. (We shall return to this point subsequently.)

The boiler gave way at the longitudinal riveted seam on the rear course of plates, this course and the rear head being torn from the rest of the shell, the rear sheet being found near its original position, while the head was carried forward for a distance of 42 feet. The remaining portion of the boiler, consisting of the three forward courses of plates, the front head, and the tubes, was projected in a direction nearly parallel to Denton Street, to a distance of 211 feet. The general course of the boiler will be understood by reference to Figs. 2 and 3, in which its trajectory is shown by the dotted line and the full, curved line, respectively. (Fig. 3, while not pretending to accuracy in such unimportant particulars as the number of windows in the building, is correct in its essential

FIG. 4.—GENERAL VIEW OF THE FACTORY RUINS.

features, being prepared from a surveyor's sketch of the ground plan. Some minor buildings which were not essentially connected with the explosion have been omitted from the engraving in the interest of clearness.) In Fig. 3, the original position of the boiler is shown at *A*. At *B* the boiler encountered the residence of Engineer David W. Rockwell, through which it passed. It next collided with the front end of the wagon shown in Fig. 8, after which it struck the ground at *C*, rebounding and crashing into the residence of Mrs. Effie Hood with such violence as to move it considerably on its foundations. The final position of the boiler is indicated at *D* in Fig. 3, and by the cross in Fig. 2. The boiler itself is also shown, in its final position, in Fig. 9.

In the investigation that was conducted after the explosion, a specially careful examination was made of the plates, in order to verify the quality of the material of which they were composed. Some of the stamps were quite distinct, and indicated the material to be a good quality of firebox steel, made by Carnegie, Phipps & Company, Limited, and having a tensile strength of 60,000 pounds per square inch. The stamp upon the sheet whose failure caused the explosion was very difficult to decipher, since the sheet itself, being left behind in the ruins, had been through the fire, and had been heated very highly in spots. The word "Firebox" was distinct, however, on this sheet. The mark "P. 7," within a circle, also appeared on this plate, as it did on the others; indicating that this plate was from the same lot as the others. The remaining letters and figures were not distinctly legible, but, so far as they could be read, they appeared to be identical with those found on the other sheets.

Fig. 5.—General View of the Factory Ruins.

The records of the inspections that have been made of this boiler show that its condition was at all times found to be satisfactory, except at the examination made on May 25, 1898, at which time the cast-iron manhole frame was found to be fractured. This frame was removed and replaced by a pressed steel frame; a section of the plate in the immediate vicinity of the manhole frame being removed, at the same time, and replaced by a new section of plate, $\frac{7}{16}$ in. thick, to which the new manhole frame was riveted. No other defects had developed on the boiler (so far as known), nor had the boiler shown any signs of distress or leakage.

Since 1900, the exploded boiler had been used only in the summer months, when work was light; the larger No. 1 boiler having been installed for winter service when the work was heavier. Part of the power used in the factory, recently, was electric power, furnished by an outside company; so that there does not appear to have been any need of forcing the boiler at all. There is, in fact, no evidence whatever that it was forced in the slightest degree. The boiler was insured for 90 pounds to the square inch, at which pressure it was considered to be quite safe. The usual working pressure was only about 80 or 85 pounds, and the inspection records show that the safety-valve (which was of the lever type) was examined by the inspectors whenever they visited the plant, and always found to be in good order. Whenever the boiler was under steam at the time of the visit, the inspector (as certified in the written reports submitted at the time) determined the pressure at which the valve would open. It was never found to require more than 90 pounds to open it, and it would sometimes begin to blow when the pressure reached 86 or 87 pounds. The last inspection with the boiler under pressure was made on October 28, 1904, at which time the safety-valve and

Fig. 6.—View of the Factory Ruins, looking toward Engineer Rockwell's House.

The chimney shows on the left-hand edge of the engraving. The exploded boiler stood in the immediate foreground, its position being marked by the white cross.

other appliances were reported to be in good order, the former blowing freely at 90 pounds. The steam pressure reported by the inspector as found recorded by the gauge at the time of this visit was 80 pounds. Similar reports were made at previous visits, but we do not need to give them in detail. There is no evidence whatsoever that the boiler was ever run at a pressure exceeding that at which it was believed to be entirely safe. The last internal inspection of the boiler was made on December 28, 1904, at which time no defects were found; and the inspector, after a thorough examination, pronounced the boiler perfectly safe for continued service. So far as the records of the Hartford Steam Boiler Inspection and Insurance Company show (and all the testimony given by employes of the Grover company corroborate these records) the boiler was not in service at any time since that last inspection, until it was fired up on Sunday, March 19, the day before the explosion; the larger boiler (No. 1) being then put out of service.

The inspector having reported, on December 28th, that the boiler was in good condition and free from defects, why did it explode practically as soon as it was fired up again? In cases of this sort we generally hear a great deal said about low water, and the carelessness of the engineer. In the present instance there was but little talk of this nature. There is no evidence that the engineer was negligent in any respect, and there is, on the contrary, plenty of evidence that there was a proper quantity of water in the boiler. The condition of the fusible plug alone would be sufficient evidence on this point. The Massachusetts law

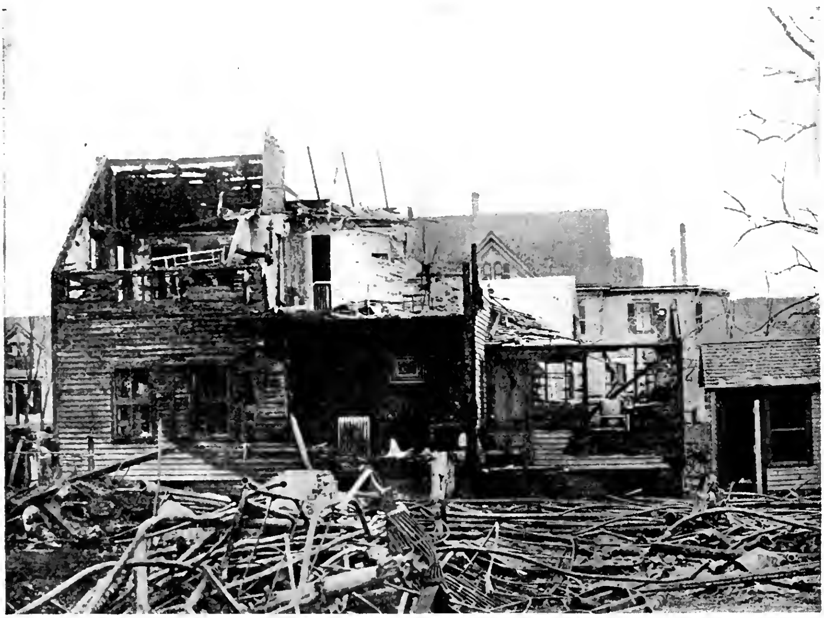


Fig. 7.— Engineer David W. Rockwell's House viewed from the Factory Side.

requires that every boiler shall be provided with a fusible plug, filled with tin or some other substance melting at a low temperature; this plug being so situated that it will be covered with water (and therefore prevented from melting) so long as the water in the boiler is at a safe level, but will be uncovered (and therefore exposed to the heat of the furnace without protection) when the water level falls to a dangerous point. In case the water in the boiler becomes dangerously low, the fusible plug is supposed to melt and permit the steam in the boiler to escape; the pressure being thereby reduced, and the engineer's attention directed to the fact that the boiler has too little water. This boiler was provided with such a plug, and after the explosion the plug was found to be in good condition, and unmelted.

The real cause of the explosion appears to have been a defect that is technically known as a "lap-joint crack" in the outer sheet, where that lapped over the inner one, in the rear course of the boiler. The crack in question is shown in Fig. 11. which gives a sectional view of the longitudinal joint that failed in the Brockton boiler. "Lap-joint cracks" are well-known sources of danger in boilers, and they are diligently sought for by inspectors. They may occur in either the inner or outer lap of the joint, and they invariably start from the interior surface, where the two plates are in contact, then extending into and through the plate, until its strength is practically destroyed. When a crack of this character has developed to such an extent that the plate is actually *perforated*

FIG. 8.—ENGINEER ROCKWELL'S HOUSE VIEWED FROM THE SIDE TOWARDS THE HOOD HOUSE.

The chimney of the factory is seen in the background. The wagon in the foreground was struck slightly at the front end by the boiler.

at some point, it is possible for the inspector to detect the defect. It is common, however, for such a crack to penetrate the plate quite deeply and uniformly, for a considerable distance along the joint, before actual perforation takes place at any point. Detection is then a matter of the greatest difficulty, and (as we confidently believe was the case in the present instance) it may even be actually impossible. We have no positive evidence that the crack in the Brockton boiler existed at the time our inspector made his last visit; but even if it be admitted, for the sake of argument, that it *did* exist at that time, a glance at Fig. 11 will show that unless there was an actual *perforation* of the plate the crack could not be seen either from the inside of the boiler or from the outside; and unless the crack had actually perforated the plate at some point, or had run into a rivet hole somewhere, its presence could not have been betrayed by even the slightest leakage. If there were any known way of detecting these hidden cracks, insurance inspectors and state inspectors alike would hail its discovery with joy.

It is theoretically possible, by the use of X-rays or of the radiations from radium, to detect "lap-joint cracks" that have not penetrated the plate at any

FIG. 9.—SHOWING THE BOILER IN ITS FINAL POSITION, AGAINST THE HOOD HOUSE.

The Hood residence, which is here shown, was partially wrecked, and was moved on its foundation about sixteen inches.

point. Radium cannot be seriously considered for this purpose at the present time, however, because the total available supply of it is still too small to permit of its use. Furthermore, the expense involved would be so great that only a national government or a Rockefeller could afford to purchase a sufficient quantity to serve in the practical work of making inspections. The habitual use of radium in considerable quantities would moreover be attended with dangers of the most serious kind to the inspectors, involving the probable production of blindness, and the development of destructive diseases of the tissues, such as cancer. The X-ray is perhaps a practical possibility, but certainly the subject has not yet been developed far enough to make X-ray inspections feasible. The Hartford Steam Boiler Inspection and Insurance Company perceived the possibilities of the X-ray along these lines, immediately upon its discovery, and took immediate steps to investigate the subject thoroughly. In fact, the discovery was announced in the Sunday papers, and on the very next day (Monday) experiments were begun at the Hartford office of the company, with a view of ascertaining the possibilities of the new radiation in the detection of "lap-joint cracks." The hope of ultimate success has not yet been abandoned, but it has been found (up to the present time) to be impossible to devise an apparatus which should be powerful enough to generate rays that will penetrate a boiler plate satisfactorily, and yet be sufficiently portable to admit of employment in the making of inspections. (A more extended discussion of the "lap-joint crack" will be found in a separate article in the present issue.)

FIG. 10.—GENERAL VIEW, SHOWING THE RUINS OF THE FACTORY, AND OF THE DAHLBORG BLOCK, THE IOLA HOUSE, AND OTHER BUILDINGS.

The inquest, which was called by District Attorney Asa P. French, technically for the purpose of determining how Richard Sprigings, one of the identified victims, came to his death, but really in order to investigate the cause of the explosion and find out who was to blame for it, was held at Brockton, on March 29th, Judge F. M. Bixby presiding. Fifteen witnesses were examined in all. Three of them, comprising the medical examiner, the city marshal, and an employe in the fated factory, testified as to the death of Richard Sprigings. Three other witnesses told about the exploded boiler. In this group was the man who made the boiler, the man who bought it, and the man who last inspected it. Then came five boiler experts, including two state inspectors of steam boilers and three inspectors of boiler insurance companies, who told of the characteristics of the type of boiler which exploded — *i. e.*, the lap-seam boiler. They corroborated one another in all essential points, chief of which was the liability of the development of the "lap-joint crack," and the impossibility of discovering it by any known test. The last four witnesses testified as to the condition of the engineer on the morning of the explosion, and as to the amount of steam pressure in the boiler as shown by the gauge a few minutes before the explosion.

At the conclusion of the inquest, District Attorney French made the following statement: "No evidence has been presented to me to show the criminal responsibility of any person for this explosion, which caused such a large loss of life, and in which the public is so deeply interested. The explosion was due

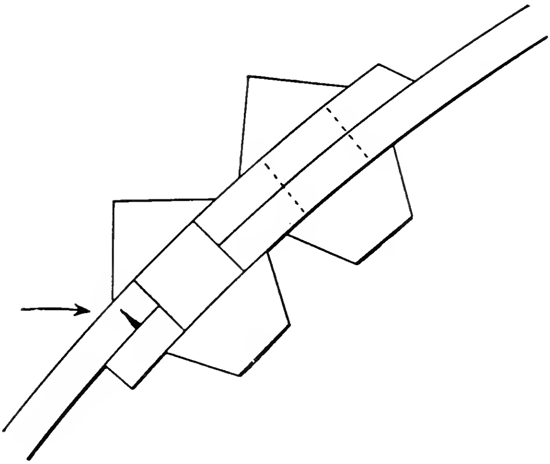


FIG. 11.— ILLUSTRATING THE HIDDEN CRACK WHICH CAUSED THE EXPLOSION.
This cut is drawn to scale, one-half the actual size. For a more extended account of lap-joint cracks, see the separate article on this subject, in the present issue.

to a danger peculiar to this class of boilers, a danger in the structural form of the boiler, almost impossible of detection, and therefore a defect all the more dangerous because so subtle. To paraphrase an old saying, I would say that the person morally responsible for this explosion and the loss of life is the man who devised this particular type of boiler." (That is, the lap-joint boiler.)

The newspapers that reported the facts of the Brockton horror made many statements (in most cases quite honestly) which had no sufficient foundation in fact, and certain of them, indulging in an uncontrollable desire for sensational matter, printed statements which were utterly unjustifiable, as their editors could easily have found out, supposing (for the sake of charity) that they did not know it in the first place. The circumstantial account of the appeal that the wife of Brockton's mayor made for contributions to the relief fund, containing, as it did, the exact phraseology of her open letter, was a masterpiece of mendacity on somebody's part, because it speedily transpired that she did not make any such appeal, at all. It was darkly hinted in many journals that there was damaging evidence of some sort or other that would be brought out against the insurance company, and against the engineer, and against others; and a strong intimation was made that these papers possessed "inside information" to the effect that when the time was ripe, an "example" would be made of some unnamed person or persons. All this was mere foolish talk, as was abundantly shown by the finding at the inquest. Engineer David W. Rockwell, instead of having fled through fear of retribution on account of his alleged "carelessness," was found to have been killed at his post of duty. No evidence worthy of a moment's consideration was adduced, tending to show that his conduct had been other than exemplary in all respects. The report was circulated that the boiler insurance company, feeling that the boiler was unsafe, had reduced the pressure upon it, within a year, from 95 pounds to 85 pounds. If this were so, surely the insurance company should be commended for its watchfulness and caution, instead of blamed. As a matter of fact, however, there was no such reduction of pressure, as there was no reason found for making such a reduction. It was also reported that engineer Rockwell had expressed himself as afraid of the boiler. If he said anything of this kind, he certainly was not serious about it, for on December 28, 1904, he asked our inspector if he could not allow more pressure on it. This the inspector declined to do, because while he considered the boiler safe at the pressure previously carried, it did not appear advisable to increase it. It was said that the state officials would have limited the pressure to 80 pounds (instead of 90, as permitted by the insurance company). It is hard to answer this, because probably the state officials themselves do not know what they would have done, if they had been consulted before the explosion. If they had known of the existence of any dangerous defect, of course they would not have allowed the boiler to run at all; and if they had no such knowledge, we can see no reason for supposing that they would have cut the pressure down. It was said that the boiler was patched. This was not true, except as regards the replacement of the sheet in the vicinity of the cracked manhole, as already noted. The boiler did not fail at this repaired place, however; and it is certain that the repairs were well made, so that the boiler was in excellent condition, about the region of the manhole. It was said that the Brockton boiler was an old one, and that it should have been retired from service on account of its age. This criticism is certainly unwarranted, so far as the mere number of years that the boiler had been in service is concerned. Fourteen years cannot be regarded as being a sufficiently long term of service to condemn a boiler, in the absence of definite symptoms of infirmity or weakness. The American Society of Mechanical Engineers, which counts in its membership most of the leading mechanical engineers of the country, considered this question of the lifetime of a steam boiler, in 1881. (*Transactions*, Vol. ii.) The general opinion of the members was, that it is impossible to state any term of service which should not be exceeded by a boiler. Some boilers deteriorate very rapidly, and others, being perhaps better made, or built of better materials, or managed more intelligently, or run under less trying conditions, or with better water, may continue to be serviceable for far longer terms. The only intelligent way of deciding upon the safety of a boiler appears to be, to have it inspected at proper intervals by men of undoubted competence. The inspection was criticised in some quarters, because the hydrostatic test was not applied. Now, if hydrostatic pressure *had* been applied habitually in the past, and the defect had not been detected, and the boiler had afterwards failed, there would have been plenty of critics who would have said that it was the application of the hydrostatic pressure that led to the formation of the fracture. There are two sides to this question, as there are to most others. The Hartford Steam Boiler Inspection and Insurance Company's men never hesitate to apply the hydrostatic test, when that appears to be called for; and it is likely that they have made as many of these tests, altogether, as the employes of any other organization in the world. It will be seen, for example, in the summary of our inspector's work given elsewhere in this issue, that the total number of such tests made by them for this company up to January 1, 1905, was no less than 211,022. The Brockton boiler was tested hydrostatically by us when it was first built, but, experience having indicated that the hammer test is superior for the general run of inspections, that method had been used in the subsequent examinations, although, as has been said, there would not have been the least hesitation about applying the hydrostatic test in addition, or in the place of the hammer test, if any good reason had been discovered for so doing. We should like to call attention to the fact that the inspectors of the Hartford company detected no less than 3,914 fractured plates during the year 1904, 614 of these fractures being classed as dangerous, and likely to lead to explosions. During the same period 6,581 cases of leakage at the seams of boilers were noted, of which 403 were pronounced dangerous. These two classes of defects, — fractured plates and leakage at joints, — include the "lap-joint cracks" that were discovered during the year. Of course they also include other defects also, but some idea can be formed from these figures of the vast number of defects related to the "lap-joint crack" that are detected by our inspectors in the course of a twelvemonth. The failure to detect this particular crack, under conditions where detection was practically impossible, must not be taken as evidence of incompetence, but rather as one occasional instance in which human limitations assert themselves along this line of work.

A resolution was passed, in connection with the Brockton explosion, by a certain organization of workingmen, in which a call was made for the appointment of boiler inspectors who would wear overalls and carry a hammer, and who would not be "afraid to soil their high collars," or mar their canes, etc., etc. We do not consider that a resolution of that kind is really worthy of serious editorial attention; but as it may be construed by those who are not informed to the contrary as a reflection upon the man who inspected the Brockton boiler, we think it is only fair by that man to state that he is very far from being the sort of individual that this resolution might imply. The history of the inspector in question, briefly, is as follows: As a boy, he was employed in firing up, wiping, cleaning, and running around the yard on a dummy engine used on a street railway. He was next employed as a fireman in both freight and passenger service, and he then learned the machinist's trade in a shop where steam engines and boilers were built and repaired. From this he turned to running stationary engines, and was next a steamboat fireman, oiler, and marine engineer, having had a license for fourteen years. He was engineer for the city institutions on Deer Island, Boston Harbor, and outside machinist for a machine shop, engaged in setting up, delivering, and repairing locomotives and steam shovels, and was then employed as master machinist by the United States Army Corps of Engineers, having under his supervision steamers, towboats, dredgers, and stone quarrying machinery. He has been employed as inspector for this company since 1881, and during that time he has probably made as many as 15,000 boiler inspections. It gives us pleasure to add that this is the first accident that has ever occurred to any boiler under his charge, in all this long term of service, extending over nearly a quarter of a century. We consider that it is only necessary to state these simple facts to show how unjust and unworthy the resolution to which we have referred was, if it was intended in any sense as a reflection upon the man who inspected the Brockton boiler.

The particular defect which caused the destruction of this boiler occurs, occasionally, in boilers having lap-joints (that is, joints at which one of the plates laps over the other one, as in Fig. 11), but we have never known it to occur in a boiler provided with butt joints (that is, joints in which the two plates to be joined are brought together so that their edges abut, and in which a pair of straps, one internal and the other external, are provided for riveting purposes). This fact has led a good many persons to use the Brockton explosion as a text for preaching that lap-joints should not be allowed in boilers at all, or else that they should be allowed only under certain restrictions as to the size of the boilers, and the pressures that they are to be allowed to carry. The Hartford Steam Boiler Inspection and Insurance Company has advocated the use of the butt joint for many years past, and doubtless its insistent advocacy of that form of joint has been largely responsible for the growing favor with which the butt joint is regarded at the present time. As long ago as 1880, we drew attention to the danger from "lap-joint cracks." (See The Locomotive for September, 1880, page 147, and for October, 1880, page 167.)

In commenting on the Brockton explosion, a number of persons, including some very well-known engineers, have suggested that the use of the lap seam be absolutely prohibited by law. This appears to us to be a very drastic proposition. We should like to see the lap seam discarded altogether for boilers carrying considerable pressures; but we are aware, at the same time, that the lap-joint is regarded by many competent authorities as entirely satisfactory. At all events, designers of admitted ability continue to make use of it as they would not do if they were satisfied that it was markedly dangerous. It is probable that 85 per cent. of all the boilers now in use in the United States have lap-joints; and the proposition to make the further use of these boilers illegal strikes us as calling for the most serious consideration before acceptance. Certainly there never has been (so far as we are aware) any municipality or state or government, nor any bureau of steam engineering, which has yet made any wholesale condemnation of the lap-joint. In view of these facts, it is certainly reasonable to suggest that the matter be most carefully considered before manufacturers and boiler owners generally are put to the enormous expense and inconvenience that would be involved in prohibiting, at once, the use of lap-seam boilers.

The "Lap-Joint Crack" in Steam Boilers.

The fearful boiler explosion at Brockton, Mass., which is described and illustrated in the present issue of The Locomotive, was due to an undiscoverable defect known as a "lap-joint crack." Although there is nothing new about this defect, which has been known and recognized for many years among boiler experts, yet the terrible Brockton disaster has attracted great attention to it, and the general interest that is felt is well shown by the many letters that we have received, and also by the numerous articles that have appeared in periodicals both technical and general. We have repeatedly described and discussed the lap-joint crack in The Locomotive; but in view of the interest in the subject that has been manifested by the public at large, we feel that our article on the

Brockton explosion would not be truly complete unless it were accompanied by some further explanation of the defect in question.

A "lap-joint crack," as the name implies, is a crack in a boiler plate, which follows the general course of the longitudinal lap-riveted joints by which the plates of the boiler are held together. Any kind of a crack possessing this peculiarity of position would, strictly speaking, be a "lap-joint crack"; but the name is usually applied to one particular kind of defect, which is illustrated in

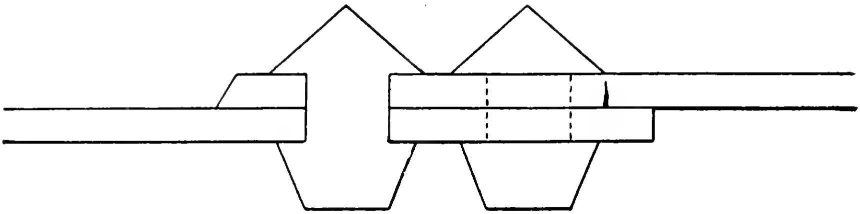


Fig. 1.—A Lap-Joint Crack Under the Outer Edge of the Rivet Heads.

Figs. 1 and 2, and to which our present attention will be confined.

The "lap-joint crack," in this usual and most dangerous form, consists in a fracture of one of the plates of the boiler, which follows the general course of the riveted joint in such a manner that (as indicated in Fig. 1) it lies very nearly under the extreme edges of the rivet heads, and is at the same time entirely covered by the projecting lap of the unaffected plate. (In Fig. 2, which represents an actual crack that was detected by one of our inspectors, the position of the edge of the overlapping plate with reference to the crack is indicated by the dotted line.) The main thing to observe in connection with Figs. 1 and 2 is that the crack, although it may occur in either the inner or the outer plate of the boiler, always starts from that face of the affected plate which is in contact with the overlapping plate, progressing into the metal more and more deeply until the boiler is weakened perhaps to the point of explosion; and being itself so situated that it cannot be seen from either the inside or the outside of the boiler. It is this peculiarity of position which makes the defect so dangerous, the strength of the plate being sometimes greatly reduced before there is any external, visible evidence that the crack exists at all.

It occasionally happens that a lap-joint crack extends, at some point, beyond the edge of the overlapping plate, and in this case the inspector can reasonably be expected to discover it. Unfortunately, however, these cases are not at all common, for the main part of the crack almost invariably lies entirely back of the lap of the other plate. It is not uncommon for radiating, hair-like branch cracks to extend out from under the lap, but these, when they exist, are almost always exceedingly delicate, and as they are more or less covered with dirt or scale, it is next to impossible to detect them in the course of a regular inspection. When the crack, or some branch of it, runs into a rivet hole, there may be leakage around the rivet when the boiler is in service, and the crack may betray itself in this manner. Leakage does not necessarily occur, however, even under these circumstances; for steam cannot escape around the rivet if the rivet itself fits the plate tightly at every point of contact, both in the shank and under the head.

If the crack is so deep that the plate is actually perforated at one or more points, the inspector may be expected to detect the defect, either by observing the crack itself or by observing leakage of steam through it, according as the boiler is shut down at the time of his visit, or under steam. If the plate is not perforated at any point, and if there is no leakage around rivets, and if the crack lies (as it usually does) entirely under the lap of the adjacent plate, and if there are no discoverable branch cracks running out from under the lap, then it is practically impossible to detect the defect without destroying the boiler. The rivets could of course be cut out, and the plates separated; but this proceeding is altogether too heroic to be in favor among boiler owners, unless there is some previous and tangible reason for suspecting that a lap-joint crack exists.

One of the most unfortunate things about these hidden cracks is that they show a marked tendency to extend nearly through the affected plate for a considerable distance along the joint, without actually perforating it anywhere. Fig. 3 illustrates a well-marked case of this sort. The piece of plate which it represents was cut out of a boiler that was affected by a lap-joint crack. The crack, in this instance, did not actually perforate the plate at any point, but it extended so nearly through it that (if we remember correctly) the specimen here shown was bent over by hand. (The position of the edge of the overlapping plate is indicated, in this engraving, by the dotted line.)

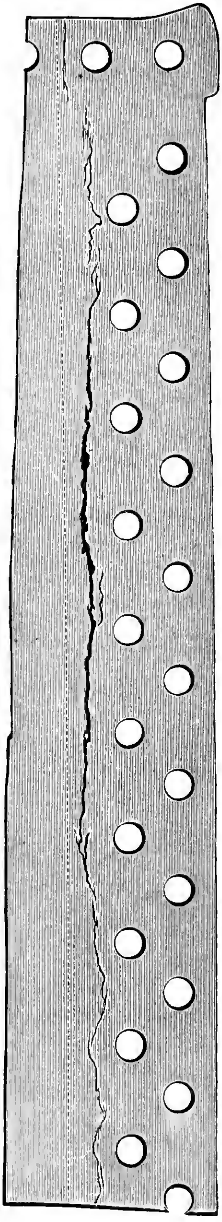


Fig. 2. — Section of a Boiler Plate with a Lap-Joint Crack.

When we come to consider the causes of these lap-joint cracks, we have to fall back upon reasonable conjecture, since we have no certain knowledge on the subject. We cannot even say, with absolute positiveness, whether they are developed slowly or rapidly; and it is likely that there is a great range in this respect. It appears probable that there are two main causes contributing to the formation of lap-joint cracks, these being (1) the treatment that the plates receive in the course of the manufacture of the boiler, and (2) the action of the normal stresses to which the plates are exposed during the service of the boiler, on account of the steam pressure. We shall consider these two causes separately.

First, as to the processes of manufacture and their effects. In rolling plates into the cylindrical form, preparatory to riveting them up into shells, the rolls do not "grip" the plate as effectively near the end of the operation as they do in the middle of it; for the last end has a tendency to slip off of the first roll, and spring back so as to be flatter than the desired radius would require. If the plate were solid, and had no rivet holes in it, the resulting cylinder would look something like Fig. 4, one end of the shell "standing off" from the general curve, as represented. If, on the other hand, there are one or more rows of rivet holes along the edges of the plate that is being rolled, it may easily happen that the plate takes a sharper bend along one or more of these rows of holes, owing to the weakening of the plate at these points, from the removal of the material in forming the holes. The ends of the plate, where they come together, may then present the aspect represented on a greatly exaggerated scale, in Fig. 5. The main point is, that as the plate is passed through the rolls, it will not, in general, receive a perfectly uniform curve, from one extreme edge to the other, but will depart more or less, at the ends, from the curvature that is required in the finished boiler. It is necessary, therefore, to force the ends to the proper curvature, either by sledging, or by some other equivalent means; and this puts a stress in the plate near the joint, which persists in the finished boiler, unless the sheet is carefully annealed after being bent to shape. The magnitude of the stresses introduced in boiler plate in the process of manufacture is hardly realized, in all probability, by the general run of our readers. It will be evident, however, that the very operation of rolling must strain the metal of the sheet beyond its elastic limit, at least on its inner and outer surfaces, or otherwise there could be no permanent change of shape from the action of the rolls. Who shall say what stresses are introduced in the material by the indefinable modifications of structure that are brought about by sledging? Certainly such stresses exist, and they are of considerable magnitude, and they persist after the boiler is completed and put into service, and their effects are added to those due to the normal steam pressure that the boiler is called upon to carry.

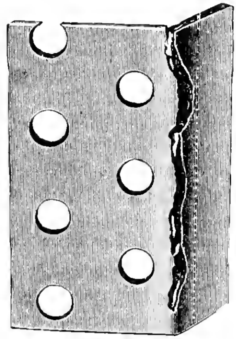


FIG. 3. — A PLATE ALMOST PERFORATED BY A LAP-JOINT CRACK.

Let us next consider the action of the stresses that are set up in the boiler by the steam pressure within it, as illustrated in Figs. 6 and 7. Fig. 6 represents an ordinary double-riveted lap-joint, and it is to be observed that when the boiler is under steam, the tensions on the respective plates which are united by the rivets cannot possibly act in one and the same straight line. The plates do not abut against each other at the edges, but are laid one over the other, and the tensions to which the plates are subjected must be related to each other somewhat as indicated by the arrows. It is evident, therefore, that there will be a tendency, in such a joint,

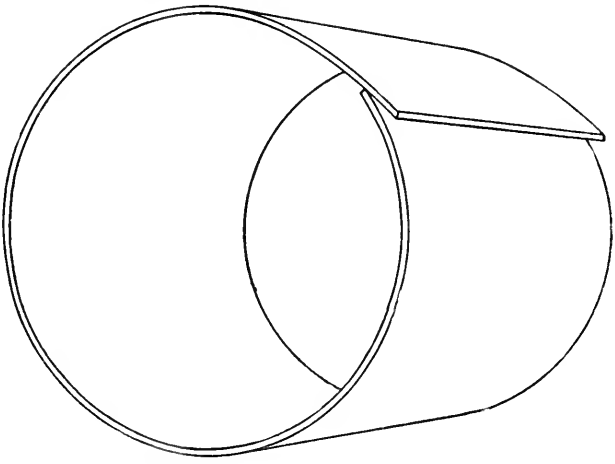


FIG. 4. — ILLUSTRATING THE "OFF-SET" OF THE LAP.

for the rivets to "cock up" somewhat after the fashion shown in Fig. 7. The action will not be as violent as here represented, but the tendency will be for the joint to be deformed *towards* a position in which the two overlapping plates would come into one and the same straight line, as suggested by the dotted lines in Fig. 7. The parts of the plates which lie between the rivet shanks and under the rivet heads will be held firmly together by the rivets; and the bending action to which the plates are subjected will therefore be most severe immediately under the edges of the rivet heads, where it first becomes possible for the plates

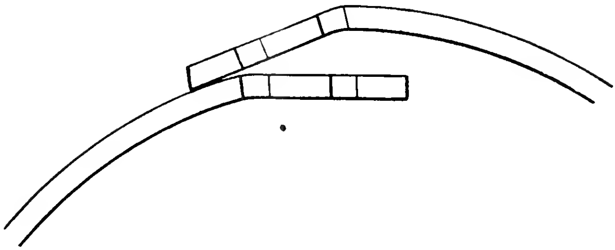
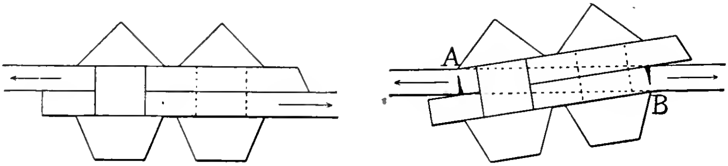


Fig. 5. — Showing the Action of the Rolls. (Exaggerated.)

to bend to any perceptible extent. As the steam pressure in the boiler varies, the bending action upon the plates will also vary, and hence there will be a tendency, sooner or later, to form a crack in the plate, either at *A* in Fig. 7, or at *B*. The action here outlined appears to us to be a very real one, and when the stresses to which it gives rise are added to the uncertain but perhaps very severe ones due to the sledging of the edges of the sheet in the process of manufacture, we are of the opinion that the "lap-joint crack" may reasonably be assumed to be the result. No doubt a great deal depends upon the quality of the material of which the boiler is constructed, for one grade of material might stand an inordinate amount of maltreatment with the sledge, and a protracted exposure to continually varying bending stresses in the course of actual service, without developing any crack, while another grade might give out very soon. Ductility appears to be of the greatest importance for the protection of the plate against the effects of the strains occurring in manufacture and in service, and the Hartford Steam Boiler Inspection and Insurance Company has therefore paid the greatest attention to securing this property in all boilers built under its supervision.

So far as we are aware, the lap-joint crack (as is implied by its name) does not occur except in connection with lap-joints; and for this reason (among others) we have for many years advocated the use of butt joints, in which the plates that are to be joined together are caused to abut directly, at the edges, as shown in Fig. 8, so that the plate-stresses act in the same straight line. All types of boilers which have riveted shells and lap joints appear to be liable to lap-joint cracks, and if the plates are thick and the shells are of small diameter, the liability appears to us to be even greater than it is when the shells are thin and of relatively large diameter.

Butt joints, such as the one shown in Fig. 8, are growing in favor among boiler makers and designers, but we are confident that at least 85 per cent. of all the boilers now in use in the United States still have lap joints, and we are aware that many designers consider the lap joint to be satisfactory, provided it has a proper efficiency for the stress to which it is to be exposed. As we have already said in the article on the Brockton explosion, in the present issue, we therefore feel that careful consideration should be given to the matter, before lap-riveted joints are subjected to a wholesale condemnation. (For a study of riveted joints of various kinds, with respect to their strength and efficiency, see THE LOCOMOTIVE for July, 1891. In some copies of that issue two errors occur, which we here take occasion to correct. On page 101, line 3, the number "57,031" should be "67,031"; and on page 104, line 10, the decimal "0.475" should be "0.375." Consult, also, the issues of THE LOCOMOTIVE for October and November, 1890.)



FIGS. 6 AND 7.— BEHAVIOR OF A LAP-RIVETED JOINT UNDER PRESSURE.

The hidden crack is by no means peculiar to American practice. Thus Mr. Lavington E. Fletcher of the Manchester Steam Users' Association, England, at a meeting of the Institution of Mechanical Engineers held some few years ago, in speaking of riveted joints for boiler construction, said that he had recently had three locomotive boiler explosions brought to his notice, in which the primary rent had occurred just at the edge of the inner lap, along one of the longitudinal joints of the barrel of the boiler, although the plates were of the best quality, and the boilers were built by first-class makers. Engineers were familiar, he said, with the ordinary groove, from which a number of locomotive boilers had exploded; but in this case there was no true groove, but only a fine hair-like crack lurking under the edge of the overlap. To get at the bottom of the matter, he cut up the boiler of a sister engine that had not failed, and upon

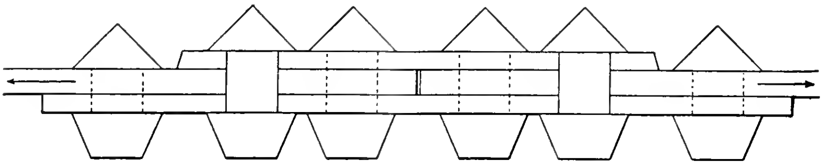


FIG. 8.— DOUBLE-STRAP BUTT JOINT.

taking the plates out, and bending back the overlap, they were found to be cracked almost through to the skin in some places, although the crack was so fine that it might easily have escaped detection. He recommended that the longitudinal joints in locomotive barrels be made with double butt straps, so that the boiler might be truly cylindrical, and changes of shape under varying pressures be avoided.

In a discussion on riveted joints, as reported in the *Minutes* of the same society for 1881, Mr. Jeremiah Head spoke of the dangers incident to rolling plates after the holes are punched. His argument is very similar to that advanced above, and conforms with our own experience. The danger of forming a sharp bend along a row of holes is greater in a double-riveted lap joint than in a single-riveted one, and still greater yet in the triple-riveted lap form. "If there were three rows of holes," said Mr. Head, "the third row gave a great additional leverage for the rolls to act with; and certainly the plate would prefer to bend at that row, rather than to bend equally throughout the part between the rolls. He had frequently seen in boiler-makers' works about the country . . . . that if the plates were double-riveted, and bent cold after punching, there was a sharp bend to be observed in both plates along the inside row of rivets, which was certainly very bad. In such a case, where a boiler-maker supposed he was getting extra strength by a double row of rivets, he was really making that part a very weak place in the boiler. But that was not the whole question. The effect of bending after punching was to suddenly increase the curvature at each line of rivets; and when the plate came to be brought round with a circle for a small boiler, it was evident that the two ends would come into the position shown (on an exaggerated scale, of course,) in Fig. 5. Then, since this joint had to be riveted together, the edges had to be knocked back by some means or other, and very likely in a country shop that would be done very roughly. He thought engineers ought not to forget that weak point."

We desire to acknowledge the receipt of *Bulletin No. 107,* issued by the University of Wisconsin, and relating to the "Summer School for Artisans" which is maintained, in connection with the University, by the state of Wisconsin, at Madison, Wis. This summer school is maintained for the benefit of young men who are unable to take a regular engineering course, and the instructors are from the regular faculty of the College of Engineering of the University. The students also have the use of the University shops and laboratories. The fifth annual session begins on June 16th, and continues for six weeks. Full information concerning the school may be had from Frederick E. Turneaure, Dean, College of Engineering, Madison, Wis.

During the year 1903-4 Yale University gave a course of lectures upon the general subject of insurance, the lecturers being non-resident gentlemen who are professionally engaged in insurance of one kind or another. These lectures, which covered practically every important branch of insurance, have now been published in two volumes, and these volumes will constitute a very valuable addition to the library of any person who is interested, directly or indirectly, in insurance. The first volume is devoted to life insurance, and the second to fire and miscellaneous insurance. The lecture on boiler insurance (in which, presumably, our readers would be more especially interested) is in the second volume, and was delivered by A. D. Risteen, of the Hartford Steam Boiler Inspection and Insurance Company. (Cloth, $2.15 per volume. Published by The Yale Alumni *Weekly,* New Haven, Conn.)

The present issue of The Locomotive has been delayed, in order that we might be enabled to print, at an earlier date than would otherwise be possible, an accurate account of the terrible boiler explosion at Brockton, Mass. We trust that the somewhat extended discussion of this disaster that we now present will be considered a sufficient recompense for the delay.

The Locomotive.

FOUNDED BY J. M. ALLEN, A.M., M.E.

HARTFORD, APRIL 15, 1905.

THE LOCOMOTIVE *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each. (*Any volume can be supplied.*)

Agency Changes.

Mr. Scott R. Benjamin, who for several years has been with the Hartford Steam Boiler Inspection and Insurance Company, satisfactorily filling the office positions to which he was from time to time assigned, and more recently has been General Agent of the Home Department, has closed his connection with the company, and entered the service of the Travelers Insurance Company, in their Liability Department.

Mr. E. H. Warner, who has been in the service of the "Hartford" for several years as Special Agent for the Massachusetts portion of the Home Department, with office at Springfield, succeeds Mr. Benjamin as General Agent of the Home Department, with headquarters at Hartford.

Mr. H. C. Long has been appointed Special Agent in the Home Department; office also at Hartford. Mr. Long had a mechanical training and experience before entering the insurance field; he was General Agent and Adjuster for the Jersey City Fire Insurance Company, and also for the Orient Fire Insurance Company of this city; later he entered the service of the Liability Department of the Ætna Life Insurance Company as mechanical and general Inspector.

We commend General Agent Warner and Special Agent Long to the present patrons of the company and the entire steam using public, and trust they will receive the same cordial support and confidence so long accorded to the company and its representatives.

On the Mechanical Energy Developed by Exploding Boilers.

The mechanical energy developed by an exploding boiler is often so great as to lead inexperienced persons to the belief that the accident must have been due to dynamite, or some other similar high explosive. It is difficult to believe that so much energy can be developed by a few cubic feet of heated water. The subject was investigated theoretically by Airy, and by Clausius, and by Rankine, and, as is well known to steam engineers, these investigators showed that it is quite possible to account for the tremendous energy that is observed. Airy, for example ("On the Numerical Expression of the Destructive Energy in the Explosions of Steam Boilers," *Philosophical Magazine*, Series iv, vol. 26, November, 1863, page 329), shows that after making all due allowances for various circumstances that he mentions, we must admit that "the destructive energy of one cubic foot of water at the temperature which produces the pressure of 60 pounds to the square inch is equal to that of one pound of gunpowder." Professor R. H.

Thurston has given some of the results of the investigations that have been made along these lines, in his little work entitled *Steam Boiler Explosions* (New York, John Wiley & Sons), to which the reader is referred for a fuller discussion of the subject than can be here attempted. Professor Thurston gives Rankine's formulas, but he does not satisfactorily explain their origin; and it is our main purpose, in the present article, to show how these formulas may be derived.

In the first place, it must be explained that we cannot calculate the exact quantity of mechanical energy that may have been liberated by any given explosion, because we can never tell precisely what happened when the boiler gave way. We can, however, compute a *maximum limit* to the quantity of mechanical energy so liberated. That is, we can determine a quantity of mechanical energy such that the total amount liberated by the explosion may perhaps have been equal to this quantity, while, on the other hand, we can rest assured that the total mechanical energy set free could not exceed this limit, by any possibility. Whether the quantity of such energy actually developed was one-fourth of this, or one-half, or some other fraction, we cannot tell without knowing what the exact course of events was, in the few brief moments from the time the boiler gave way until the destruction was complete.

It must be carefully remarked that we are speaking, throughout, not of the total quantity of energy liberated by the boiler, without regard to its type, but only of the amount of *mechanical* energy set free; — energy, in other words, that could manifest itself by dislocating buildings and walls, by projecting the boiler into the air, and by performing other mechanical acts of like nature. It would be easy enough to calculate the total quantity of energy of all kinds liberated from the boiler, for in order to do this we should merely have to compare the heat energy that the boiler and its contents contained before the explosion with the heat energy possessed by the iron and the dissipated steam and water after the explosion was complete. But such a calculation would have little interest, because the question would still remain, How much of this total quantity of energy dispensed could have been expended in the actual production of mechanical effects, and how much of it must necessarily have remained, all the time, in the form of heat, without directly contributing to the work of destruction?

The difference between these two things can be easily made manifest in the following manner. Let us imagine a boiler full of steam and water, at a temperature of 340° Fahr. If we should allow this boiler to radiate its heat freely until the whole had cooled down to the temperature of the atmosphere (say 70° Fahr.), and should then discharge its cooled contents into the air, we should, by the process as a whole, remove from the boiler all the energy that it contained; but no part of the energy so removed would produce destructive effects. On the other hand, suppose we had permitted the boiler, while it was full of steam and hot water at the original temperature, to burst, and to discharge its contents directly into the air. We should then find that a considerable part (though by no means all) of the energy that it contained would produce mechanical effects. By either method we should remove the same total quantity of energy from the boiler, but in one case we should have mechanical work performed, while in the other we should not. The general problem that we propose to solve, in this article, is to find what is the greatest quantity of mechanical energy that could possibly be developed by the explosion of a given boiler, when the circumstances of the explosion are the most favorable possible to the production of such energy.

It will be necessary to make use of mathematical symbols and processes, because the subject does not admit of treatment otherwise. The problem, in other words, is intrinsically a mathemathical one, and hence it must be solved by strictly mathematical methods. The main difficulty, however, does not appear to lie in the mathematics, so much as it does in the attainment of a clear understanding of the physical principles upon which the mathematical treatment is based; and we shall therefore endeavor to make these physical principles as intelligible as possible.

Rankine, Airy, Thurston, and most (and perhaps all) of the other workers in this field take a special view of the nature of a boiler explosion, which does not appear to us to be entirely beyond reproach. These authorities attribute the destruction that takes place in a boiler explosion solely to the direct expansion of the steam that is liberated when the boiler gives way. A portion of the contents of the boiler exists in the form of steam at the moment immediately preceding the explosion, and as the pressure upon the water in the boiler is relieved, a certain portion of that water evaporates so as to form a further supply of steam, and this also expands and adds to the mechanical work performed. Now there is no doubt but that much of the work of destruction is performed in this manner, and yet we do not think that this tells the whole story. We are of the opinion, in fact, that the expansion of the *air* in the vicinity of the boiler has much to do with the mechanical work performed; this expansion being due to the heating of the air, as the contents of the boiler is discharged into it. Assume, for the sake of illustration, that the boiler gives way in such a manner that the heated water that it contains is projected into the surrounding air in the form of a spray of fine droplets. Each of these droplets is highly heated at the moment of its liberation, and we proceed to consider how this heat is expended. In the first place, there can be no doubt but that some portion of the heat of each droplet is given up, almost instantly, to the layer of air by which the droplet is immediately surrounded. There can also be no doubt but that a part of the droplet becomes vaporized with similar suddenness. Lastly, there can be no doubt but that the steam that is formed in this manner, together with that previously existing in the boiler, will very soon condense, so as to give up its latent heat to the air in which it is suspended. Now air, when it is heated, tends to expand, as is well known; and the point that we desire to make is, that in the actual explosion the mechanical work that is performed is due partly (but not wholly) to the direct expansion of the steam, and partly also to the expansion of the air that is heated by the projected steam and water.

The authorities cited above take no account of the damage from the expansion of the air, and hence we might perhaps expect to find their results in error by a considerable amount. It happens, however, that we do not have to make any change in the *form* of their formulas, in order to make all proper allowance for the expansive work of the air. The only difference that this makes, in fact, is that in considering the fall of temperature of the contents of the boiler as the destructive work is being done, we must stop (as they do) at 212° Fahr. if we adopt the view that the damage is done by the direct expansion of steam alone, because the formation of steam will cease when the temperature of the water-drops has fallen to 212° Fahr. On the other hand, if we admit that air-expansion has something to do with the mechanical energy developed, we must consider that work is still performed after the temperature falls below 212° Fahr., and until the droplets have cooled to the actual temperature of the surrounding air. The difference may be quite large, and we must take it into account, if we wish to obtain a really accurate estimate of the greatest possible quantity of mechanical work that an exploding boiler can do.

Rankine deduces the mechanical energy that can be developed by attributing it to the direct expansion of the steam, and then calculating how much work a given mass of mixed steam and water can do, in expanding adiabatically from the original temperature of the boiler down to 212° Fahr. We shall not make any such special assumption as to the precise manner in which the damage is done, but will base our calculations upon the general principles of thermodynamics, and in particular upon the theorem of Carnot and Clausius, which gives the greatest quantity of mechanical energy that it is possible to develop from a given quantity of heat, under given conditions of temperature. The theorem in question (which is well known in thermodynamics) states that when heat is taken from a source whose temperature is T_1, and is passed through any sort of a process by which it is partially converted into mechanical work, any of the heat that may remain unconverted into work being finally given up to a body whose constant temperature is T_2, then it is absolutely impossible, both theoretically and practically, to convert the *whole* of the original heat into mechanical energy. A fraction of it, whose value is $\frac{T_1 - T_2}{T_1 + C}$, may be so converted, under certain ideal conditions; but under no circumstances can the conversion be greater than that. (The temperatures are here supposed to be ordinary Fahrenheit temperatures, and the constant C is the temperature of the Fahrenheit zero, on the "absolute scale" of temperatures. See THE LOCOMOTIVE for April, 1901.)

In the application of this principle to the problem in hand, we shall represent the original temperature of the boiler by T_1 and the temperature of the surrounding air by T_2 (the air being, in this case, the body to which the untransformed part of the heat is given up). In order to compute the greatest possible amount of mechanical work that could be obtained from our hypothetical boiler, we shall suppose that we take from it a small quantity of heat, and subject this heat to any sort of a process for effecting its conversion into mechanical energy, the last part of this process being the rejection into the atmosphere of any portion of heat which may finally remain unconverted; but while we shall not particularize as to the exact kind of process employed, we shall assume that it is of such a nature that it will yield the greatest possible quantity of mechanical energy. We then know, from the Carnot-Clausius principle, that for every heat unit taken from the boiler while it is at the temperature T_1, a quantity of heat represented by $\frac{T_1 - T_2}{T_1 + C}$ is converted into mechanical energy. If J represents the mechanical equivalent of heat, then the first unit of heat that we take from the boiler can, at the very most, develop $\frac{J(T_1 - T_2)}{T_1 + C}$ foot-pounds of mechanical energy. It may (or may not) happen that by abstracting this unit of heat we have cooled the boiler somewhat. If we *have* cooled it, let T be its new temperature (this being very nearly equal to T_1, the former temperature). Then let us take away another unit of heat, and pass it through a similar course. The number of foot-pounds of mechanical energy developed from this second unit of heat will be $\frac{J(T - T_2)}{T + C}$, since (assuming the temperature to have been changed by the abstraction of the previous unit of heat) we must now write T in the formula, in the place of T_1. In general, the abstraction of this second unit of heat will (or may) cause a still further fall of temperature in the contents of the boiler. If so, we note what the new temperature is, and we proceed to abstract a third unit of heat, and so the process is continued until, by these repeated abstractions of heat, we have finally cooled the boiler and its contents to the temperature of the surrounding air. The sum of all the separate quantities of mechanical energy thus found to be possible of development will give the total quantity of mechanical energy that could, by any means, be developed by the explosion.

In applying this method of calculation in a practical way, we may divide the problem into two parts, and give separate consideration to the heat that is in the original steam that the boiler contains, and to that which is in the water. Let us suppose that the boiler originally contains m pounds of steam, having a temperature of T_1, and occupying a volume of V cubic feet per pound (or a total volume of mV cubic feet). Let us first abstract heat from the steam until it all condenses into water, at the same temperature, T_1. If L is the latent heat of vaporization at the temperature T_1, — that is, if each pound of the steam, in condensing into water at the same temperature, gives out L units of heat, — then the m pounds, in condensing, will give out mL units of heat, all at the same temperature, T_1. If we pass this heat through a process such as is imagined and discussed above, discharging the untransformed heat into the atmosphere at the temperature T_2, then it follows that the greatest amount of mechanical energy that we can realize from this quantity of heat is $\frac{JmL(T_1 - T_2)}{T_1 + C}$. It must be noted, however, that it will not be possible to abstract heat from the steam in the manner here assumed, unless, as the steam condenses, the volume that it occupies is reduced simultaneously, so that the uncondensed steam may continue to have the same density as before. If we neglect the volume of the water of condensation (as Rankine does), on account of its small importance with respect to the volume of the steam, it follows that in effecting the reduction of the volume occupied by the steam, from mV cubic feet to nothing, we must perform, against the pressure of the steam, a quantity of mechanical work which is expressed by PmV, where P is the pressure of the steam, *in pounds per square foot,* corresponding to the temperature T_1. The mechanical energy that can be developed from the heat in the steam alone, and which can be expended upon bodies *external to the boiler,* is therefore $\frac{JmL(T_1 - T_2)}{T_1 + C} - PmV$ foot-pounds.

We now pass to the second stage of the process, in which, the condensation being complete, the boiler contains nothing but water, at an initial temperature T_1. We shall assume, as before, that the heat units that the boiler contains are removed, one by one, and subjected to some such process as we conceived in the case of the heat from the steam. The principle of the calculation is the same as before, but the details of the mathematical work are different. Let the total weight of the contents of the boiler be M pounds, and let us suppose that a sufficient quantity of heat is removed from the boiler to cool the contained water by an amount dT. Then the quantity of heat so abstracted is equal to $Mk.dT$, where k is the specific heat of water. (It will be seen that we take no account of the heat that is contained in the metal of the boiler. This is partly because the total amount of such heat is relatively insignificant, and partly because other writers have also omitted this item, and we desire our results to be strictly comparable with theirs.) It is usual, in engineering calculations, to take the specific heat of water as unity at all temperatures. This assumption is very nearly true, and we shall adopt it in the present case. The quantity of heat that must be removed in order to cool the boiler by the infinitesimal amount dT, is therefore to be written $M.dT$. Let us fix our attention for the moment upon the particular quantity of heat that is removed, when the temperature of the boiler has already fallen, from previous similar abstractions, from the initial temperature T_1 to some lower temperature, T. Then the same reasoning that we followed before will show that the maximum quantity of mechanical energy developable from this quantity of heat, $M.dT$, under any conditions, however favorable, is $\frac{J(T-T_2)\,M\,dT}{T+C}$ foot-pounds. If we kept on removing small quantities of heat in this manner, we should continuously reduce the temperature of the boiler; but whatever the temperature might be, we could always calculate, by the formula just given, the maximum quantity of mechanical energy that each little quantity of heat ($M.dT$) could generate. The sum of all the quantities so calculated would give the total quantity of mechanical energy that could be produced, under the most favorable circumstances, while the second stage of the operation was being performed; that is, while the boiler contained nothing but water. The summation in question is readily performed by means of the integral calculus, the operation by which it is effected being known as "integration." Thus to obtain the sum of all the little quantities of the form $\frac{J(T-T_2).M.dT}{T+C}$, from the time when the temperature of the boiler was T_1 to the time when it became T_2, we should merely have to integrate this expression between the limits T_1 and T_2. The details of the work of integration need not be given, as they will be familiar to students of the calculus, and unintelligible to others. It is sufficient to say that the result is

$$JM\left\{(T_1+C)-(T_2+C)-(T_2+C).\,hyp\ log\left(\frac{T_1+C}{T_2+C}\right)\right\},$$

where "hyp log" means "the hyperbolic logarithm of." This is the number of foot-pounds of mechanical energy that could be developed, at the very most, by the heat given out by M pounds of water, in cooling from T_1 Fahr. down to T_2 Fahr. If we add to this the maximum number of foot-pounds of mechanical energy that could be developed and exerted upon bodies external to the boiler from the heat that was removed from the boiler during the condensation of the steam, we have, finally, as the greatest quantity of mechanical energy which could possibly be developed by the explosion of the boiler, under the most favorable circumstances possible,

$$JM\left\{(T_1+C)-(T_2+C)-(T_2+C).\,hyp\ log\left(\frac{T_1+C}{T_2+C}\right)\right\}+\frac{JmL(T_1-T_2)}{T_1+C}-PmV.$$

To facilitate the comparison of this formula with the one given on page 5 of Thurston's *Steam Boiler Explosions*, we may rearrange it slightly, and write it in the following precisely equivalent form:

$$MJ(T_2+C)\left\{\frac{T_1+C}{T_2+C}-1-hyp\ log\left(\frac{T_1+C}{T_2+C}\right)\right\}+\frac{JmL(T_1-T_2)}{T_1+C}-PmV.$$

It will be observed that this differs from Rankine's formula in three respects. (1) Thurston, in citing Rankine's formula, assumes that the constant, C, has been added in advance to each of the temperatures T_1 and T_2; whereas we have preferred to retain the constant formally, in order that it may not be forgotten. (2) Instead of L, the latent heat of the steam in heat units, Rankine uses a different quantity, H, which is the same latent heat as expressed in foot-pounds. Hence in Rankine's formula the factor J does not appear in the second term, while in ours it does. (3) The last term in our equation is not given by

Rankine. We believe, however, that this term is required, in order to make the formula correct.

The foregoing formula, as Rankine has well observed, is somewhat unwieldy in form; and he makes the excellent suggestion that the hyperbolic logarithm of $(T_1+C)\ /\ (T_2+C)$ is very nearly equal to $\frac{2\{(T_1+C)-(T_2+C)\}}{(T_1+C)+(T_2+C)}$, so long as T_1 does not exceed T_2 by too great an amount; and he suggests that this simpler expression "may be used for temperatures not exceeding 428° Fahr." (That is, for initial pressures not exceeding 320 pounds per square inch, by gauge.) If we substitute this closely approximate expression for the logarithm in the foregoing formula, that formula, after an easy algebraic reduction, becomes:

$$\frac{MJ(T_1-T_2)^2}{(T_1+C)+(T_2+C)}+\frac{JmL(T_1-T_2)}{T_1+C}-PmV.$$

Rankine takes $J=772$, and $C=461.7°$ Fahr. We prefer to adopt the more modern values, $J=780$, and $C=459.6°$ Fahr. To reduce the formula to a yet more convenient form for calculation, let us assume that the temperature, T_2, of the air surrounding the boiler is 70° Fahr. The formula then becomes

Maximum mechanical energy developable =

$$\frac{780M(T_1-70°)^2}{T_1+989.2°}+\frac{780mL(T_1-70°)}{T_1+459.6°}-PmV.$$

Here, it will be remembered, M is the total weight, in pounds, of the entire contents of the boiler, including both water and steam; m is the weight, in pounds, of the steam alone; L is the number of heat units given out by a pound of saturated steam, of temperature T_1, when it condenses into a pound of water at the same temperature; P is the pressure of the steam in the boiler, in pounds per square foot; V is the volume, in cubic feet, of one pound of the steam originally present in the boiler; and T_1 is the original temperature of the boiler, just previous to the explosion.

It may be of interest to apply this formula to the calculation of the greatest possible quantity of mechanical energy that could have been developed in the recent boiler explosion at Brockton, Mass. The dimensions of the boiler are given in the leading article of the present issue, and it will only be necessary to add that the distance from the top of the shell to the normal water line was about 20 inches. It is easy to show that the boiler contained about 240 cubic feet of water, and 103 cubic feet of steam. Taking the pressure (as read from the gauge) as being 90 pounds to the square inch, we find from any good steam table that a cubic foot of the steam would weigh about 0.237 of a pound, and a cubic foot of the water about 58 pounds. This makes the total weight of the steam 24.4 pounds, and the total weight of the water about 14,000 pounds. Furthermore, the temperature corresponding to a gauge pressure of 90 pounds per square inch is about 331° Fahr., and the latent heat of one pound of the steam is about 881 heat units. Thus we have, in the foregoing formula, $m=24.4$; $M=24.4+14{,}000=14{,}024.4$; mV (the total volume of the steam in cubic feet) $=103$; $L=881$; $P=90\times 144=12{,}960$; and $T_1=331°$.

With these values, the first term in the formula gives 564,443,000 foot-pounds, and this is the maximum quantity of mechanical energy that could be developed from the heat given out by 14,024.4 pounds of water, when that water cools from 331° Fahr. to 70° Fahr. The second term, with the same data, gives 5,535,000 foot-pounds, which is the maximum quantity of mechanical energy that could be developed from the heat given out by 24.4 pounds of steam, at 90 pounds pressure by gauge, when that steam condenses into water at the same temperature. The third term of the formula takes the value 1,335,000 foot-pounds, this being the work that must be expended *upon* the contents of the boiler, as explained above, in order that it may be possible for the steam to condense in the manner assumed. The total quantity of mechanical energy that could be developed by the heat in the boiler under the most favorable circumstances is found by adding the first and second terms of the formula, and subtracting the third. The result so obtained is 568,643,000 foot-pounds. The boiler and its contents (when filled with water up to the normal level) weighed approximately 30,000 pounds. Hence we see that the maximum mechanical energy that could be d veloped from the heat that the boiler contained would, if it were applied properly and efficiently, be sufficient to raise the boiler and its contents to a height of 568,643,000 ÷ 30,000 = 18,954 feet, or over three miles and a half. As al eady explained, we cannot compute the actual amount of mechanical energy that *was* developed; but the calculation here presented will suffice to show that the enormous work of destruction that is often done when a boiler explodes may be very easily accounted for, without making any gratuitous assumptions as to the use or presence of dynamite or other high explosive.

Inspectors' Report.

December, 1904.

During this month the inspectors of the Hartford Steam Boiler Inspection and Insurance Company made 12,278 inspection trips, visited 25,413 boilers, inspected 8,946 both internally and externally, and subjected 745 to hydrostatic pressure. The whole number of defects reported reached 11,773, of which 1,064 were considered dangerous; 68 boilers were regarded unsafe for further use. Our usual summary is given below:

Nature of Defects.	Whole Number.	Dangerous.
Cases of incrustation and scale,	3,111	97
Cases of deposit of sediment,	1,264	88
Cases of internal grooving,	281	22
Cases of internal corrosion,	902	47
Cases of external corrosion,	812	53
Defective braces and stays,	153	23
Settings defective,	435	44
Furnaces out of shape,	489	33
Fractured plates,	359	69
Burned plates,	406	43
Blistered plates,	136	13
Cases of defective riveting,	278	48
Defective heads,	184	18
Leakage around tubes,	907	76
Leakage at joints,	588	55
Water gauges defective,	272	64
Blow-offs defective,	263	113
Cases of deficiency of water,	37	12
Safety-valves overloaded,	112	27
Safety-valves defective,	133	33
Pressure gauges defective,	499	30
Boilers without pressure gauges,	13	13
Unclassified defects,	139	43
Total,	11,773	1,064

Summary of Inspectors' Reports for the Year 1904.

During the year 1904 our inspectors made 159,553 visits of inspection, examined 299,436 boilers, inspected 117,366 boilers both internally and externally, subjected 12,971 to hydrostatic pressure, and found 883 unsafe for further use. The whole number of defects reported was 154,282, of which 13,390 were considered dangerous. The usual classification by defects is given below:

Summary, by Defects, for the Year 1904.

Nature of Defects.	Whole number.	Dangerous.
Cases of deposit of sediment,	16,994	902
Cases of incrustation and scale,	42,126	1,014
Cases of internal grooving,	2,820	258
Cases of internal corrosion,	13,167	671
Cases of external corrosion,	10,455	723
Defective braces and stays,	2,286	588
Settings defective,	5,877	480
Furnaces out of shape,	6,686	278
Fractured plates,	3,983	614
Burned plates,	5,642	566
Blistered plates	1,148	107
Defective rivets,	3,374	660
Defective heads,	1,511	194
Leakage around tubes,	11,986	1,821
Leakage at seams,	6,581	403
Water gauges defective,	3,752	696
Blow-out defective,	4,146	1,179
Cases of deficiency of water,	290	133
Safety-valves overloaded,	1,348	403
Safety-valves defective,	1,364	350
Pressure gauges defective,	6,666	426
Boilers without pressure gauges	350	350
Unclassified defects,	1,730	574
Total,	154,282	13,390

The following table shows that our inspectors have made over two million visits of inspection, since the company began business, and that they have made more than four millions of inspections, over a million and a half of which were complete internal inspections. The hydrostatic test has been applied in more than two hundred thousand cases. Upwards of two and three-quarters millions of defects have been discovered and pointed out to the owners of the boilers; and nearly three hundred thousand of these were, in our opinion, dangerous. The number of boilers condemned by us as unfit for further service is practically seventeen thousand, good and sufficient reasons for the condemnation being given in each case.

Grand Total of the Inspectors' Work since the Company Began Business, to January 1, 1905.

Visits of inspection made,	2,128,969
Whole number of boilers inspected,	4,161,396
Complete internal inspections,	1,615,666
Boilers tested by hydrostatic pressure,	211,022
Total number of defects discovered,	2,861,581
Total number of dangerous defects,	296,550
Total number of boilers condemned,	16,985

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1905.

Capital Stock, ... $500,000.00.

ASSETS.

	Par Value.	Market Value.
Cash in office and in Bank, ...		$200,088.96
Premiums in course of collection (since Oct. 1, 1904),		173,296.65
Interest accrued on Mortgage Loans, ...		18,357.32
Loaned on Bond and Mortgage, ...		775,270.00
Real Estate, ...		16,390.00
State of Massachusetts Bonds, ...	$100,000.00	100,000.00
County, City, and Town Bonds, ...	372,000 00	389,700.00
Board of Education and School District Bonds,	46,500.00	48,500.00
Drainage and Irrigation Bonds, ...	7,000.00	7,000.00
Railroad Bonds, ...	1,111,000 00	1,238,940.00
Street Railway Bonds, ...	60,000.00	62,650.00
Miscellaneous Bonds, ...	55,500.00	56,905 00
National Bank Stocks, ...	41,800 00	57,100.00
Railroad Stocks, ...	176,900 00	235,247.00
Miscellaneous Stocks, ...	35,500.00	33,100.00
	$2,005,300.00	
Total Assets, ...		$3,412,544.93

LIABILITIES.

Re-insurance Reserve, ...		$1,811,665.96
Losses unadjusted, ...		55,833.25
Commissions and Brokerage, ...		34,679 33
Surplus, ...	$1,010,366.39	
Capital Stock, ...	500,000.00	
Surplus as regards Policy-holders, .	**$1,510,366.39**	1,510,366.39
Total Liabilities, ...		$3,412,544.93

On December 31, 1904, the Hartford Steam Boiler Inspection and Insurance Company had 91,137 steam boilers under insurance.

L. B. BRAINERD, Pres. and Treas. FRANCIS B. ALLEN, Vice-President.
J. B. PIERCE, Secretary. L. F. MIDDLEBROOK, Asst. Sec'y.

C. S. Blake, Supervising General Agent.
E. J. Murphy, M.E., Consulting Engineer.

Board of Directors.

The Locomotive

PUBLISHED BY THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

VOL. XXV. HARTFORD, CONN., JULY, 1905. No 7.

The Flanged Mouth-piece Rings of Vulcanizers and Similar Vessels.

In the course of certain manufacturing operations it is necessary to submit the articles manufactured, or the material of which they are made, to a definite temperature for a time; and if the required temperature is not too high, it may be most conveniently realized by means of saturated steam of a known pressure. In the operation of vulcanizing or devulcanizing rubber, for example, the articles to be vulcanized or devulcanized are usually enclosed in a cylindrical vessel, into which steam is passed at a pressure sufficient to give the temperature that is needed to effect the desired change in the material. The articles to be

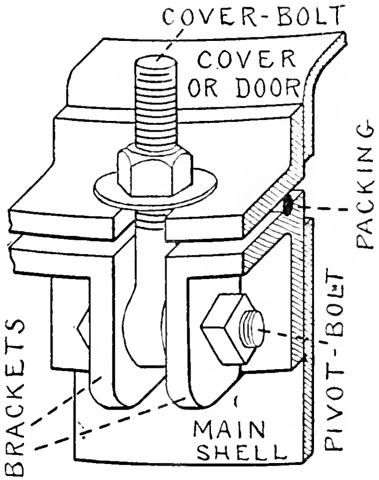
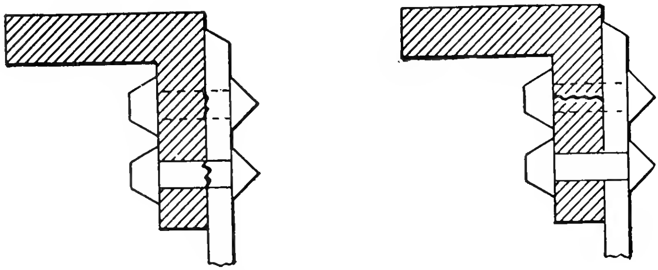


FIG. I. — ILLUSTRATING CERTAIN DETAILS OF THE COVER-BOLTS AND SLOTS.

treated are commonly loaded on cars, which are run into the steam chamber on rails, the chamber itself being placed horizontally, with rails along its interior upon which the car can be run into place.

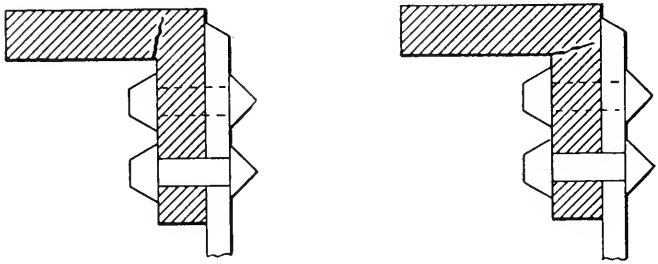
To facilitate the introduction and removal of the goods to be treated, it is usual to have one of the heads of the steam vessel mounted upon a hinge, so that it can be swung aside in such a way as to give an opening for the admission of the loaded car, equal to the entire diameter of the shell of the vessel. It is essential, of course, to provide means for closing the door tightly before the steam is turned on; and the fastenings by which it is secured must be sufficiently strong to resist the pressure of the steam safely, and they must also be of such a nature that the operation of closing or opening the door can be expeditiously performed. These conditions are most commonly realized by the use of swinging bolts that are secured to a flanged mouth-piece that is riveted to the shell, the bolts swinging into slots on a similar flanged ring that is secured to the cover, or door. The construction will be understood by reference to Fig. 1. The flanged ring that is riveted to the shell is slotted at the edge to a sufficient depth



FIGS. 2 AND 3.—METHODS OF FAILURE OF THE RING.

to admit of the "cover-bolts," or bolts by which the cover is held in place; and beneath the flange there are brackets with pivot-bolts between them, upon which the cover-bolts can turn. When the cover or door is to be opened, the nuts are slacked up (but not necessarily removed entirely), and the bolts are swung out of the slots in the flange of the cover-ring. In closing the door, this operation is reversed, and when the bolts have been swung into place, their nuts are set up just sufficiently to prevent leakage when the pressure is turned on.

In the present article we shall deal exclusively with the strength of the



FIGS. 4 AND 5.—METHODS OF FAILURE OF THE RING.

flanged ring which is riveted to the main shell of the vessel, and in fact, we shall give extended consideration to only one particular mode of failure of this ring. The shell-ring might conceivably fail by the shearing of the rivets, as suggested in Fig. 2, or by direct fracture across the net section of one of the rivet rows as in Fig. 3, or by fracture from the inner angle of the flange, as in Figs. 4 or 5. We shall not treat of these modes of failure in the present article, however, partly because they are not the commonest modes in which failure occurs, but mainly because there is no great difficulty in ensuring sufficient strength in any of these respects; the methods of computation to be adopted in each of these cases being already known. The mode of failure that we shall consider in this article is the one indicated in Fig. 6. In this mode of failure, which, in our experience, is the most common one, cracks start at the free edge of the hub of the shell-ring, and progress into the metal as indicated at *CCC*, sometimes passing into the rivet holes, and sometimes avoiding them. As will be understood from what follows, there is a circumferential tension in the hub of the shell-ring, which is greatest at the free edge of the hub; and it is this circumferential tension which gives rise to the cracks in question.

The books on machine design and kindred subjects do not appear to give any formula for computing this circumferential tension, and it is our present purpose to suggest such a formula, and to indicate how it may be most conveniently applied in practical calculations. We desire to state, however, that we are well aware that the formula that we here submit gives values of the circumferential tension which sometimes appear to be excessive. For example, when

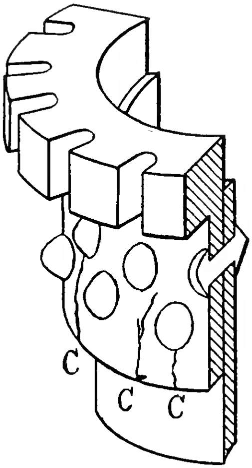


Fig. 6. — Showing "Hub Cracks."

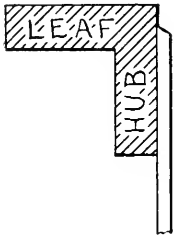


Fig. 7. — Names of the Parts of the Ring.

it is applied to certain particular cases, the formula indicates the existence of a circumferential tension approaching the ultimate strength of the material, although we know positively that the vessels to which these apparently dangerous rings are attached have been operated for some years without giving any trouble. On the other hand, the formula successfully predicts failure when applied to certain other cases in which the shell-rings have actually failed in practice, by the development of cracks such as are shown in Fig. 6. We have thought best to publish the formula, in the hope that future experience may throw light upon its deficiencies and its limitations, and perhaps lead to substantial improvement in its form. At all events, we feel assured that the formula will always err upon the right side, so that hub cracks need never be feared in any shell-ring whose circumferential tension it indicates to be within safe limits.

For the sake of simplicity in making references, we shall hereafter suppose that the shell has been turned up on end, so that the end to which the ring under discussion is attached is uppermost. We shall also adopt the terminology suggested in Fig. 7, for naming the parts of the ring; the part that is riveted directly to the shell being called the "hub," while the projecting flange will be called the "leaf" of the ring.

The internal stresses, within the material of the ring, are due, of course, to the external forces to which the ring is subjected. Firstly, the steam pressure, acting upon the interior of the vessel after the manner indicated in Fig. 8, produces a longitudinal tension, *S*, in the shell; and this tension is thrown upon the ring, through the rivets by which the shell is attached to the ring. The total pull of the shell upon the ring (which we shall denote by the letter *L* in the formula) is found by multiplying the area of the circle whose radius is *R* in Fig. 8, by the pressure of the steam within the vessel, as expressed in pounds per square inch. The pressure of the steam radially upon the upper part of the ring, where the ring is not covered by the shell, undoubtedly gives rise to a corresponding stress in the ring; but the stress due to this cause will be small, and

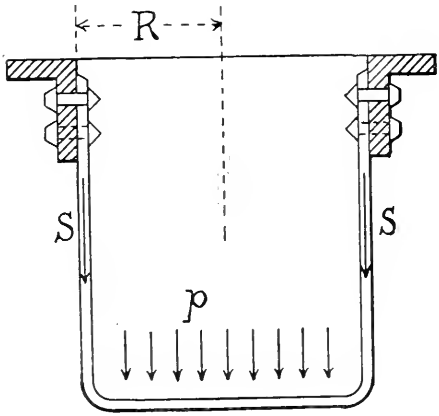


FIG. 8. — ILLUSTRATING THE "TOTAL STEAM LOAD."

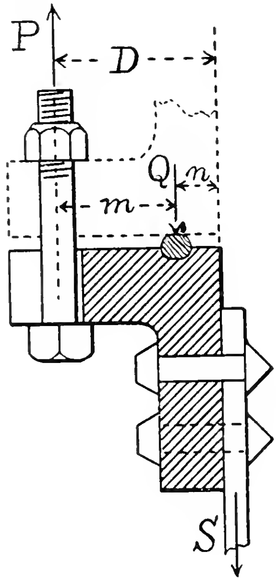


FIG. 9. — THE PRINCIPAL VERTICAL EXTERNAL FORCES.

we shall not take it into account. The radial pressure of the steam against that part of the shell which overlaps the ring is probably carried, for the most part at least, by the shell itself, without material direct influence upon the ring. The pressure of the steam upon the circular space on the top face of the ring, which lies just within the packing circle, likewise gives rise to a stress within the ring; but this also is small, and we need not take it into account, unless we do so in computing the total tensile stress that the cover-bolts must carry, in order to just sustain the steam load upon the cover.

In addition to the direct steam pressure that we have just considered, the ring is subject to two other sources of stress, which are indicated in Fig. 9 by the forces *P* and *Q*, *P* being the total tension upon one cover-bolt, and *Q* being the downward pressure of the cover upon as much of the packing circle as corresponds (measured around the circumference of this circle) to one of the cover-bolts.

Under the influence of these various forces, the ring becomes deformed in the manner indicated, on a grossly exaggerated scale, in Fig. 10. The actual deformation of the ring is of course very small indeed, — so small that it ought to be practically impossible to demonstrate any deformation at all, by direct observation of the ring itself; — yet, small as it is, it is undoubtedly as real as it would be if the ring were composed of rubber. In plastically elastic materials such as rubber, a large deformation is accompanied by the development of only a comparatively small amount of internal stress; but in a material such as iron or steel, the development of an exceedingly small deformation corresponds to the existence of internal stresses that are enormous when compared with those in the rubber. Hence the deformation of the ring we are considering is of the greatest importance, even though it is exceedingly small.

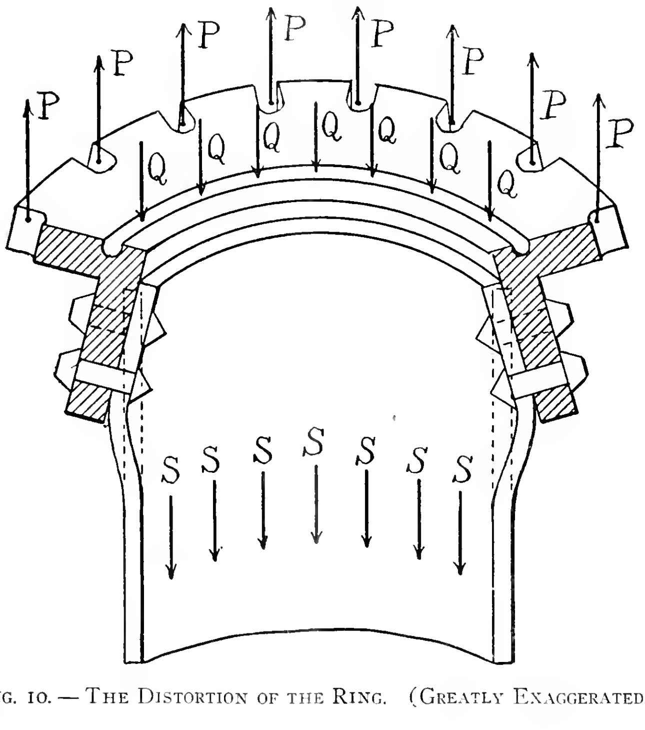


Fig. 10. — The Distortion of the Ring. (Greatly Exaggerated.)

The deformation of the ring, as illustrated in Fig. 10, may be described as follows: The cover-bolt tensions, *P*, acting upon the leaf of the ring near its outer edge, tend to raise this outer edge; and the downward pressure on the packing circle tends to depress the inner edge, and so also does the longitudinal tension, *S*, upon the shell. The result is, that the ring tends to take such a form that the upper face of the leaf assumes a conically concave shape. The ring being supposed to be stiff enough so that it does not bend materially at the angle where the leaf and the hub join (this stiffness is pretty well assured in those forms of ring in which there are brackets beneath the leaf), the hub of the ring must be thrown outward at the same time that the leaf bends upward; and the shell, which is rigidly secured to the hub, will therefore be deformed as well as the ring. At its upper edge, the sheet may be slightly compressed; but as we pass downward and away from the edge, the compression, if it exists, diminishes and soon disappears, and below the point of its disappearance, the shell becomes subject to an increasing stretch, which reaches its maximum somewhere near the lower row of rivets. After we pass this region of maximum stretch, the shell quickly attains the normal diameter that it would have if the ring were absent altogether. It will be apparent that the deformation of the shell, here explained and illustrated, must give rise to considerable tensions upon the rivets, which will tend to restore the ring to its original, undeformed state. The actual tensions upon the rivets are hard to compute, however, and we have therefore been forced to leave them out of consideration, and to treat the ring as though it were subject to no external force save the steam pressure, and the forces P and Q. No doubt this explains, in part, why the formula gives results that appear too large in some cases; but the omission of the rivet-tensions may be justified, perhaps, on the ground that the ring ought to be quite strong enough, in itself, to resist the forces to which it is exposed, without any help from the shell.

The way in which the deformation of the ring gives rise to circumferential tension in the hub will be understood by reference to Fig. 11, which shows a

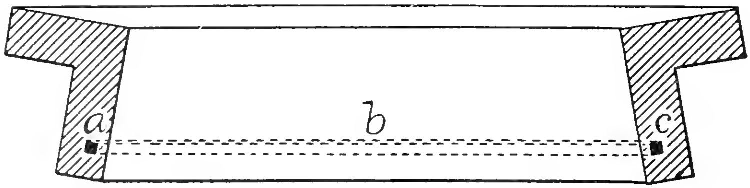


FIG. 11. — ILLUSTRATING A CIRCULAR FIBER OF THE RING.

cross-section of the ring. If we consider any fiber of the material, such as *abc*, which runs around the ring circularly, it will be apparent that the deformation of the ring increases the length of this fiber, if the fiber is situated in the lower part of the hub, and so must necessarily throw it into a state of tension. If the fiber is situated in the upper part of the leaf of the ring, it will be shortened instead of stretched, and it will therefore be subject to compressive stress. The entire ring (except along a single imaginary horizontal surface which separates the parts in tension from those in compression, and which therefore corresponds to the "neutral surface" or "neutral axis" of a beam,) will be, therefore, in a state of circumferential tension or compression; the lower part of the ring being in tension, and the upper part in compression. We might proceed at once to the mathematical analysis of this circumferential stress, and deduce a formula for finding its maximum value, for given values of the steam pressure and of the cover-bolt tensions. It has been thought best, however, to give this mathematical work in a separate article, which is printed elsewhere in this issue. In the present article we shall give only the formula which results from the analysis, together with explanations and a table, to make the application of the formula clear.

The formula for finding the maximum circumferential tension in the ring (this maximum tension coming at the bottom of the hub), is

$F = \frac{(mNE + LD)(h - a)}{6.2832\ (I - a^2A)}$. The significance of most of the letters will be understood from Fig. 12. A is the area of the cross-section of the ring, in square inches; a is the distance, in inches, from the face of the leaf to the center of gravity of the cross-section; I is the "moment of inertia" of the cross-section, with respect to the line OX; h is the total length of the ring, in inches, from the face of the leaf to the extremity of the hub; D is the distance, in inches, from the inner face of the ring to the cover-bolt circle; L is the total steam load on the head of the vulcanizer, in pounds; N is the total number of the cover-bolts; m is the distance, in inches, from the middle of the packing to the cover-bolt circle; and E is the excess of the actual tension on each cover-bolt, over and above that which would be just sufficient to sustain the steam load on the head of the vulcanizer. A, a, and I are to be computed for the smallest cross-section; — namely, for one that passes through a bolt-slot.

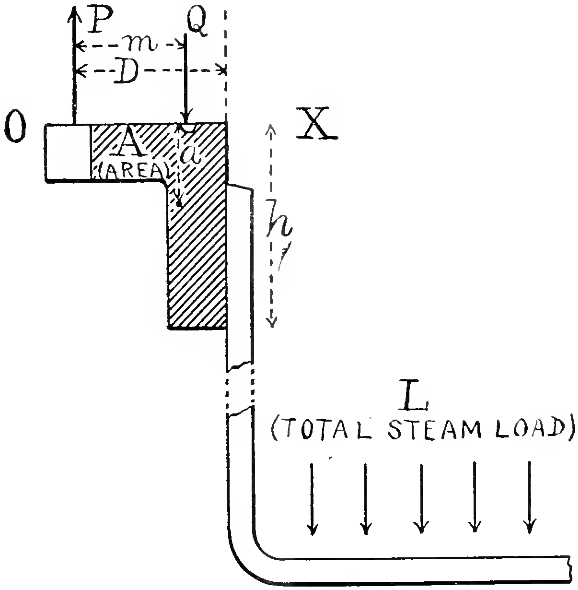


FIG. 12. — ILLUSTRATING THE MEANING OF CERTAIN SYMBOLS.

The quantity I, which occurs in this formula, is difficult to explain to those who are not familiar with it in the theory of beams and other structures. It is found by dividing up the area of the cross-section into a great number of little parts, multiplying the area of each part by the square of its distance from the line OX, and then taking the sum of all the little products so obtained. This operation, which sounds rather formidable, is readily performed by the aid of the integral calculus. It will not be necessary for us to enter further into the details of the calculation of the quantity I, because for the purposes of practical calculation we may make use of the accompanying table, which enables us to obtain the numerical value of I in a very simple manner. The table gives the value of the moment of inertia (I) of a rectangle one inch wide and h inches long, about one of its ends. For example, Fig. 13 shows a rectangle that is h

inches long and 1 inch wide; and from the table we can take, directly, the value of the moment of inertia of this rectangle with respect to the line *OX*. The moment of inertia of a rectangle having any other width than one inch is found by taking out the tabular value for a rectangle of the same length, and multiplying this tabular value by the actual width of the given rectangle, in inches. To find the moment of inertia of the rectangle shown in Fig. 14, for instance, we

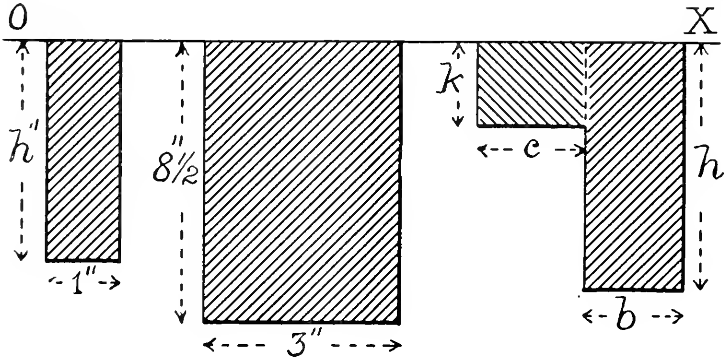


FIG. 13. FIG. 14. FIG. 15.
MOMENTS OF INERTIA.

first look in the table for the value $h = 8\frac{1}{2}$ in., and opposite this we find 204.71, which is the value of the moment of inertia of a rectangle having a length of 8½ inches, and a width of one inch. The given rectangle being 3 inches wide, we have to multiply the tabular value by 3; and we find $204.71 \times 3 = 614.13$, as the concluded value of *I* for the proposed rectangle.

To find the value of *I* for a section of the shape shown in Fig. 15, we conceive the section to be divided into two rectangles as shown by the dotted line.

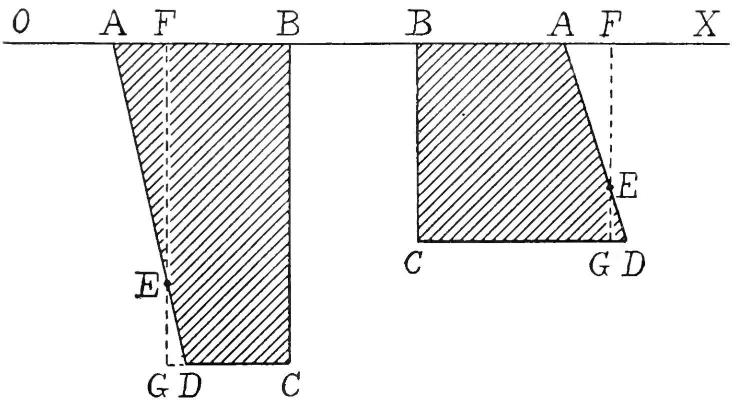


FIG. 16. FIG. 17.
MOMENTS OF INERTIA OF A TRAPEZOID.

We then find the moment of inertia of each of these rectangles separately, and add the two, and the sum is the moment of inertia of the whole.

To find the moment of inertia of a shape such as that shown at *ABCD* in Fig. 16, where the sides *AB* and *CD* are parallel, and the side *BC* is perpendicular to *AB*, we take a point *E*, situated on the line *DA* and at a distance from *D* equal to one-fourth of *DA*, and through the point *E* we draw the line *GF*, so as to form a rectangle *CGFB*. The moment of inertia of the original given figure, *ABCD*, is then equal to that of the rectangle *CGFB*; and we can find the latter by means of the table, as already explained. If the large end of the original figure is *away* from the line *OX*, as in Fig. 17, the construction is precisely similar. Thus we take the point *E*, one-fourth of the distance from *D* to *A*, and the moment of inertia of the original figure is equal to that of the rectangle *BFGC*.

It not infrequently happens that the hub of the vulcanizer ring is tapered, so that the cross-section of the ring has the shape suggested in Fig. 18. In that event the moment of inertia of the section may be found most conveniently thus: The line *DE* is continued until it intersects *AB* at *G*. We then determine the moments of inertia of the parts *AGEF* and *GDCB* separately, according to the method just given, and the sum of the two is the moment of inertia of the cross-section as a whole.

To find the area of a cross-section of the form shown in Fig. 15, we have merely to find the areas of the constituent rectangles separately, and add the

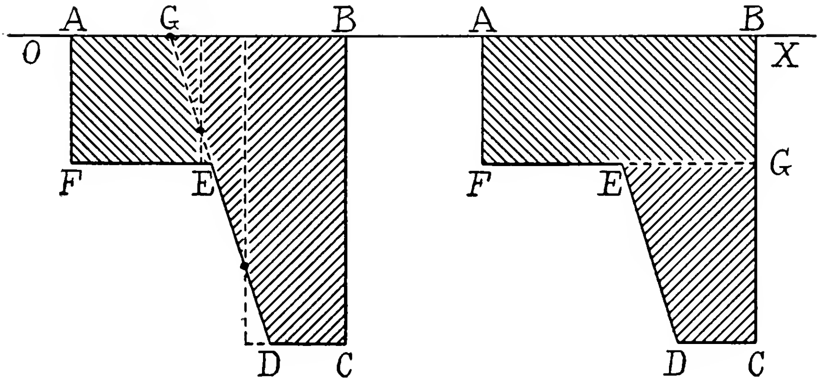


FIG. 18. FIG. 19.

FINDING *I* AND *A* FOR A TAPERED HUB.

two together. The area of the cross-section of a ring in which the hub is tapered may be found most conveniently as follows: We divide the cross-section into two parts as shown by the line *EG* in Fig. 19. The area of the rectangular part, *AFGB*, is easily obtained; and the area of the part *EGCD* is found by taking the half-sum of *EG* and *DC*, and multiplying this half-sum by *CG*. The sum of the areas of the two parts is then equal to the area of the whole.

To find the center of gravity of a cross-section such as that of Fig. 15, we may proceed thus: The center of gravity, *X*, of the rectangle *AGEF*, in Fig. 20, is at the center of the rectangle; and that of the rectangle *GDCB* is at the center, *Y*, of *GDCB*. The center of gravity, *Z*, of the whole cross-section must lie on the line joining *X* and *Y*, and its distance from the line *AB* is found thus: Multiply the distance *r* by the area of *AGEF*, and the distance *R* by the area of *GDCB*, add the two products so obtained, and divide the sum by the area of the whole cross-section. The distance of *Z* from *AB* is the quantity denoted by *a* in the formula.

If it is desired to find the center of gravity of a cross-section of the form shown in Fig. 15 by means of drawing-board operations, we may conveniently proceed as indicated in Fig. 21. We here complete the big rectangle *ABCH*, and we draw *DG*, as before, cutting *AB* at *G*. Then *X* being the center of *GDCB*, *W* the center of *AGF*, *U* the center of *FDH*, and *V* the center of *ABCH*, we join *U* and *V*, and also *W* and *X*, and the intersection of the lines *UV* and *WX* is the desired center of gravity of the whole shaded cross-section.

When the hub of the ring is tapered, the problem of finding the center of gravity of the cross-section is a little more complicated. We begin by dividing the cross-section into two parts by means of the line *EG* in Fig. 22, just as we did in finding the area of a cross-section of this kind. The center of gravity of the part *EGCD* lies upon the line joining the central points of *EG* and *DC*, and its distance from the line *AB* is found thus (the significance of the letters being

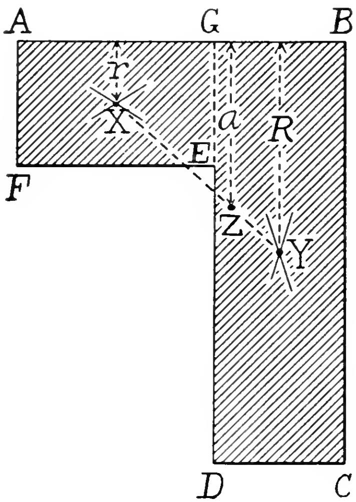


Fig. 20.

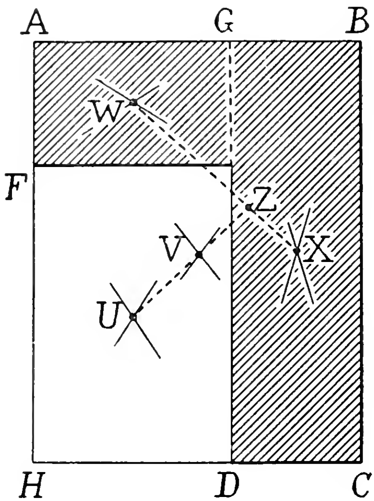


Fig. 21.

Center of Gravity of a Ring-section with Straight Hub.

given in the diagram): Multiply *k* by *c*, and divide the product by three times the sum of *c* and *b*. To the quotient add *l*, and add also one-third of *k*. The sum so obtained is the distance of the center of gravity of *EGCD* from the line *AB*. The center of gravity of the rectangle *FGBA* is at the center of that rectangle, *Y*. The center of gravity of the whole cross-section lies on the line joining *X* and *Y*, and its distance from the line *AB* (which is the quantity denoted by *a* in the formula) is found thus: Multiply *R* by the area of *EGCD*, and multiply *r by* the area of *FGBA*, and take the sum of the two products. Divide this sum by the area of the whole cross-section, and the quotient is the desired distance of the center of gravity of the whole cross-section from the line *AB*, and is the quantity to be used in the formula for *a*.

A drawing-board method for finding the center of gravity for a cross-section of this shape can easily be devised, but it does not appear to be of much practical value, the method given above being easier in its application.

The quantity *E* in the formula, which is described above as "the excess of the actual tension on each cover-bolt, over and above that which would be just sufficient to sustain the steam load on the head of the vulcanizer," is unfortunately, quite uncertain in magnitude. The subject of the tension on cover-bolts is dealt with elsewhere in this issue. We can only say, in the present place, that the workman, if he chooses, can easily put an enormous tension upon each cover-bolt, so as to stress both the bolt and the mouth-piece ring to which it is connected, far more severely than is necessary. The ideal way to set up the nuts on the cover-bolts is to screw up each nut carefully, with an amount of force just sufficient to prevent leakage when the vessel is put under pressure. There is no use in trying to compute what the actual tension on the bolt may be, with careless handling of the wrench. As has been well said, all that any formula can aspire to is to give the stress on the bolt when a "reasonable amount of foolishness" has been exerted by the workman. Any attempt to estimate what he can do when he resorts to *unreasonable* foolishness is foredoomed to failure. Generally speaking, we may perhaps assume that in good practice the stress applied by the wrench to each bolt will not exceed by more than (say) 1,000 pounds the tension that would be required in order to keep the joint tight. Hence it will be fair, perhaps, to take 1,000 or (at most) 1,200 pounds as the value of E in the formula; provided the workman who tightens up the nuts on the cover-bolts does the job intelligently.

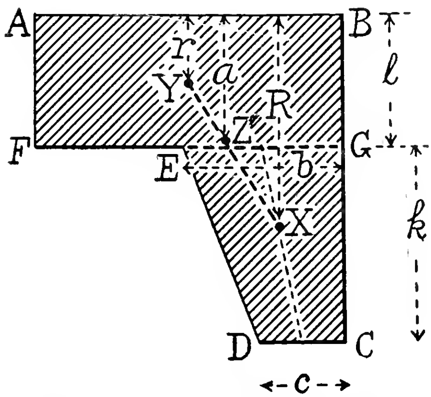


FIG. 22. — CENTER OF GRAVITY OF RING-SECTION WITH TAPERED HUB.

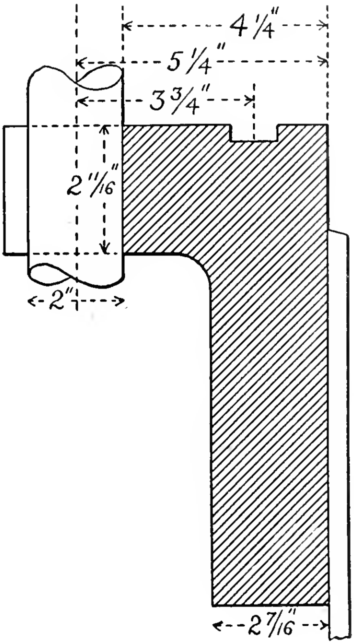
Let us now compute the maximum circumferential stresses in the hubs of two vulcanizers that have been observed for a considerable time in actual practice. For this purpose we shall select one that has a straight hub, and one in which the hub is tapered.

The dimensions of the selected ring with the straight hub are shown in Fig. 23. The radius of the vessel, in this case, is 30 inches, the maximum working pressure is 150 pounds per square inch, and the number of cover-bolts is 23. The total steam load on the lower head of the vessel is computed as follows: The diameter of the vessel being 60 in., the area of the lower head is 2,827 square inches, as will be seen from the table of the areas of circles, given in the issue of THE LOCOMOTIVE for October, 1903. Hence the total steam load on the lower head is $150 \times 2827 = 424{,}050$ pounds. From these data, and from the data that are given in the engraving, it is apparent that the quantities that occur in the formula have the following values for this ring: $N = 23$; $R = 30$; $L = 424{,}050$; $m = 3\frac{3}{4}$ in.; $D = 5\frac{1}{4}$ in.; $h = 10$ in. The values of a and A and I have yet to be computed. To find the area, A, of the cross-section, we proceed as indicated in Fig. 15. There is no difficulty in showing that in the present case the total area of the cross-section is 29.24 square inches; the area that is cut away to form the packing ring being neglected, and also the area added in forming the fillet. To find I for this ring-section, we proceed as indicated in Fig. 15. By the aid of the table we find that the moment of inertia of a rectangle 10 inches high and 1

Table of Moments of Inertia of Rectangles.

h (inches)	I	h (inches)	I	h (inches)	I
0	0.000	**5**	41.667	**10**	333.33
1/8	0.000	1/8	44.870	1/8	345.99
1/4	0.005	1/4	48.234	1/4	358.96
3/8	0.018	3/8	51.762	3/8	372.26
1/2	0.042	1/2	55.458	1/2	385.88
5/8	0.082	5/8	59.326	5/8	399.82
3/4	0.141	3/4	63.370	3/4	414.10
7/8	0.223	7/8	67.593	7/8	428.71
1	0.333	**6**	72.000	**11**	443.67
1/8	0.475	1/8	76.594	1/8	458.96
1/4	0.651	1/4	81.380	1/4	474.61
3/8	0.867	3/8	86.361	3/8	490.61
1/2	1.125	1/2	91.541	1/2	506.96
5/8	1.430	5/8	96.925	5/8	523.67
3/4	1.786	3/4	102.516	3/4	540.74
7/8	2.197	7/8	108.317	7/8	558.19
2	2.667	**7**	114.333	**12**	576.00
1/8	3.199	1/8	120.57	1/8	594.19
1/4	3.797	1/4	127.03	1/4	612.76
3/8	4.465	3/8	133.71	3/8	631.71
1/2	5.208	1/2	140.62	1/2	651.04
5/8	6.029	5/8	147.77	5/8	670.77
3/4	6.932	3/4	155.16	3/4	690.89
7/8	7.921	7/8	162.79	7/8	711.41
3	9.000	**8**	170.67	**13**	732.33
1/8	10.173	1/8	178.79	1/8	753.66
1/4	11.443	1/4	187.17	1/4	775.40
3/8	12.814	3/8	195.81	3/8	797.55
1/2	14.292	1/2	204.71	1/2	820.13
5/8	15.878	5/8	213.87	5/8	843.12
3/4	17.578	3/4	223.31	3/4	866.54
7/8	19.395	7/8	233.02	7/8	890.38
4	21.333	**9**	243.00	**14**	914.67
1/8	23.396	1/8	253.27	1/8	939.39
1/4	25.589	1/4	263.82	1/4	964.55
3/8	27.913	3/8	274.66	3/8	990.15
1/2	30.375	1/2	285.79	1/2	1016.21
5/8	32.977	5/8	297.22	5/8	1042.72
3/4	35.724	3/4	308.95	3/4	1069.68
7/8	38.619	7/8	320.99	7/8	1097.11
5	41.667	**10**	333.33	**15**	1125.00

inch wide is 333.33; and multiplying this by $2\frac{7}{16}$, we find that the moment of inertia of the right-hand rectangle in Fig. 15 is 812.49. Similarly, we find that the moment of inertia of the left-hand rectangle in Fig. 15, for this ring, is 11.74; so that the total moment of inertia of the entire cross-section is $812.49 + 11.74 = 824.23$. By the method shown in Fig. 20, we find that the value of a, — that is, the distance of the center of gravity of the cross-section from the face of the leaf of the ring, — is 4.392 in. Hence we have $A = 29.24$ square inches; $I = 824.23$;



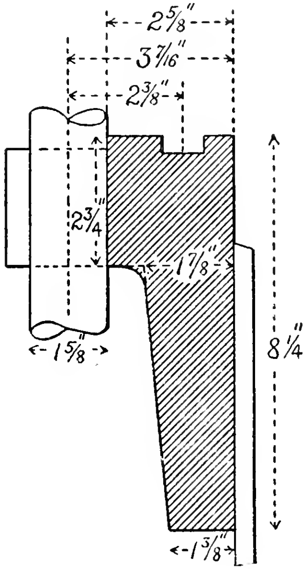


Fig. 23. Fig. 24.
Cross-sections of Actual Rings.

and $a = 4.392$. With these values, the formula gives, as the value of the circumferential tension at the free edge of the hub (that is, its *maximum* value),

$$F = \frac{(3\frac{3}{4} \times 23E + 424{,}050 \times 5\frac{1}{4})\ (10 - 4.392)}{6.2832\ (824.23 - 4.392 \times 4.392 \times 29.24)}$$

or

$$F = \frac{483.69E + 12{,}485{,}000}{1{,}635}$$

If, as has been suggested above, we take $E = 1{,}200$ pounds, we have, as the maximum circumferential tension upon the ring (namely, the tension at the free edge of the hub),

$$F = 7{,}991 \text{ pounds per square inch.}$$

This ring is made of cast steel, with a conjectured tensile strength of about 55,000 pounds per square inch of sectional area. A pair of vulcanizers are run, side by side and under similar conditions, each having a ring of the dimensions here indicated. The ring of one of them shows "hub cracks" such as are indicated in Fig. 6, while the ring of the other does not show any signs of distress. The rivets, in these vulcanizer rings, come rather too near to the free edge of the hub, so that the circumferential stresses are too much concentrated in the vicinity of the edge of the hub. (See Fig. 27, in the mathematical sequel to this article.) We are of the opinion that in the case here cited, the formula gives a reasonable result for the maximum circumferential tension upon the ring.

Let us now consider the second illustrative example, in which the hub is tapered. The radius of the vessel is here 24⅜ in., the number of cover-bolts is 16, and the maximum working pressure is 90 pounds per square inch. The other principal data are given in Fig. 24. The area of a circle of radius 24⅜ in. is (by the table already cited) 1866 square inches; and hence the total steam load upon the head of the vessel is $1866 \times 90 = 167,940$ pounds. The total area of the cross-section, as found by the method suggested in Fig. 19, is (omitting the fillet and the groove for the packing) 16.16 square inches. The moment of inertia of the cross-section is to be found as indicated in Fig. 18. The distance BG in that figure has the value, for the cross-section under consideration, of 2.125 in., and the moment of inertia of the part $GDCB$ is equal to that of a rectangle 8¼ in. high, and 1.562 in. wide. By the aid of the table, this moment is readily found to be equal to 292.36. Passing then to the consideration of the moment of inertia of the portion indicated by $AGEF$ in Fig. 18, we similarly find this to be 4.77. Hence the total moment of inertia of the cross-section shown in Fig. 24 is $292.36 + 4.77 = 297.13$. It only remains to find the value of a, according to the method suggested in Fig. 22. The method having been fully described, it will not be necessary to give the details of the calculation. The general result is, that the center of gravity of the whole section lies at a distance of 3.58 inches from the upper surface of the leaf.

The data for computing the maximum circumferential tension, F, in the ring shown in Fig. 24, are therefore as follows: $R = 24\frac{3}{8}$ in.; $N = 16$; $L = 167{,}940$ pounds; $m = 2\frac{3}{8}$ in.; $D = 3\frac{7}{16}$ in.; $h = 8\frac{1}{4}$ in.; $a = 3.58$ in.; $A = 16.16$ square inches; and $I = 297.13$. With these values, the formula gives

$$F = \frac{(2\frac{3}{8} \times 16E + 167{,}940 \times 3\frac{7}{16})\ (8.25 - 3.58)}{6.2832\ (297.13 - 3.58 \times 3.58 \times 16.16)}$$

or

$$F = \frac{177.46E + 2{,}695{,}963}{565.61}$$

If, as before, we take $E = 1{,}200$ pounds, we find, as the maximum value of the circumferential tension in this hub (this maximum value occurring, as it always does in these rings, at the free edge of the hub),

$$E = 5{,}143 \text{ pounds per square inch.}$$

The ring whose maximum circumferential tension we have just computed is made of an excellent quality of cast-iron, and it has been in service for a long time, without giving any trouble. If the computed tension as given by the formula is correct, we must admit that the factor of safety in this case is smaller than could be desired. It is not customary to take the tensile strength of cast-iron as much, if any, greater than 20,000 pounds per square inch. Thurston (*Materials of Engineering*, Part 2, edition of 1903, page 442), gives the following values of the tensile strengths that "should be given by the best sorts of cast-irons":

Good pig iron, . . .	20,000 lbs. per square inch.
Tough cast-iron, . . .	25,000 lbs. per square inch.
Hard cast-iron, . . .	30,000 lbs. per square inch.
Good tough gun iron, . .	30,000 lbs. per square inch.

These values appear to us to be somewhat high; but if they really represent practice faithfully, then provided we admit that the casting upon which we have just figured (and which is known to be of excellent quality) is equal to Thurston's "tough cast-iron," we see that it has a factor of safety of approximately 5, so far as the development of "hub-cracks" is concerned; the tension as computed by the formula being assumed to fairly represent that actually existing in the ring.

It will be seen, from these examples, that the term which depends upon the assumed value of E is much smaller than the one which does not depend upon E. Hence a considerable range of values might be given to E without affecting F to an extent that would be of serious import. We make this observation because if the fact itself were not noted, it might be supposed that the formula would yield seriously indeterminate values of F, on account of the arbitrary quantity, E, that it contains.

Mathematical Theory of the Stresses in the Mouth-Piece Rings of Vulcanizers and Similar Vessels.

We have elsewhere in this issue given an article on the general subject of these rings, in which we have proposed a formula for computing the circumferential stresses that occur in them. As the formula is a new one, so far as we are aware, we have thought it best to publish the line of reasoning upon which it is based, in the hope that by criticism and perhaps extension of this reasoning, the formula may be improved and brought into closer accord with practice than it now seems to be, in certain cases. The present article is therefore to be considered as supplementary to the other one, and as we shall have occasion to refer to some of the illustrations that have already been used, we have numbered the illustrations in the present article consecutively with those that have been given before, so that a mere reference to an illustration by number will be sufficient to identify it, without specifying in which article it occurs. The notation employed will also be substantially the same as in the preceding article.

In order to deal with the stresses and forces in a satisfactory manner, we will consider the equilibrium of a wedge-shaped section of the ring; this section being bounded by two planes which each pass through the axis of the vessel to which the ring is attached, and which include, between them, a segment of the ring equal to one Nth of the entire circumference, N being the total number of cover-bolts. There will then be one cover-bolt to every such segment; and we will suppose that the planes of section are so situated that the cover-bolt that they include comes in the center of the segment. A segment of the ring such as has here been described will be called, for definiteness and brevity, a "unit" of the ring. The entire ring, it will be seen, is composed of N such units, all exactly alike, except that the number of rivets passing through the shell and the ring will not necessarily be the same in each unit, and hence the stress communicated from the shell to the unit of the ring will not be identically the same in every case. We shall *assume* the stress thus communicated from the shell to the rivets to be the same in every case, however, because the division into units, here suggested, is a purely imaginary one, and the stresses that are transmitted through the rivets will average, when considered along a few contiguous units, very much the same as we are here assuming. Fig. 28 shows one of these "units" of the ring.

If R is the internal radius of the vessel, and p is the steam pressure in pounds per square inch, then the total steam load that comes longitudinally upon the shell is πR^2p, where π, as usual, stands for 3.1416; and hence the stress S, that is sustained by that part of the shell which corresponds to a single unit of the ring, is $S = \pi R^2p/N$. P being the total tensile stress upon a single cover-bolt, and Q being the total compressive force exerted downward upon as much of the packing circle as is included in one unit of the ring, we have next to consider that one of the conditions of equilibrium of the ring-unit is, that the resultant of all the external vertical forces acting upon it must be zero. (In strictness, we should observe that the steam pressure acts vertically downward upon that strip of the ring-unit which lies within the packing-circle, and hence we should take account of this vertically-directed steam pressure, in considering the equilibrium of the vertical forces. The effect of this steam pressure is insignificant, however, when compared with the effects of the other forces involved; and hence we shall omit it from consideration, since its inclusion would complicate the problem, without adding any precision that would be of practical importance.)

The equilibrium of the vertical forces acting upon a ring-unit therefore involves that the sum of all the upwardly-directed external forces should be equal to the sum of all the downwardly-directed external forces. That is, $P = Q + S = Q + \pi R^2p/N$.

We cannot yet treat of the equilibrium of the ring-unit with respect to horizontal forces, nor with respect to the tendencies of the various forces to produce rotation of the ring-unit; for in order to write the equations which express these conditions, we have to include the internal stresses in the ring, which we have not yet considered.

A few remarks must be made about the foregoing equation between P and Q, before we pass to the next subject. When the nuts on the cover-bolts are first screwed up, before steam is introduced into the interior of the vessel, it is obvious (since $p = 0$ in that case) that $P = Q$. The total tensile stress, P, to which the cover-bolt is then subject, depends solely upon the force with which the attendants have screwed up the cover-bolt nuts. We may compute the approximate value of P by means of the formula given in the article on bolt-tensions in the present issue, if we have sufficient data for that purpose. In practice, we can only conjecture what numerical values should be assigned to these various data; and hence the calculation of P, even in the simple case in which the steam pressure is zero, is necessarily uncertain and unsatisfactory. Suppose, however, that we have determined, in some manner, what the value of P (and therefore of Q) is, when there is no steam pressure within the vessel; and let us suppose that steam is then introduced, until the pressure rises to p, the pressure at which the apparatus is to be operated. How will the values of P and Q be changed by the introduction of the steam? This subject was considered at some length in the issue of THE LOCOMOTIVE for November, 1897, where it was shown that the change in the value of P, due to the introduction of steam, depends to a large extent upon the nature of the packing against which the cover-plate bears. It was shown, in fact, that if the packing is absolutely inelastic, the steam will not cause any material increase in the value of P; the steam load, in this case, being balanced by a diminution in the value of Q. It was also shown that if the packing is exceedingly elastic, the stress, P, on the cover-bolt may be increased by nearly the full value that corresponds to the total steam load. (For a similar conclusion, see Unwin's *Elements of Machine Design*, edition of 1898, volume 1, page 152.) In actual practice we must admit, in most cases, that the packing possesses *some* elasticity; but the elasticity is usually not very great, and hence we may fairly conclude that in practice the turning on of the steam pressure is not accompanied by an increase in the value of P that is greater than a small but unknown fraction of the total steam load; the balance of the vertical forces that are externally applied to the ring being maintained chiefly by a reduction in the value of Q, rather than by an increase in P.

We come, now, to the consideration of the internal, circumferential stresses in the ring, whose existence and cause was pointed out in the earlier article. The deformation of the ring, under the combined influence of the pull on the cover-bolts, the pressure downward upon the packing circle, and the longitudinal tension on the shell, is illustrated in Fig. 10, and it is easily seen that this deformation is of such a nature that every cross-section of the ring experiences a rotation in its own plane, about some point whose position we have yet to determine. (It will be observed that we are tacitly assuming that the shape of the cross-section of the ring is not materially altered by the action of the external forces. This assumption may not be sufficiently accurate in the case of wrought iron or

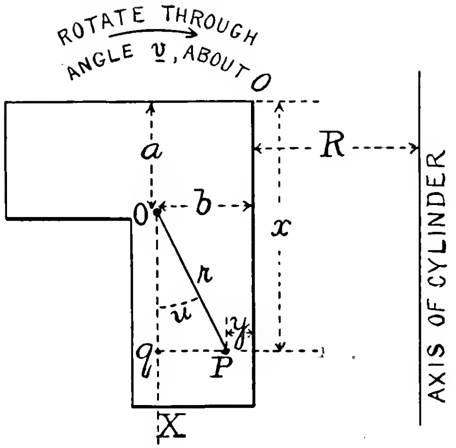


Fig. 25. — Illustrating the Rotation of the Cross-section.

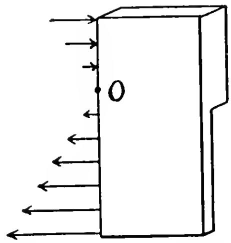


Fig. 26. — Illustrating the Circumferential Tensions.

steel rings which are light in construction, and which are unprovided with brackets between the leaf and the hub of the ring. It is doubtless very nearly true, however, for heavy rings, and for rings which are stiffened by brackets. At all events, we shall make the assumption, as we consider it accurate enough to serve the purposes of a first approximation to the theory of these rings; and a first approximation is all that the present investigation purports to be.)

Let us now consider a cross-section of the ring, and let us define the position of the as yet unknown center about which this section rotates in the following manner: Denote its distance below the upper surface of the leaf of the ring by a, and its distance from the inner surface of the hub of the ring by b. These dimensions are indicated in Fig. 25, to which our attention will be for the moment confined. (It is to be understood, of course, that either a or b, or both of them, may be negative.) O being the unknown center of rotation, let us suppose that a line OX is drawn through it, parallel to the axis of the shell. Then consider any point, P, in the cross-section of the undeformed ring. Let its distance from O be r, and let the line OP make an angle u with OX, as indicated in the diagram. The distance of OX from the central line of the shell being $R + b$, and the length of Pq being $r.\sin u$, the distance from the point P to the axis of the shell is $R + b - r.\sin u$. Now let the stresses be applied to the ring, so that the section shown rotates clock-wise through an angle v, about the point O. After this rotation, as may be very easily shown, the distance from the point P to the axis of the shell becomes $R + b - r.\sin(u - v.)$ If we now consider the fiber of material that runs circularly around the collar through P, we see that *before* the rotation the length of this fiber is $2\pi \{R + b - r.\sin u\}$; while *after* the rotation it is $2\pi\{R + b - r.\sin(u - v)\}$. Hence the rotation has stretched this fiber by the amount $2\pi r\{\sin u - \sin(u - v)\}$. We know from trigonometry that $\sin(u - v) = \sin u.\cos v. - \cos u.\sin v$; and hence it appears that the stretch of the fiber under consideration is equal to $2\pi r$ $\{\sin u - \sin u.\cos v + \cos u.\sin v\}$, or to $2\pi r\{1 - \cos v\}\sin u + 2\pi r.\cos u \sin v$. In the actual conditions of practice the angle v is exceedingly small, — so small, in fact, as to be almost unmeasurable. We may therefore take $\sin v = v$, and $\cos v = 1$. With these simplifications, the expression for the elongation of the fiber reduces to the form $2\pi r\ v.\cos u$. Now $r.\cos u = Oq$. Hence the stretch of the fiber is $2\pi v.(Oq)$.

According to Hooke's law, the increase in length of a given material fiber is proportional to the stress to which the fiber is subjected. This principle, which is quite accurately true when an isolated fiber is strained within its elastic limit, we shall apply also to the circumferential fibers of the ring under discussion. In an ideal and complete analysis of the stresses in a structure of this sort, we should not assume Hooke's law to be of precisely this form, but, instead, we should take the elongation of the fiber passing through any given point to be a linear function of the three principal stresses existing in the material at that point. This complete analysis involves difficulties, however, which the writer has not succeeded in overcoming satisfactorily; and hence in the present tentative analysis, the extension is taken as proportional to the circumferential tension alone. It is to be noted that this mode of treatment of elastic problems is a very common one, it being adopted, in fact, by practically all of the writers who deal with the theory of beams and similar structures. Hence we may presumably be permitted to make use of it in the present case, without reproach.

If we adopt Hooke's law in the simple form stated above, and if we knew the modulus of elasticity, M, of the material, and the angle, v, through which each of the cross-sections of the ring is rotated, as well as the position of the point O about which the rotation takes place, we could compute the intensity of the circumferential tension, f, at any point of the material. We should have, in fact,

$$f = \frac{2\pi vM.(Oq)}{2\pi(R + b - r.\sin u)} = \frac{vM.(Oq)}{R + b - (Pq)}$$

Or, with the notation of Fig. 25,

$$f = \frac{Mv.(x - a)}{R + y}$$

In the practical case we never know the angle v. We *do* know, however, that for any given condition of stress, this angle is the same throughout the ring. We may therefore write the last expression thus: $f = K.\frac{(x - a)}{(R + y)}$, where K is a constant throughout the entire ring, for any given state of strain; although (since it is equal to Mv and therefore changes with v) K will vary with different states of strain, — that is, with varying conditions with respect to the intensities of the external forces.

In the denominator of this last equation we find the expression $R + y$. This shows that the intensity of the stress at any given point in the cross-section depends to some extent upon the horizontal distance of that point from the inner edge of the section. Now those parts of the circumferential forces which mainly determine the equilibrium of the ring are confined to the hub, and in all the important practical applications of the theory to vulcanizers and like structures, the entire thickness of the hub will not exceed (say) six per cent. of the radius of the shell of the vessel, and hence the total variation of the denominator of the foregoing expression for F will not exceed (say) six per cent. of the value of the said denominator. If we take the denominator as constant and equal to the radius of the *middle* of the cross-section of the hub, the error of the new formula so found, when that formula is applied to the calculation of the circumferential stress at any point of the hub, will not exceed (say) three per cent. of the value of that stress as computed from the more exact formula. This error will be of no consequence whatever, in practical applications, and hence, for the purposes of those applications, the formula may be written

$$f = C.(x - a) \ldots\ldots\ldots\ldots (1),$$

C being a new constant, numerically equal to K divided by the mean radius of the hub.

We have now found an expression which shows how the intensity of the circumferential stress in the ring varies from point to point of the cross-section of the ring, for any one given state of strain. To make this formula perfectly definite, and to adapt it to purposes of numerical computation, it only remains to find the numerical values of the constants C and a. These will be determined, presently, by a further study of the conditions essential to the equilibrium of the ring.

The distribution of the circumferential stresses, according to the formula just derived, is of the nature indicated in Fig. 26. This is supposed to represent a section of the entire ring, and the arrows indicate the nature of the circumferential forces. They vary in a linear manner as we proceed from the top of the leaf of the ring to the bottom of the hub; being compressive at the top, and tensile at the bottom. At the point O there is (circumferentially) neither tension nor compression. (The position of this point O is indicated on the sketch in accordance with the results of the analysis for determining its position, which is given subsequently.)

It will be observed that no attempt has been made, in the foregoing investigation, to take account of the fact that the hub of the ring is perforated by rivet holes; the ring being treated as though the hub were solid, and brazed to the shell, or united to it in some similar manner which would not require its integrity to be disturbed. This method of procedure has been adopted, partly because it would be exceedingly difficult to take accurate account of the effect of the rivet holes upon the circumferential stresses, and partly because it is believed that the circumferential stresses in the ring are not disturbed to any serious extent by the holes, except in the *immediate vicinity* of the holes. No doubt the stress upon the material of the hub is increased, close to the holes, by the fact of their presence; and hence the holes should in no case be too near the free end of the hub, where the circumferential stresses (as we shall subsequently see) are greatest. If this condition be fulfilled, however, it will be assumed that the effects of the holes may be neglected. By way of illustrating the point at issue, Fig. 27 may be considered. This represents a portion of the ring, with rivet holes punched through it. The distribution of the circumferential stresses across a section, such as *AB*, which passes midway between a pair of rivet holes, may be assumed to be much the same as it would be if the ring were solid, and had no rivet holes in it at all. In a section, such as *CD*, which passes through the center of one of the upper rivet holes, we may also assume that in those parts of the section which are remote from the rivet hole, the circumferential stresses will also be sensibly the same as they would be if the ring were solid. The tension that would exist (in the solid ring) across the line *ef*, however, must be borne by the material in the immediate vicinity of the hole in the perforated plate; and we may think of the lines of circumferential tension as diverging, as they approach the hole, so as to allow those that naturally tend to cross the hole to pass around it, immediately above and below it. The metal in the vicinity of *g* and *h*, therefore, must bear not only the tension that would naturally belong to those points, but also that which would come upon the metal between *g* and *h*, if the hole did not exist. We need not discuss, at present, the precise

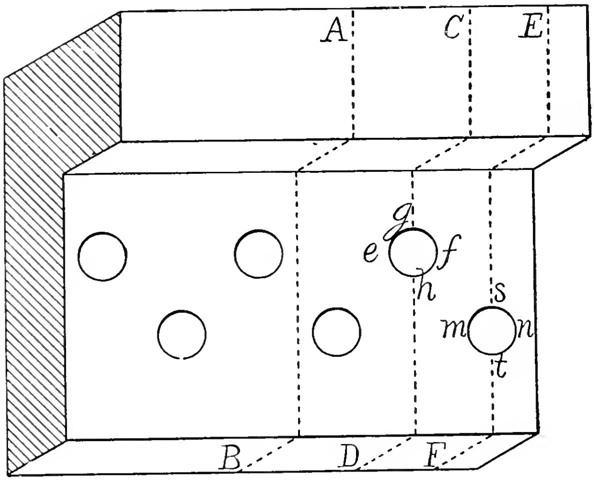


FIG. 27. — EFFECT OF THE RIVET-HOLES.

increase in the intensity of the circumferential tension in the vicinity of the hole, this being a subject reserved for more extended treatment on a future occasion; but we shall assume that the disturbance of the stress, due to the presence of the hole, is mainly confined to the metal in the near neighborhood of the hole; so that the effect of the holes may be neglected, so far as the formation and discussion of the general equations of equilibrium of the ring are concerned. In the design of the ring, care should be taken that the holes are not unnecessarily large, and that they do not come unnecessarily close to the free edge of the hub. Chain riveting should also be avoided, in securing the hub to the shell, since it is manifestly better to have only one hole in any single vertical section of the hub, than it is to have two.

We have considered, above, the condition that must be fulfilled in order that the forces acting vertically upon the ring-unit may be in equilibrium. A second condition essential to the equilibrium of the unit is, that the forces acting upon the unit in a direction perpendicular to the plane *OX* in Fig. 28 shall balance one another. This condition is evidently fulfilled identically, by reason of the symmetry of the system. Hence this condition gives us no information with respect to the forces acting within the ring.

The third and final condition of equilibrium, so far as translation is concerned, is that the forces acting upon the ring-unit horizontally and parallel to the plane OX shall balance one another. To investigate this condition, let f be the intensity of the circumferential tension at the depth x, which is to be measured from the top face of the leaf of the ring. Then the total tension, acting normally upon the little rectangle whose width is dx and whose length is z, is $fz.dx$. This force has a horizontal component, parallel to OX, whose magnitude is $\sin D.fz.dx$, as will be understood by reference to Fig. 29. (It is to be noted that z is equal to the thickness of the hub in the lower part of the ring, and to the width of the leaf, measured to the bottom of the bolt-slot, in the upper part.) This component, it will be noted, is directed towards

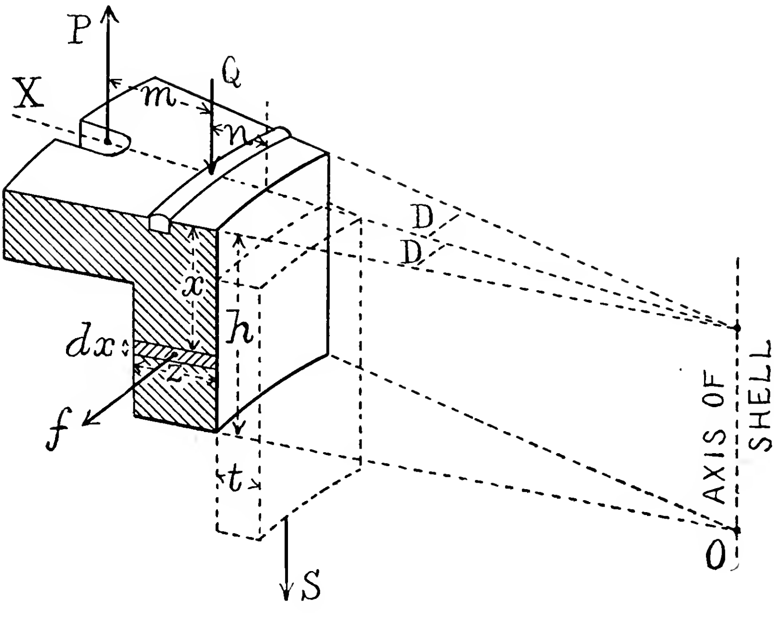


FIG. 28. — A "UNIT" OF THE RING.

the axis of the shell, when the circumferential stress is a tension; and if we integrate it between the limits $x = 0$ and $x = h$, we shall obtain the total force acting upon the shaded face of Fig. 28, in a direction horizontal and parallel to the plane OX. From our previous investigation it appeared that f is of the form $C.(x - a)$; so that the expression to be integrated is $C.(x - a).\sin D.z.dx$. It will not be necessary to give the details of the integration, as it involves no difficulties of a mathematical nature. The result is $C.\sin D.A(a_0 - a)$ where A is the area of cross section of the ring, and a_0 is the distance of the center of gravity of the section below the upper face of the leaf of the ring. The back face of the ring-unit (corresponding to the shaded one) contributes an equal amount to the force in question, so that the total component of the internal, circumferential tension of the ring, acting in a horizontal direction and parallel to the plane OX, is $2CA\sin D.(a_0 - a)$.

In addition to the component of the internal, circumferential tension just found, there are certain other forces acting upon the ring, in a direction parallel to that component, and these should in strictness be taken into account. The nature of these other forces will be clearly understood by reference to Fig. 10. In the first place, the steam pressure within the vessel acts directly upon the upper part of the interior surface of the ring, where the ring is not covered by the shell-sheet. Also, it is plain from the diagram that the rivets that unite the shell to the ring are in a state of tension, so that they pull inward upon the hub of the ring. Both of these influences favor the ring, and tend to diminish the circumferential tension in the hub. The effect of the direct steam pressure against the upper part of the ring is slight, however, and may be omitted without serious error. The magnitude of the tension upon the rivets is uncertain, and hard to compute with any approach to precision. Moreover, it is our opinion that the ring should be quite strong enough, in itself, to resist the stresses that may be thrown upon it, without any assistance whatever from the shell. This last consideration, combined with the uncertainty as to the real magnitude of the tensions on the rivets, and with the knowledge that the rivet-tension favors the ring, leads us to exclude from consideration the rivet-tension and the steam pressure on the upper part of the ring, and to treat the problem as though the inwardly-directed component of the circumferential tensions in the hub were the only force acting upon the ring-unit, in a direction horizontal and parallel to the plane OX. Now since the ring-unit does not move either in or out, this assumption forces us to conclude that $2CA\sin D.(a_0 - a) = 0$; and this cannot be the case unless $a = a_0$. In other words, we are led to the conclusion that the a of formula (1), above, is equal to the depth of the center of gravity of the cross-section of the ring, below the upper surface of the leaf of the ring. We may therefore consider that the ring, under the influence of the externally applied forces, becomes deformed in such a manner that each cross-section of it rotates about its own center of gravity. It being no longer necessary to distinguish a_0 from a, the zero subscript will be omitted in the remainder of this article. (It will be observed that we have not really proved that the center of gravity *is* the center about which the rotation occurs, because we have not learned anything, as yet, about the distance of the center of rotation from the inner surface of the ring. In other words, we have not found the value of b, in Fig. 25. But the value of b, as will appear when this investigation is complete, plays no important part in the theory of the internal stresses in the ring; and hence there can be no objection to taking the center of rotation of the ring-section as identical with the center of gravity, even though we have not proved the identity in this one unessential respect.)

We have now investigated the conditions which must hold, in order that the ring-unit under consideration may be in equilibrium so far as *translation* is concerned. We have next to discuss its equilibrium with respect to *rotation*. It will be sufficient to make the turning moments zero about any three axes, of which no two are in the same plane. Let us, for the sake of definiteness and simplicity, consider the tendency towards rotation about each of the three mutually perpendicular axes shown in Fig. 30. Two of these axes are horizontal, and one is vertical. The vertical axis ("No. 1") and one of the horizontal axes ("No. 2") lie in the plane designated as OX in Fig. 28, while the third axis ("No. 3") is perpendicular to that plane. The point of intersection of the three axes that we have thus chosen is taken at the center of rotation (or center of gravity) of the section of the ring that is made by the plane OX, in Fig. 28.

Passing now to the consideration of possible rotations about these three axes, we observe, first, that there is no resultant tendency to produce rotation about axes Nos. 1 or 2, on account of the symmetry of the forces involved. We therefore have to consider nothing, in the way of rotations, save the tendency to produce rotation about axis No. 3. The forces that tend to produce rotation about this axis are (1) the tension, P, on the cover-plate bolt, (2) the compressive force, Q, acting upon the packing circle, (3) the longitudinal tension, S, upon the shell plate, and (4) the inwardly-directed component of the circumferential tension that acts upon the ring-unit. We will take these up in order.

The turning moment of the force P, with respect to axis No. 3, is equal to $P(m + n - b)$, and the direction of the rotation that it tends to produce is "clock-wise," when viewed from the left-hand end of axis No. 3, as shown in Fig. 30. (The notation employed will be understood by reference to the diagrams.)

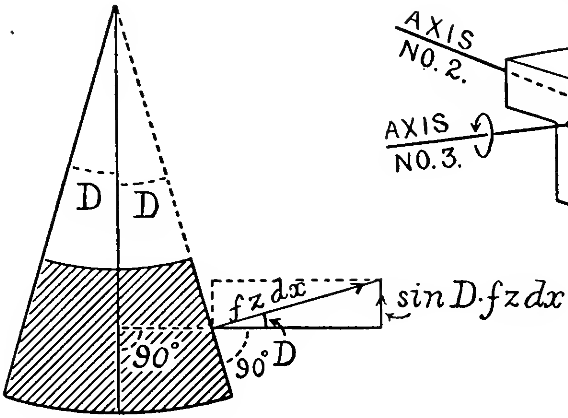


Fig. 29. — Resolution of the Circumferential Tension.

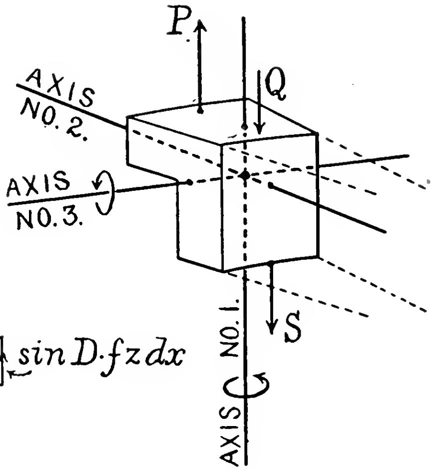


Fig. 30. — The Three Axes of Rotation.

The compressive force, Q, on the packing circle, acts upon a curved arc of radius $R + n$ and amplitude $2D$. If D_1 is the angular distance of any point of this arc from the plane OX, then the total force acting upon the little arc included between D_1 and $(D_1 + dD_1)$ is $Q.dD_1/2D$, and the moment of this elementary force with respect to axis No. 3 is $Q\{(R + b) - (R + n)\cos D_1\}dD_1/2D$. The total moment of the compressive stress upon the packing circle is the integral of this between the limits $D_1 = -D$ and $D_1 = +D$, which is $Q\left\{(R + b) - (R + n)\frac{\sin D}{D}\right\}$. This moment acts in the same direction as the moment of P, previously considered.

The longitudinal tensile stress, S, upon the shell sheet, will be assumed to be applied at the middle of the thickness of the sheet. Like the packing-circle stress, it acts along a curved arc; the radius in the case being $R - \frac{t}{2}$. By a process precisely analogous to that employed in the previous paragraph, we find that the moment of the shell-tension with respect to the axis No. 3 is $S\left\{(R+b) - (R - \frac{t}{2})\frac{\sin D}{D}\right\}$, acting in the same direction as before.

When (as happens in large vessels) the angle D is small, we may safely take $\sin D = D$; and with this simplification in the formulas of the two preceding paragraphs we have: Moment of $Q = Q(b - n)$; and Moment of $S = S(b + \frac{t}{2})$.

Referring back, now, to Fig. 28, we note that the total circumferential tension acting normally on the little rectangle of length z and width dx is, as we have already found, $C(x-a).z.dx$. This has a horizontal component, parallel to the plane OX, of magnitude $\sin D.C(x-a).z.dx$. There is also a similar and equal component force acting upon the symmetrically situated elementary rectangle on the back face of the ring-unit under consideration; and as both of these little rectangles are at a depth x below the top face of the leaf of the ring, the total moment (which is counter-clockwise) of the circumferential tension with respect to axis No. 3 in Fig. 30 is the integral, between the limits $x = 0$ and $x = h$, of $2\sin D.C(x-a)^2z.dx$. That is, it is the integral, between these limits, of $2C \sin D\ (x^2zdx - 2a.xzdx + a^2zdx)$.

The integral of x^2zdx is what is known as the "moment of inertia" of the cross-section. We may designate it by I (as is usual in all writings that have to deal with it); the axis to which I refers being, it must be remembered, the horizontal line which constitutes the upper edge of the shaded section in Fig. 28. The integral of $xzdx$ is equal, as is easily seen, to the product of a and the area of the cross-section (which area will be designated by the letter A). Finally, the integral of zdx is of course equal simply to A itself. Hence the moment of the circumferential forces, with respect to axis No. 3, is equal to $2C \sin D. (I - 2a^2A + a^2A)$, or to $2C \sin D.(I - a^2A)$; and this moment tends in a counter-clockwise direction.

Summing up the results that have been obtained with respect to the moments of the various forces with respect to axis No. 3, we find that equilibrium with respect to that axis requires that $P(m+n-b) + Q(b-n) + S(b+\frac{t}{2}) = 2C \sin D.(I - a^2A)$. Now we found that $P = Q + S$; and if, by means of this relation, we eliminate Q from the foregoing equation, we have simply

$$mP + (n + \frac{t}{2})S = 2C \sin D.(I - a^2A.) \quad\ldots\ldots\ldots\ldots (2)$$

(It will be noted that b cancels out, so that it does not appear in the final result.)

When N, the total number of cover-bolts, is fairly large, we have, approximately, $\sin D = \pi/N$; and if we attend to this relation, and then replace C in equation (1) by its value as deduced from (2), we have

$$f = \frac{mNP + NS(n + \frac{t}{2})}{2\pi\,(I - a^2A)}.(x - a)$$

as the intensity of the circumferential tension in the ring, at the depth x below the upper face of the leaf of the ring.

We are more particularly interested in the *maximum* tension, which will occur at the lowest edge of the hub of the ring, where x has the value h. We may note, also, that NS is the total steam load on the lower head of the vulcanizer shell, and hence it has the value $\pi R^2 p$. Moreover, we may note that in order that there may be no leakage around the packing, it is essential that the united tension on all the cover-bolts taken together shall be at least as great as the total steam load on the cover of the vessel. It will simplify the formula if we let L stand for the total steam load on the lower head of the vessel, and let E be the *excess* of the tension on each cover-bolt, over and above that which corresponds to the total steam load on the lower head of the vessel. This will give $NE + \pi R^2 p$ as the value of NP. With these changes made, the foregoing formula becomes $F = \dfrac{mNE + L(m + n + \frac{t}{2})}{2\pi (I - a^2 A)} . (h - a)$ as the value of the circumferential tension at the free edge of the hub. As $t/2$ is small with respect to $m + n$, we shall commit no serious error by omitting it entirely; in which case the formula reads $F = \dfrac{mNE + L(m + n)}{2\pi\ (I - a^2 A)} . (h - a) = \dfrac{(mNE + LD)(h - a)}{2\pi (I - a^2 A)}$ (see Fig. 9) which is the form in which it is employed in the previous article.

It must be observed that the symbol D, as used in this formula, does not have the same significance as in the rest of this present article. It here represents the dimension marked "D" in Fig. 12.

On the Stresses Thrown Upon Bolts by the Wrench.

It is impossible to make any very accurate computation of the tensile stress that is thrown upon a bolt, by screwing up a nut upon the end of it; but it is possible to obtain a roughly approximate estimate of that stress, when the nut is set up under given conditions.

Let us suppose that a given screw is provided with a nut, which is to be turned up solidly against some resisting structure, so as to throw a tensile stress on the screw. Let the nut be turned by means of a wrench whose effective length is L inches. When the nut has been brought up pretty well into place, let us suppose that a force of P pounds, when applied to the end of the wrench in the most effective manner, will just move it. The work done by the man at the wrench, per revolution of the nut under these circumstances, is found by multiplying the force, P, by the circumference of the circle described by the end of the wrench. The wrench being L inches long, the circumference of this circle is $2\pi L$ inches, where π stands for the decimal number 3.1416. Hence the work performed by the workman, per revolution, is $2\pi LP$ inch-pounds. Let us assume, for the moment, that the screw runs absolutely without friction, either in the nut, or against the surface where the nut bears against its seat. Then the work performed by the workman is all expended in stretching the screw, or deforming the structure to which it is attached (omitting such thermal effects as may be produced). Hence if the screw has n threads per inch of its length, and T is the total tension upon it in pounds, the work performed may also be expressed in the form T/n; for in one turn the screw would be drawn forward by $1/n$ inch, against the resistance T. Under the assumed conditions of perfection, the two foregoing expressions for the work done must be equal to each other. That is, we should have $2\pi LP = T/n$, or

$$T = 2\pi nLP,$$

from which we could calculate the tension, T, on the bolt, if the screw were absolutely frictionless in all respects.

We come, now, to the matter of making allowances for the fact that in the real screw the friction is very far from being negligible. The actual tension that the given screw would produce in the bolt will be smaller than the value here calculated, and the fraction (which we will denote by the letter E) by which the foregoing result must be multiplied in order to get the true result is called the *efficiency* of the screw. The efficiency of screws has been studied both experimentally and theoretically; but the experimental data that are at present available are far less numerous than might be supposed, considering the elementary character and the fundamental importance of the screw, in nearly every branch of applied mechanics. In the *Transactions* of the American Society of Mechanical Engineers, Volume 12, 1891, pages 781 to 789, there is a paper on screws by Mr. James McBride, followed by a discussion by Messrs. Wilfred Lewis and Arthur A. Falkenau, to which we desire to direct the reader's attention. In this place Mr. Lewis gives a formula for the efficiency of a screw of the ordinary kind, which appears to be quite good enough for all ordinary purposes, and which may be written in the form

$$E = 1/(1 + nd),$$

where d is the external diameter of the screw. If we multiply the value of T, as found above, by this "factor of efficiency," the value of T, as corrected for friction, becomes

$$T = \frac{2\pi nLP}{(1 + nd)}$$

As an example of the application of this formula, let us consider the case in which a workman turns up a nut on a two-inch bolt, by means of a wrench whose effective length is 50 inches; the maximum effort exerted at the end of the wrench being (say) 100 pounds. A standard two-inch bolt has 4.5 threads per inch; so that in this example the letters in the foregoing formula have the following values: $n = 4.5$; $L = 50$ inches; $P = 100$ pounds; $d = 2$ inches; and π (as usual) stands for 3.1416. Making these substitutions, the formula gives

$$T = \frac{2 \times 3.1416 \times 4.5 \times 50 \times 100}{(1 + 4.5 \times 2)} = \frac{141,372}{10} = 14,137 \text{ lbs.}$$

That is, the actual total tension on the bolt, under these conditions, is somewhat over 14,000 pounds, according to the formula. As another example, let us consider a screw 1.5 in. in external diameter, with the nut set up with the same force and the same wrench as before. A standard screw of this size has six threads to the inch, so that the formula gives, in this case,

$$T = \frac{2 \times 3.1416 \times 6 \times 50 \times 100}{(1 + 6 \times 2)} = \frac{188,496}{13} = 14,500 \text{ lbs.},$$

or a total tension on the bolt of 14,500 pounds.

In setting up a nut on a bolt, it all too frequently happens that the workmen take a long wrench, slip a piece of pipe over the end of it to obtain a still greater leverage, and then two or three of them get together and force the nut practically to the limit of their united strength. Under circumstances of this sort, there is little use in trying to compute what the tensile stress upon the bolt may be. It does not often happen, even in this kind of treatment, that a large bolt is actually pulled apart by the wrench. A small one may be, and often is; but the tensile strength of a bolt (say) 1½ or 2 inches in diameter is so great that even the most violent mishandling usually fails to cause direct and immediate separation on account of the tension exceeding the ultimate strength. The nuts on the cover-bolts of vulcanizers and other similar vessels must run freely on the threads, as a matter of convenience in the repeated handling to which they are subjected; and the threads on the nuts and bolts often do not fit one another perfectly, on account of the slight play that the looseness requires. The mishandling of the wrench in tightening up loose nuts is apt to cause an undue wear on the threads, and after a time they are likely to strip. As has been said, however, direct failure from excessive tension in the body of the bolt is not common in the case of bolts of large size. Repeated application of excessive stress may cause the bolt to fail after a time, however, by "fatigue" of the material.

Obituary.

Mr. Oscar F. Davis.

Mr. Oscar F. Davis, who was well known to a great many of our patrons in the Pennsylvania Department, died at his home in Philadelphia on June 22, 1905, after an illness of only a few days. He was seventy-three years of age, but was so active and efficient in his work that he was commonly believed to be much younger. Mr. Davis had been a special agent for the Hartford Steam Boiler Inspection and Insurance Company for more than twenty years, and had served it during all that period with great faithfulness. He was held in the highest esteem by the company's officers and other employes, and his death will be deeply regretted by all who knew him.

Boiler Explosions.

December, 1904.

(337.) — On December 1st a flue failed in a boiler at the plant of the Mitchell & Lewis Wagon Company, at Racine, Wis. Nobody was injured, and the property loss was small.

(338.) — On December 1st three cast-iron headers fractured in a water-tube boiler at the plant of the Shenango Valley Steel Works, Newcastle, Pa. Nobody was injured, and the property loss was small. The plant in which the accident occurred belongs to the United States Steel Corporation.

(339.) — At Clemson College, Clemson College P. O., S. C., a slight rupture occurred, on December 2d, in a boiler in one of the buildings. The property loss was small.

(340.) — A slight rupture occurred, on December 3d, in a boiler at the plant of the Pioneer Cereal Company, Canal Fulton, Ohio.

(341.) — A boiler exploded, on December 2d, in Henry Holt's sawmill, at Frankford, Del. Joshua Banks, John Timmons, and Charles Timmons were killed, and James Holt, a son of the proprietor of the mill, was seriously injured. The mill was entirely demolished.

(342.) — A large heating boiler exploded, on December 3d, in the Ontario & Western Railroad station, at Campbell Hall, N. Y. Mrs. H. B. Lamay had her leg broken, and four other persons were slightly injured. The windows of the station were shattered, and beams, floor, and ceiling were splintered.

(343.) — On December 3d a boiler exploded in the foundry and machine shop of the C. Hegewald Company, at New Albany, Ind. Nobody was injured. The property loss is estimated at $1,000.

(344.) — The boiler of a C. & P. freight locomotive exploded, on December 3d, as the train was passing Bedford, Ohio. Fireman H. C. Beyers was seriously, but not fatally, injured, and the engineer received lesser injuries.

(345.) — A boiler exploded during the course of a fire, on December 4th, in the big three-story warehouse of Thorndike & Hix, at Rockland, Me. Nobody was injured by the explosion. The total property loss was about $40,000, but nearly all of this was due to the fire.

(346.) — A hot water boiler exploded, on December 5th, in the four-story brick building of the Central Heating & Construction Co., on the northeast corner of First and Olive streets, St. Louis, Mo. Nobody was seriously injured. The property loss is estimated at $700.

(347.) — On December 5th a blow-off pipe failed in the electric lighting and manufacturing plant belonging to the estate of Charles Dought, at Randolph, Mass. Engineer John Anderson was slightly injured.

(348.) — Four cast-iron headers fractured, on December 5th, in a water-tube boiler at the plant of the Youngstown Consolidated Gas & Electric Company, Youngstown, Ohio. Nobody was injured.

(349.) — On December 6th a boiler exploded at the mill of the Pacific Lumber Company, at Carrollton, near Kalama, Wash. Joseph Thenn was instantly killed, and William McCune received injuries which are believed to be fatal. The front head of the boiler was blown out, and the building in which the boiler stood was reduced to splinters.

(350.) — Two small boilers exploded, on December 7th, in the dry-house of the Gross Lumber Manufacturing Company, at Lexington S., C. Frederick N. Gross and Jasper D. Trice were seriously injured, and the dry-house was completely destroyed.

(351.) — A boiler exploded, on December 7th, in Alfred Fuller's sawmill, some twelve miles south of Tuscumbia, Ala. The proprietor of the mill and his son, Shivers Fuller, were instantly killed.

(352.) — The boiler of a locomotive exploded, on December 7th, in the roundhouse of the Erie Railroad, at Salamanca, Pa. A fireman and a hostler were somewhat injured, and the building was considerably wrecked.

(353.) — On December 8th, a boiler exploded on a steam derrick at the plant of the Lackawanna Steel Company, Buffalo, N. Y. Engineer John Erickson was injured so badly that he died a few hours later.

(354.) — A slight explosion occurred, on December 10th, in the Twin Tree Lumber Company's plant, at Maplesville, Ala. There were no personal injuries.

(355.) — A boiler used for operating a wood-sawing machine exploded, on December 12th, on the farm of John Eikstadt, four miles west of Bemidji, Minn. William Eikstadt was killed almost instantly, Frederick Eikstadt, Alfred Brewer, and Albert Brewer received injuries that were thought to be fatal, and William Haberli and George Hand received lesser injuries.

(356.) — On or about December 13th, a boiler exploded in the Tracy cotton gin, on North Fork, Baxter County, Ark. John Carson was fatally injured.

(357.) — On December 13th three boilers in a battery of seven exploded in the Parke County Coal Company's No. 10 Mine, three and a half miles south of Rosedale, Ind. Engineer John Dorman was fatally injured, and the fireman, whose name we have not learned, was seriously injured, but will recover. The property loss is variously estimated at from $6,000 to $8,000.

(358.) — A tube failed, on December 13th, in a boiler in the power house of the Columbus Railway & Light Company, at Columbus, Ohio. Fireman William E. Goff was seriously scalded, and Joseph Ketcham, a bricklayer, received lesser injuries.

(359.) — A tube ruptured, on December 13th, in a horizontal tubular boiler at the Nelson Baker Company's plant, Detroit, Mich. Nobody was hurt.

(360.) — A boiler exploded, on December 14th, in J. A. Garrett's sawmill, two miles north of Byrdstown, Tenn. William Craig, who was the only person present at the time, was fatally injured. The building in which the boiler stood was almost completely demolished.

(361.) — A heating boiler exploded, on December 14th, in Hotel Albion, at Albion, Mich. The boiler was thrown 60 feet into the air, passing over a livery stable in its course.

(362.) — On December 15th a boiler exploded at the coal mine of W. H. Bates & Co., at Winchester, near Jacksonville, Ill. The resulting property loss was estimated at $8,000. We have not learned of any personal injuries.

(363.) — On December 15th a tube ruptured in a water-tube boiler at the plant of the Foster Engineering Company, Newark, N. J. There were no personal injuries.

(364.) — A boiler exploded, on December 16th, at the plant of the Everett Lumber Company, Vienna, Ga. David Lupo was killed, and several others were injured.

(365.) — The boiler of a locomotive hauling a west-bound freight train on the Grand Trunk Railroad exploded, on December 17th, about one mile west of Vaudreuil, Canada. Engineer Thorpe and Brakeman Benoit were seriously scalded.

(366.) — A small boiler exploded, on December 17th, at the headquarters of the Ingram Lithia Water Company, Birmingham, Ala. J. M. Martin and Frank Farmer each had a leg broken, and two other persons received slight injuries.

(367.) — On December 17th a vertical water-tube boiler exploded in the Brower & Love Brothers cotton mills, at Indianapolis, Ind. Assistant Engineer John Perkins was seriously scalded, and Firemen Curtis Boyd and W. A. Watts received lesser injuries. Two batteries of boilers were thrown down, the boiler house was demolished, and considerable other damage was done; the total property loss being estimated at $15,300. The boiler was projected high into the air, and fell 350 feet from its original position.

(368.) — Four sections fractured, on December 17th, in a cast-iron heating boiler in schoolhouse No. 21, Jersey City, N. J. The damage was confined to the boiler, and nobody was hurt.

(369.) — On or about December 18th a boiler exploded in a mill at Portland, Ore. William A. McEwan was killed.

(370.) — On December 18th the boiler of locomotive No. 1465, on the Chicago, Rock Island & Pacific Railroad, exploded, three miles west of Davenport, Iowa. Engineer Michael Calhoun and Fireman F. H. Kinney were killed, and Russell Sherrard, Augustus Smith, George Nettleton, and Thomas Gimel were injured.

(371.) — A boiler exploded, on December 20th, in Benjamin Redline's sawmill, near Rohrsburg, Columbia County, Pa. Charles Wright, Irvin Kline, Elias Ash, and William Redline (a son of the owner of the plant) were killed.

(372.) — A flue failed, on December 21st, in the puddling mill of the Republic Iron and Steel Company's Valley plant, at Youngstown, Ohio. We have not learned further particulars.

(373.) — A blow-off pipe ruptured, on December 21st, in the plant of the Battle Island Paper Company, Fulton, N. Y. Edward La Point was injured. The property loss was trifling.

(374.) — On December 21st a blow-off pipe ruptured in the plant of the Intervale Mills Corporation, at Dudley, Mass. One man was slightly injured.

(375.) — A cast-iron header ruptured, on December 22d, in the Thirteenth and Mount Vernon Street power plant of the Philadelphia Rapid Transit Company, Philadelphia, Pa. Nobody was injured.

(376.) — On December 22d a slight boiler explosion occurred on J. B. Levert's plantation, at St. Martinsville, La.

(377.) — A cast-iron header fractured, on December 24th, in a water-tube boiler at the plant of the Torrington Company and Excelsior Needle Company, Torrington, Conn.

(378.) — The lower tube-sheet of a vertical boiler fractured, on December 24th, in the plant of the National Novelty Company, at Brattleboro, Vt.

(379.) — A tube ruptured, and three cast-iron headers fractured, on December 26th, in a horizontal water-tube boiler at the plant of the Colorado Springs Electric Company, Colorado Springs, Colo. One man was injured.

(380.) — A boiler exploded, on December 27th, in the Oklahoma Gas & Electric Company's plant, at Oklahoma, Ok. Nobody was injured, but considerable damage was done to the building.

(381.) — On December 27th a boiler exploded with great violence in the electric lighting plant at Covington, Ga. Engineer John L. McCollough was instantly killed, and the entire plant was practically destroyed. The property loss was estimated at $12,000.

(382.) — A boiler exploded, on December 28th, in the plant of the Walworth & Neville Manufacturing Company, at Walville, a milling town twenty-seven miles west of Chehalis, Wash. R. G. Hicks, Frank Dowell, Pares Epling, and Roy Ickes were killed outright, and William Buchanan was injured fatally. Elias Paquette and I. C. Dasher were also injured, but subsequently recovered. There were six boilers in the battery, and all but two were badly damaged. The boiler house was wrecked, and the main mill and dynamo room were also damaged to a considerable extent. The property loss was estimated at $13,000.

(383.) On December 28th a tube ruptured in a horizontal water-tube boiler at the plant of the Cedar Rapids & Iowa City Railway & Lighting Company, Cedar Rapids, Iowa, injuring two men. The property loss was small.

(384.) — The crown sheet of a Philadelphia & Reading locomotive failed, on December 28th, as the train to which the locomotive was attached was passing Abrams, near Norristown, Pa. E. C. Fitzpatrick, who was firing the locomotive at the time, was scalded so badly that he died in a short time. E. F. Gilbert was also seriously injured.

(385.) — A tube ruptured, on December 29th, in a horizontal water-tube boiler at the plant of the Cedar Rapids & Iowa City Railway & Lighting Company, Cedar Rapids, Iowa. Nobody was injured.

(386.) — On December 31st a blow-off pipe ruptured in the plant of the Susquehanna Casting Company, Wrightsville, Pa. No one was injured, and the property damage was trivial.

(387.) — A heating boiler exploded, on December 31st, in the plant of the Vinton Pearl Button Manufacturing Company, at Vinton, Iowa. The north wall of the boiler room was blown out, and the husking shed of the Vinton Canning Company, across an alleyway from the scene of the explosion, was demolished. Mr. B. M. Bills was slightly scalded. The boiler house wall which was blown out was of brick, thirty feet square.

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1905.

Capital Stock, ... $500,000.00.

ASSETS.

	Par Value.	Market Value.
Cash in office and in Bank, ...		$200,088.96
Premiums in course of collection (since Oct. 1, 1904),		173,296.65
Interest accrued on Mortgage Loans, . . .		18,357.32
Loaned on Bond and Mortgage, ...		775,270.00
Real Estate, ...		16,390.00
State of Massachusetts Bonds, ...	$100,000.00	100,000.00
County, City, and Town Bonds, ...	372,000.00	389,700.00
Board of Education and School District Bonds,	46,500.00	48,500.00
Drainage and Irrigation Bonds, ...	7,000.00	7,000.00
Railroad Bonds, ...	1,111,000.00	1,238,940.00
Street Railway Bonds, ...	60,000.00	62,650.00
Miscellaneous Bonds, ...	55,500.00	56,905.00
National Bank Stocks, ...	41,800.00	57,100.00
Railroad Stocks, ...	176,900 00	235,247.00
Miscellaneous Stocks, ...	35,500.00	33,100.00
	$2,005,300.00	
Total Assets, ...		$3,412,544.93

LIABILITIES.

Re-insurance Reserve, ...		$1,811,665.96
Losses unadjusted, ...		55,833.25
Commissions and Brokerage, ...		34,679.33
Surplus, ...	$1,010,366.39	
Capital Stock, ...	500,000.00	
Surplus as regards Policy-holders, .	**$1,510,366.39**	1,510,366.39
Total Liabilities, ...		$3,412,544.93

On December 31, 1904, the Hartford Steam Boiler Inspection and Insurance Company had 91,137 steam boilers under insurance.

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J. B. PIERCE, Secretary. L. F. MIDDLEBROOK, Asst. Sec'y.

C. S. Blake, Supervising General Agent.
E. J. Murphy, M.E., Consulting Engineer.

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The Locomotive

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VOL. XXV. HARTFORD, CONN., OCTOBER, 1905. No. 8.

A Boiler Explosion in an Electric Light Plant.

The engravings presented herewith illustrate a boiler explosion which occurred a few months ago in a municipal electric lighting plant in the South. The boiler that exploded is shown in the foreground of Fig. 1. It was of the horizontal tubular type, with its longitudinal joints lapped and triple riveted. The engineer was killed, and the plant itself, as will be seen from the engraving, was almost entirely destroyed. The property loss was about $15,000, and the boiler was not insured.

FIG. 1. — GENERAL VIEW OF THE RUINS.

The boiler which exploded was 60 inches in diameter and 16 feet long. It was built in 1901, and had not been in service four years when the accident occurred. The initial rupture occurred on the bottom of the shell, extending fore and aft along the entire length of the rear course of plates. The rear shell-ring was torn from the boiler, breaking loose from it around the girth joint, as will be understood by reference to Fig. 1. The plant contained two boilers in all, and in the engraving the second one (which was thrown from its setting but did not explode) may be seen close to the ruined building.

Examination of the remains of the exploded boiler showed beyond all doubt that the accident was due to the fact that the shell was badly corroded, its thickness being reduced, in some places, to less than the sixteenth of an inch. In Fig. 2 we present a photographic reproduction of a piece of the shell that was cut from the bottom of the ring that was torn away. The length of this specimen extended girthwise of the boiler, or, in other words, perpendicularly to the initial fracture; and the right-hand end of the specimen (as it appears in the engraving) formed a part of the original fracture. It will be seen that the plate was corroded very

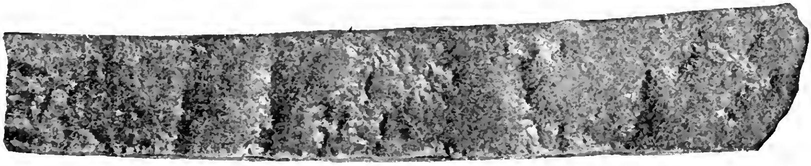

Fig. 2.—A Piece Cut From the Shell Plates, Showing Corrosion.

deeply and extensively. By placing a piece of paper against the edge of the specimen shown in Fig. 2, we have obtained the tracing presented in Fig. 3, which shows, on a scale about three-fourths of the full size, the variation in thickness along that edge. The original plate was ⅜ in. thick, and we have indicated this thickness in Fig. 3, where the *total* width of the strip corresponds to ⅜ in., and the heavy black part shows the portion that had wasted away by corrosion. The thinnest part of the undestroyed plate in Fig. 3 is about 3-32 in. thick; but at some points away from the edge of the specimen, the calipers show a thickness of only 3-64 in.

We desire to record (1) that the builder of this particular boiler is said to

Fig. 3.—Section of the Foregoing Piece.
(The Black Area Shows the Metal Lost by Corrosion.)

have made a statement, not long before this accident, that boilers made by him do not explode; and (2) that the City Council having charge of this plant had declined to insure the boilers in it, presumably because they believed such insurance to be unprofitable. We do not make these remarks in criticism of either the builder or the Council. The builder turned out a good boiler, so far as anything we know to the contrary is concerned, although we know nothing about the pressure that could safely be allowed upon it; and we believe that the City Council acted in good faith, and for what it considered to be the best interest of the city. We merely wish to illustrate, by this convenient example, how fallacious the reasoning was, which led to the belief that this particular boiler was safe, and did not need insurance and inspection.

The present issue of The Locomotive has been seriously delayed by labor troubles for which we are in no way responsible. The strike among the compositors in the job printing offices of the eastern part of the country, which has now continued for some weeks, has made it difficult to get our copy into type.

Boiler Explosions.

January, 1905.

(1.) — On January 2 a boiler exploded in the plant of the National Rendering Co., at Bernice, near Harvey, Ill. Fireman James Cavin was fatally scalded.

(2.) — A slight boiler explosion occurred, on January 2, in the Naperville Electric Light & Water Works, Naperville, Ill.

(3.) — A blow-off pipe ruptured on January 2, in the plant of Hearne Bros. & Co., Whitaker, N. C. One man was killed.

(4.) — On January 3 a boiler exploded on the tow-boat *Defender*, at Huntington, W. Va. Perry Spender, Horace Wetzel, James Seese, Albert Hamilton, Michael Stafford, Thomas Duffy, William Wetzel, and George Kidd were killed, and Ira Ellis, Robert Holland, and Robert Mann were injured. The boat was destroyed.

(5.) — A boiler in use for drilling a well exploded, on January 3, at North Grove, near Peru, Ind. Charles North was fatally injured.

(6.) — A boiler exploded, on January 4, on an oil lease at Poneto, ten miles south of Bluffington, Ind. Michael Dailey and his son Samuel were severely injured. The power house was wrecked. The boiler was used to steam oil, and not to run the machinery.

(7.) — The boiler of Bert C. Bailey's portable sawmill exploded, on January 4, at Catlin Hollow, Charleston township, N. Y. Fireman George Saxton was severely scalded and burned.

(8.) — A boiler exploded, on January 5, in James Bailey's sawmill, three miles south of Elizabethtown, Ky. James Bailey and James Melton were killed, and the mill was completely wrecked.

(9.) — Six sections of a cast-iron heating boiler fractured, on January 5, in an apartment house owned by Arthur Leeds, at Boston, Mass. Nobody was injured, and the property damage was confined to the boiler.

(10.) — A cast-iron header in a water-tube boiler fractured, on January 5, in the power-house of the Philadelphia Rapid Transit Co., at Fifteenth and Mt. Vernon Sts., Philadelphia, Pa.

(11.) — On January 5 the boiler of locomotive No. 1582, of the Erie railroad, exploded on the Susquehanna division, between Waverly and Owego, N. Y. Engineer John Young and fireman F. O. Wing were badly injured, and the locomotive was demolished.

(12.) — A boiler exploded, on January 6, in a sawmill at Hampton, near Jackson, Ky. Lafayette Parks (the owner of the mill) and his three sons, and two other men named Turner and Smith, were seriously injured.

(13.) — A blow-off pipe ruptured, on January 6, in the Sabine Lumber Company's plant, at Zwolle, La. O. D. Allison and Frederick Johnson were injured.

(14.) — A boiler exploded, January 7, in the sash and blind factory of J. M. Glasby & Co., Newark, N. J. George Wolf and Anthony May were seriously and perhaps fatally injured.

(15.) — Fireman Louis Resch was scalded, on January 8, by the rupture of a blow-off pipe in the works of the Wyandotte Gas Co., at Bethlehem, Pa.

(16.) — The boiler of locomotive No. 2571, of the Boston & Albany railroad, exploded, on January 9, at Canaan, N. Y. Engineer Daniel Graham, brakeman Edward Ryder, and fireman Behan were seriously injured.

(17.) — A boiler exploded, on January 9, in Larison & Marjarum's coal and wood yard, just outside of Lambertville, Pa. Thomas H. Larison was injured so badly that he died a few hours later. The property loss was estimated at $6,000.

(18.) — On January 10 a boiler exploded in the Faris bath house, at the "magnetic" mineral springs, Terre Haute, Ind. Engineer John Burns was instantly killed, and the entire rear end of the building was wrecked.

(19.) — Three sections of a cast-iron heating boiler fractured, on January 10, in the Polish Orphan Asylum, New Britain, Conn.

(20.) — On January 10, eight cast-iron headers fractured in a horizontal water-tube boiler at the Royalton Hotel, New York City.

(21.) — The boiler of locomotive No. 257, on the Erie railroad, exploded, on January 11, at Creston, twelve miles north of Wooster, Ohio. Engineer Frederick Keeler and fireman Philip Hafleck were instantly killed, and Joseph Newman was terribly burned and scalded. The locomotive was literally torn to pieces.

(22.) — Several tubes ruptured, and a cast-iron header fractured, on January 11, in the plant of the Dodge Manufacturing Co., at Mishawaka, Ill.

(23.) — The boiler of a traction engine exploded, on January 12, on the main street of Mitchellville, Iowa. Edward Lightner, proprietor of the Cottage Hotel, was fearfully injured, and Tyler Rooker and Charles Rooker received injuries which were less serious.

(24.) — A vertical boiler, used for heating water, exploded, on January 13, in the Herron Gymnasium, at Miami University, Oxford, Ohio. John Huston, a student, was injured, and the gymnasium was badly damaged.

(25.) — A cast-iron header fractured, on January 13, in the power house of the Philadelphia Rapid Transit Company, at Thirteenth and Mt. Vernon streets, Philadelphia, Pa.

(26.) — A boiler exploded, on January 13, in the starch plant of the Corn Products Company, at Oswego, N. Y. Fire followed the explosion, and the total property loss was estimated at $225,000.

(27.)—A tube ruptured, on January 13, in the plant of the Hanging Rock Iron Co., at Hanging Rock, Ohio.

(28.) — A boiler exploded, on or about January 13, in the Melton mill, at Boydville, Clay County, Ark. Claude Baker was fatally injured, and Walter Allen was injured seriously but not fatally.

(29.) — A patch blew off of a boiler in the Vulcan power building, on St. Clair street, Cleveland, Ohio, on January 14. Luke Gay and Joseph Wilkes, firemen, were killed.

(30.) — On January 17, a boiler exploded in W. C. Martin's sawmill, at Graves Mountain, Lincoln County, Ga. William Martin, Jr. (a son of the owner of the mill), and William Johnson were killed, and a man whose name we have not learned was fatally injured. William C. Martin, the owner, was badly scalded.

(31.) — A boiler exploded, on January 18, in the Stoddard washery at Wolf

Creek, near Pottstown, Pa. Harry Confair, Philip Russell, and John Slighticus were seriously scalded. The boiler house was demolished, and the seven other boilers that it contained were badly damaged.

(32.) — A slight boiler explosion occurred, on January 18, in the plant of the Orwell Basket Co., at East Orwell, Ohio.

(33.) — A blow-off pipe ruptured, on January 18, in the plant of the Milwaukee Rubber Works Co., at Cudahy, Wis. Fireman Joseph Barylock was injured.

(34.) — On January 18, a boiler exploded in the sawmill of A. W. Lamp & Son, of Shanghai, near Martinsburg, W. Va. A. W. Lamp and E. C. Dunham were injured.

(35.) — A boiler exploded, on January 18, on the Draper lease in the Sycamore oil field, two miles west of Lewisville, Monroe County, Ohio. John Hopkins and Sherman Barker were killed.

(36.) — A boiler exploded, on January 19, in Whitehead's sawmill, at Cultus, a small town near Langdon, Ont. Charles Penard, George Aspden, George McCallum, and Freeman Moffat were killed, and George Whitehead, Michael Aspden, and Charles Whitehead were injured. The property loss is estimated at $15,000.

(37.) — Eight sections of a heating boiler fractured, on January 20, in the State house at Columbia, S. C. Nobody was seriously injured. The property loss was estimated at $1,000.

(38.) — On January 20, a boiler exploded in Godby's sawmill, near Bernetta, in the western part of Pulaski County, Ky. Woodson Dalton and Milton Roberts were killed, and John Carver, Thomas Norfleet, and Charles Gaston were injured.

(39.) — A boiler exploded, on January 21, on the steamer *Olympia,* which had just sailed from Gomox, B. C., for Vladivostock. Two men were scalded seriously and perhaps fatally.

(40.) — The boiler of locomotive No. 2,000, on the Baltimore & Ohio railroad, exploded, on January 22, at Mountain Lake Park, near Cumberland, Md. Fireman Charles L. Simpson and brakeman Frank Johnson were killed, and engineer A. W. Stanhagen and conductor Joseph Howell were injured. The locomotive was completely wrecked.

(41.) — On January 23, one section of a heating boiler fractured in the Winthrop school, at New London, Conn. The failure occurred while school was not in session, and there were no personal injuries, nor any panic.

(42.) — A boiler exploded, on January 25, in the plant of the Standard Wheel Works, at Terre Haute, Ind. Thomas Patterson, Horace Colvin, and Levi Whittaker were killed, and George Davis was seriously injured. The property loss was estimated at $15,000, the boiler house and several adjoining buildings being wrecked.

(43.) — One section of a cast-iron sectional boiler fractured, on January 26, in the Sherman Hotel, at Appleton, Wis.

(44.) — On January 27, a tube failed in the boiler of a Pennsylvania railroad locomotive, at Bucyrus, Ohio. Fireman Osborn was badly scalded and burned.

(45.) — A heating boiler exploded, on January 27, in the plant of the Bush & Gerts Piano Company, at Memphis, Tenn.

(46.) — The boiler of a locomotive of the Lehigh Valley railroad exploded, on January 27, at Gratwick, N. Y., midway between Tonawanda and Niagara Falls. Engineer Chester Hoyt and brakemen John Wood and George Wood were killed, and fireman Harry F. Ryan was injured.

(47.) — On January 28, a slight explosion occurred in the water works plant, at Atlantic, Iowa.

(48.) — The boiler of a locomotive belonging to the "Big Four" railroad exploded, on January 29, between Kingsgrove and Danvers, near Bloomington, Ill. Fireman William Paddy was fatally injured, and brakeman Ray Lawrence ws injured less seriously. The explosion consisted in the failure of several of the tubes.

(49.) — A heating boiler exploded, on January 29, in the Tremont House, Mansfield, Ohio.

(50.) — The boiler of a Rock Island locomotive exploded, on January 30, near Solon, Iowa. Engineer William Kirby, fireman C. R. Smith, and brakeman John W. Kelley were killed.

(51.) — A boiler exploded, on January 30, in the Liberty Electric Light Plant, Liberty, Mo. Fireman Benjamin Johnson was killed, and the building was demolished.

(52.) — A locomotive boiler exploded, on January 31, on the Pittsburg & Lake Erie railroad, at Pittsburg, Pa. Nobody was injured.

FEBRUARY, 1905.

(53.) — Two small boilers exploded, on February 1, in the dry house of the Gross Lumber Co., at Lexington, S. C. Frederick H. Gross, one of the owners of the plant, was fatally injured, and Jasper D. Trice was injured seriously but not fatally. The dry house was destroyed.

(54.) — A locomotive boiler exploded, on February 1, on the Cheyenne & Northern branch of the Colorado & Southern railroad, some 22 miles north of Cheyenne, Wyo. Fireman W. H. Smith was seriously injured.

(55.) — On February 1, a blow-off pipe ruptured in the plant of the Troy Knitting Co., Troy, N. Y. Engineer Richard Smith and fireman Orville Moak were scalded.

(56.) — A tube ruptured, on February 3, in a water-tube boiler in the plant of the Merchants' Light & Heating Company, Indianapolis, Ind.

(57.) — On February 3, five cast-iron headers fractured in a water-tube boiler at the Diamond State Fiber Co's. plant, Bridgeport, Pa.

(58.) — A boiler exploded, on February 3, in Anton Brucken's sawmill, near Madisonville, Ky. James Hendricks, the engineer, was killed. The property loss was estimated at $4,000.

(59.) — An express train was wrecked under very unusual circumstances, on February 4, on the New York Central railroad, at Whitesboro, three miles west of Utica, N. Y. As two trains were passing, the boiler of the locomotive of one of them exploded, with the result that the other train was entirely derailed, its thirteen cars being thrown from the track like toy coaches. John Allen and John Brennan, the engineer and fireman, respectively, of the locomotive whose boiler exploded, were killed by the explosion, and about twenty-five persons on the derailed train were more or less seriously injured.

(60.) — A heating boiler exploded, on February 4, in the residence of Richard Blue, at Essex Fells, near Caldwell, N. J.

(61.)—On February 4, a tube ruptured in a water-tube boiler at the plant of the Dayton Malleable Iron Co., Dayton, Ohio. Fireman R. H. Franklin was scalded.

(62.) — A blow-off pipe failed, on February 4, at the plant of the LaPorte Carriage Co., La Porte, Ind.

(63.) — On February 5, a boiler exploded in the Bethel Military Academy, Bethel Academy, Fauquier County, Va. The building in which the boiler stood was considerably damaged, but nobody was injured.

(64.) — A boiler exploded, on February 6, in the Sage elevator, at Alexander, Mo. John Boyd was killed, and the plant was considerably damaged.

(65.) — A small boiler exploded, on February 8, in C. A. Long's grist mill, near the Wheeling & Lake Erie railroad station, at Dresden, Ohio. James Fisher, engineer at the mill, was injured.

(66.) — On February 8, a boiler exploded in the Germantown Brewery, Louisville, Ky. Nobody was injured. The property loss was variously estimated at from $2,000 to $5,000.

(67.) — A boiler exploded, on February 10, at the plant of the Central Union Gas Company, Port Morris, the Bronx, N. Y. John Kelly, Henry Mohr, Theodore Fenweger, and Robert Gibbons were severely burned, and Martin Burke and Thomas Tantany were injured to a lesser degree. The plant took fire after the explosion, and the total property loss was estimated at $100,000.

(68.) — A slight boiler explosion occurred, on February 12, in the power house of the Rochester & Eastern trolley line, at Canandaigua, N. Y.

(69.) — A tube failed, on February 13, in a boiler at the plant of the American Car & Foundry Company, Detroit, Mich. Frederick Kerr was fearfully burned, and William Henselman, Henry Trites, and Paul Duas were injured less seriously.

(70.) — On February 13, a blow-off pipe ruptured in the automobile factory of Thomas B. Jeffrey & Co., at Kenosha, Wis. William Milke and James McDonough were injured.

(71.) — A tube burst, on February 14, in a water-tube boiler at the Fulton Bag & Cotton Mills, Atlanta, Ga.

(72.) — A heating boiler exploded, on February 14, in the residence of Mrs. T. M. Winters, Lansing, Mich.

(73.) — One boiler in a battery of five exploded, on February 14, in the Allis-Chalmers Works, at Scranton, Pa. Frank Singer was injured so badly that he died in a few hours, and Frederick Klots and Michael Gannon were also injured seriously.

(74.) — A boiler exploded, on February 16, in the Hampton Stave Factory, at Rison, Ark. John Ratterford was killed, Marion Walker and a man named

Brown were fatally injured, and William Gates received burns and scalds which were serious, but not fatal. The property loss was estimated at $1,200.

(75.) — On February 18, a boiler exploded in a sawmill near South McAlester, Tex. Nobody was injured. The boiler room was wrecked.

(76.) — A boiler exploded, on February 18, in Ray Bros.' flouring mill, at Sedalia, Graves County, Ky. George W. Lambert was instantly killed, and Bud Ray, Zolin Ray, James Wyatt, Ernest Ray and his ten-year-old daughter, and a boy named McClure were injured. It was believed, at last accounts, that Bud Ray and Zolin Ray would die.

(77.) — A heating boiler exploded, on February 18, in the building occupied by the F. P. Little Electrical Company, Buffalo, N. Y. The property loss was estimated at from $500 to $2,000.

(78.) — A boiler exploded, on February 20, at the No. 1 mine of the Provident Coal Company, near St. Clairville, Ohio. William Adams, Eli Minty, Michael Meili, and an unknown Hungarian miner were either killed outright, or died within a short time. James Loftus, William Davis, David Thomas, James Santell, Melos Vorhi, and Mili Vorhi were seriously injured, and eight Slav miners whose names we have not learned were injured less seriously.

(79.) — On February 24, a boiler exploded in the Patterson sawmill, near Rosebud, Ill. Two persons were seriously injured.

(80.) — A boiler exploded, on February 24, in Christopher & Theodore Wunderlich's planing mill, at Antigo, Wis. Fireman Edward Pluegart was instantly killed, and Peter Engle was fatally injured. The boiler house was totally demolished, and the mill itself was badly wrecked.

March, 1905.

(81.) — A boiler exploded, on March 1, at Rapid City, S. D. Richard Mansfield and Frederick Farrar were injured.

(82.) — A boiler exploded, March 2, on the David James oil lease, six miles east of Marion, Ind. Frank Stout was seriously injured, and the boiler house was wrecked.

(83.) — On March 2, the elbow of a blow-off pipe ruptured in Mill No. 2, of the Parsons Paper Co., Holyoke, Mass. Fireman Morris Donoghue was slightly injured.

(84.) — A slight explosion occurred, on March 4, in the plant of the Nashua River Paper Co., Pepperell, Mass. Frederick Abbott and John Thurston were injured.

(85.) — The plant of the White-Miller Extracting Co., of Camden, N. J., was destroyed by fire on March 4, and during the course of the fire a boiler exploded, scattering debris in all directions, but injuring nobody.

(86.) — A slight rupture occurred, on March 4, in a water-tube boiler in the plant of the Newcastle Electric Co., Newcastle, Pa.

(87.) — At the plant of the Ironton Manufacturing Co., Ironton, Mo., a boiler ruptured on March 4. There were no serious results.

(88.) — Two or more headers in a water-tube boiler fractured, on March

5, in the city electric lighting plant, at Jacksonville, Fla. Fireman John Davis was instantly killed, and Frederick W. Ellis and L. N. Cairo were injured so badly that they died within a few days. John E. Dunn's skull was likewise fractured. The property loss was estimated at $10,000.

(89.) — A boiler exploded, on or about March 6, in John Bitting's sawmill, at Honey Grove, Juniata County, Pa. Allen Bitting was instantly killed.

(90.) — On March 6, a boiler exploded in Robert Mulholland's sawmill, ten miles southeast of Jellico, Tenn. Herbert Batson and Silas Brooks were instantly killed, and George Sheehan, Henry Foster, James Langley, and John Wilson were seriously injured.

(91.) — A boiler exploded, on March 7, in elevator B, of the Cereal Mills Company (the largest oatmeal mill in the world), at Cedar Rapids, Iowa. Fire followed the explosion, and the total property loss was estimated at $1,500,000.

(92.) — A boiler belonging to Hull & Dillon, of Pittsburg, Kans., exploded on March 8. Nobody was injured.

(93.) — A heating boiler exploded, on March 9, in the basement of the Greenwood Baptist Church, Brooklyn, N. Y. Richard Hall was instantly killed, and Raymond Denton was injured. The property loss was estimated at from $6,000 to $7,000.

(94.) — The elbow of a blow-off pipe failed, on March 10, in the W. C. Ditman plant, at Texas, Ind. Fireman George Stewart was injured.

(95.) — The drum of a water-tube boiler ruptured, on March 11, in the plant of the Davis Sewing Machine Co., at Dayton, Ohio.

(96.) — Several tubes of a water-tube boiler ruptured, on March 11, at the plant of the Remington Salt Co., Ithaca, N. Y. Nobody was injured, but the property loss was considerable.

(97.) — The boiler of locomotive No. 2909, of the New York Central railroad, exploded, on March 14, near Schenectady, N. Y. Engineer Elmer E. Allen was burned to death.

(98.) — A boiler exploded, on March 15, in a shingle mill four miles west of Lineville, near Oil City, Pa. Hudson Kline was injured so badly that he died some days later, and his son Hudson Kline, Jr., was also injured seriously, but not fatally.

(99.) — A cast-iron header on a water-tube boiler ruptured, on March 15, at the plant of the Voight Milling Company's plant, Grand Rapids, Mich.

(100.) — The boiler of freight engine No. 2132, of the Pennsylvania railroad, exploded, on March 15, at Bolivar, Pa. The explosion unfortunately occurred opposite a gang of laborers, who were making repairs to the tracks. John Riblett and Washington Wambauld were killed, and Emanuel Hull was fatally injured. G. L. Hair, A. V. Colcord, Theodore Bennett, Frank Gill, George Hysong, Daniel B. Perr, Thomas S. Lenhart, and W. M. Hair were also injured seriously.

(101.) — A boiler exploded, on March 15, in Everett Daniels' sawmill, on Greasy Creek, near Nebo, Ky. Nobody was about the plant at the time. The property loss was about $900.

(102.) — Two tubes in a water-tube boiler ruptured, on March 16, in the plant of the Ansonia Brass & Copper Co., Ansonia, Conn.

(103.) — A boiler exploded, on March 17, in the Wyoming Valley Lace mills, North Wilkesbarre, Pa. The property loss was estimated at $3,000.

(104.)—On March 18 a boiler exploded in Albert Byers' cotton gin, five miles northeast of Bastrop, Tex. Howard Byers was instantly killed, David Byers was fatally injured, and the owner of the plant was scalded seriously, but not fatally.

(105.) — A boiler belonging to Merton Howard exploded, on March 19, at Dekolia, Pa.

(106.) — On March 20, a boiler exploded in the plant of R. B. Grover & Co., manufacturers of the Emerson shoe, at Campello, Brockton, Mass. The explosion resulted in the death of 58 persons, and in injuries to 117 others. The ruins took fire, and the total property loss, to R. B. Grover & Co., and to others whose property was in the vicinity, was approximately $250,000. An extended illustrated account of this terrible catastrophe was given in the issue of THE LOCOMOTIVE for April, 1905.

(107.) — A tube ruptured, on March 22, in a water-tube boiler at the plant of the Allegheny County Light Co., Pittsburg, Pa. William Marcello and James Fietto were injured.

(108.) — A blow-off pipe failed, on March 22, at the plant of the United States Silica Company, South Ottawa, Ill. Monroe Harvey was injured.

(109.) — A boiler exploded, on March 22, on F. C. Goodwin's plantation, about two miles north of Reynolds, Ga. Two girls named Blalock were instantly killed, and two others were painfully but not seriously injured.

(110.)—A tube ruptured, on March 23, in a water-tube boiler at the concentrating mill and pump house of the Des Loge Consolidated Lead Company, Des Loge, Mo. John Earnest was injured.

(111.) — On March 25, the sheet of a boiler ruptured in the plant of the Fasig & Perrine Co., at Anna, Ill. Nobody was injured.

(112.) — The boiler of a locomotive exploded, on March 27, at Franklin Junction, near New Franklin, Mo. Joseph Messenger was slightly injured.

(113.) — A boiler exploded, on March 27, in Fitzgerald's spoke and handle factory, at Gallatin, Tex.

(114.) — A boiler exploded, on March 28, in the shops of the Illinois Central railroad, at Burnside, Ill. Details have been hard to procure. According to the *Chicago Tribune*, however, Louis Boizzan was killed, Andrew Debon, Claudislaw Dojedon and a man named Semanski were fatally injured, and John Dold, John Dumby, Charles Lewiston, Thomas Ricker, and John Sebo were injured seriously but not fatally. The explosion is said to have consisted in the blowing out of one of the heads of the boiler.

(115.) — A head blew off of a superheater, on or about March 28, in the Lycoming electric power house, at Williamsport, Pa. Fireman C. H. Seeley was killed almost instantly.

(116.) — The boiler of locomotive No. 851, of the Mexican Central railroad, exploded, on March 29, four miles south of Juarez, Mex. Fireman Samuel Sanders was instantly killed, and brakeman Pedro Santano was seriously injured. Engineer Martin J. Campbell was also injured less seriously. The explosion consisted primarily in the failure of the crown-sheet.

(117.) — The five-story brick building occupied by the Farmers' & Manufacturers' Peanut Co., near Portsmouth, Va., was destroyed by fire on March 29. During the fire one of the boilers exploded, injuring Henry Bell.

(118.) — On March 30, a boiler exploded in Walter Farrell's sawmill, on Sandstone creek, near Matewan, Mingo County, W. Va. John Sandman, Greene Sandman, and William Henderson were killed, and Frank Burgess and Alonzo Zago were injured.

April, 1905.

(119.) — Edward M. Ferrall, head janitor of the Capitol at Raleigh, N. C., was killed, on April 4, by the explosion of a boiler in a sawmill owned by him, two and one-half miles northwest of Raleigh. John Moore was also slightly injured.

(120.) — Two boilers exploded, on April 6, in the Batson, Tex., oil field. Nobody was injured.

(121.) — On April 6, a tube ruptured in a water-tube boiler at the power house of the Indiana Union Traction Co., Anderson, Ind. A. J. Black, John Richmond, George Cranor, and James Dent were scalded.

(122.)—The starboard boiler of President Roosevelt's yacht *Sylph* exploded, on April 6, near Cape Hatteras. Two men were badly scalded, and the yacht was disabled. Mrs. Roosevelt and several of her younger children had been cruising in Florida waters, but left the *Sylph* at Jacksonville, Fla., and proceeded to Washington by rail.

(123.) — A blow-off pipe ruptured, on April 7, in the spoke factory of the Imperial Wheel Co., at Dyersburg, Tenn. Fireman James Miller was scalded.

(124.) — A boiler exploded, on April 7, in W. Ferguson's sawmill, near Plantersville, Grimes County, Tex. Mr. Ferguson was badly scalded.

(125.) — A boiler exploded, on April 7, in the Union Ice Works, at Los Angeles, Cal., and the plant took fire and was destroyed, with an estimated property loss of $100,000. Mark Hazel was badly injured.

(126.) — The boiler of a freight locomotive exploded, on April 8, near Central Park, Mont. Engineer Daniel Gillis was instantly killed, and fireman Richard Kinney, brakemen Strems and Freeman, and conductor Charles Bryant were more or less seriously injured.

(127.) — On April 8, the boiler of a switch locomotive exploded in the yards of the Mobile & Ohio railroad, at Artesia, fourteen miles west of Columbus, Miss. Engineer Gregory Humphreys was instantly killed, and Felix Daugherty was injured so badly that he died a few hours later. Fireman William Davis was also fatally injured.

(128.) — A boiler exploded, on April 8, on James Berkheimer's farm, near Duncanville, Pa. George Webb and John Stiers received injuries which were thought to be fatal.

(129.) — A boiler exploded, on April 10, in the Sullivan Axle Works, Sullivan, Ind. Nobody was injured.

(130.) — A tube ruptured, on April 11, in a water-tube boiler in the plant of the New Orleans & Carrolton Railway, Light & Power Co., New Orleans, La.

(131.) — On April 15, a tube ruptured in a water-tube boiler in the power house of the Consolidated Gas, Electric Light & Power Co., at Baltimore, Md.

(132.) — A tube failed, on April 15, in a horizontal tubular boiler at the Colorado School of Mines, Golden, Colo. Nobody was injured.

(133.) — A slight boiler explosion occurred, on April 17, in the Howe & Davidson Company's paper mill, at Marseilles, Ill.

(134.) — On April 17, a water-tube ruptured in the plant of the Pittsburg Gas & Coke Co., at Otto Station, Pa. Fireman William Forsythe was injured.

(135.) — A boiler exploded, on April 18, in the mill of J. B. Aud & Bro., at Knottsville, Ky. The boiler room was wrecked, and the mill machinery was considerably damaged.

(136.) — A tube ruptured, on April 18, in a water-tube boiler in the plant of the Marion Paper Company, Marion, Ind. John Gesaman was scalded, and the property damage was considerable.

(137.) — On April 19, a tube pulled out of a water-tube boiler at the National Sewing Machine Co's. plant at Belvidere, Ill.

(138.) — A boiler exploded, on April 22, in the boiler house back of the New York block, at Superior, Wis.

(139.) — A boiler exploded, on April 24, in Peter Anderson's sawmill, five miles north of Medford, Wis. Nobody was injured.

(140.) — On April 26, a boiler exploded in Jasper Hardy's sawmill, five miles east of Lynchburg, Tenn. The owner of the mill was seriously injured, and one of his sons was injured less severely. The mill and machinery were wrecked.

(141.) — The boiler of Shay locomotive No. 4, on the Alamogordo & Sacramento Mountain railroad, exploded, on April 28, at Russia, a logging camp fourteen miles east of Alamogordo, N. Mex. Fireman Lee McNatt was killed, and Pedro Aguilar and Jose Lopez were fatally injured.

MAY, 1905.

(142.) — A cast-iron mud drum attached to a water-tube boiler burst, on May 1, in the plant of the Newcastle & Lowell Railroad Company, Edinburg, Pa.

(143.) — On May 1, a boiler exploded in J. E. Johnson's sawmill, Hixon, Tenn. J. E. Johnson and Walter Hardie were fatally injured.

(144.) — On May 2, the boiler of a Santa Fé locomotive exploded near Springer, N. M. Engineer E. W. Davis and fireman J. W. Swisher were killed.

(145.) — A small heating boiler exploded, on May 3, in the basement of the Harvard Chambers, Minneapolis, Minn.

(146.) — The boiler of locomotive No. 1947, of the Baltimore & Ohio railroad, exploded, on May 4, at DeForest Junction, two miles east of Warren, Ohio. Fireman Alexander Patterson was instantly killed, and engineer M. G. Kelley and brakeman B. H. Waldron were injured.

(147.) — A small boiler belonging to a Mr. Ward, exploded, on May 4, at the head of Sweetwater Creek, near Sweetwater, Tenn. Samuel Beel's store was damaged considerably, and engineer Custeed was injured.

(148.) — W. B. Genge's flouring mill, at Lone Rock, Wis., was wrecked, on May 4, by the explosion of a boiler.

(149.) — On May 5, a tube ruptured in a water-tube boiler in the plant of the Columbia Chemical Co., Barberton, Ohio.

(150.) — A sawmill boiler belonging to Hill Brothers, exploded, on May 5, at Springfield, Ky. John Matherly was instantly killed and Rand Hill was injured.

(151.) — A boiler exploded, May 7, in the Shevlin-Carpenter mill, Minneapolis, Minn. Nobody was injured, but one side of the boiler house was blown out.

(152.) — On May 8, a boiler exploded in McIntyre Bros.' brickyard, just outside of Montgomery, Ala. Fireman Thomas King was instantly killed, and the place was wrecked.

(153.) — A header on a water-tube boiler exploded, on May 9, at the Fulton Bag and Cotton Mills, Atlanta, Ga.

(154.) — As the result of a collision on May 11, between a freight train and a passenger train on the Pennsylvania railroad at South Harrisburg, Pa., the boiler of the passenger locomotive exploded. Many were killed and injured as a result of the collision, but the boiler explosion did not cause any injuries, so far as we are aware.

(155.) — A slight boiler explosion occurred, on May 12, in the plant of the Jeanerette Lumber & Shingle Co., Jeanerette, La.

(156.) — The boiler of locomotive No. 654, on the Wabash railroad, exploded, on May 12, at Winston, four miles south of Litchfield, Ill. Engineer Harry Taylor was instantly killed, and fireman Charles Clark and brakeman L. F. Redman were fatally injured.

(157.) — On May 16, an oil-well boiler exploded in the township of Knox, Ohio. Henry Staneart, Daniel Doss, and another man named Soales were injured.

(158.) — Peter Becker's slaughter house, at Garner, Iowa, was wrecked by a boiler explosion on May 19. Fred Becker was seriously injured.

(159.) — A boiler gave way, on May 22, in the plant of the Independent Gas Co., at San Francisco, Cal. Edward Doufchim, a boiler maker, was seriously and perhaps fatally injured. He was engaged in the very dangerous operation of making repairs to the boiler while it was under pressure.

(160.) — On May 22, a boiler exploded in one of the mills of the Neibergall Stave & Lumber Co., at Staples, near Comber, Ont. Ralph Welsh was killed, engineer Robert Fisher received injuries which were reported to be fatal, and Robert Reilly, Oliver Rondol, Oliver Chevalier, Joseph Dos, James Bailey, John Kelly, and George St. Pierre were also injured in a lesser degree. The building was demolished.

(161.) — The boiler of freight locomotive No. 41, of the Hocking Valley railroad, exploded, on May 22, near the roundhouse in Columbus, Ohio. Frederick A. Grumley, Jacob Davis, Amos Speakman, Godfrey Schudel, Edward Chapman, and Edgar Kyle Hand were instantly killed, and Ira Kainer was severely burned.

(162.) — A heating boiler exploded, on May 23, in St. Michael's Hospital, Toronto, Ont. John Mahoney, the elevator man, was badly burned and scalded, and the hospital was damaged to the extent of about $2,000.

(163.) — A small boiler exploded, on May 23, in Isaac A. Sheppard's stove factory, on the corner of Peck slip and Pearl street, New York City. James Main was badly injured. The property loss was only a few hundred dollars.

(164.) — A boiler exploded, on May 23, in the State Capitol office at Guthrie, O. T. Fireman R. W. Cahill was fatally scalded.

(165.) — A boiler exploded, on May 24, in the Ammett Manufacturing Company's plant, at Squantum, two miles east of East Jaffrey, N. H. Nobody was injured, but a two-story brick addition to the main building was thrown down, and the property loss amounted to $10,000.

(166.) — On May 26, a boiler exploded in the Licking Rolling Mills, at Covington, Ky. Frank E. Morey was seriously injured.

(167.) — The boiler of a combination dredge and pile driver, belonging to the Charleston Terminal Company, exploded, on May 27, at the north pier of the Clyde Steamship Company, Charleston, S. C. Fireman Peter Johnson was killed, and leverman John Dingate was injured. The dredge was wrecked, and surrounding property was also badly damaged.

(168.) — A boiler exploded, on May 27, in the plant of the Hilton Lumber Company, at Wilmington, N. C. Fireman W. H. Corbett was killed, and the plant was damaged to the extent of about $10,000.

(169.) — On May 30, a boiler exploded in the Barron heading and stave mill, at Barron, Wis. Walter Stowell and Oscar Peterson were badly injured. The boiler and engine rooms were wrecked.

(170.) — On May 30, two tubes ruptured in a water-tube boiler at the power plant of the Stark Electric Railway Company, Alliance, Ohio. Nobody was injured, and the property damage was confined to the boiler.

JUNE, 1905.

(171.) — On June 5 a boiler used in connection with an oil well exploded on the G. W. Ward farm, near Rehoboth, Ind. Edward Grove was seriously injured, and the building in which the boiler stood was wrecked.

(172.) — On June 5 a tube failed in a water-tube boiler at the Cohn-Gardiner Paper Company's plant, Middletown, O. The fireman was scalded.

(173.) — A slight boiler explosion occurred, on June 6, at the Emma furnace of the American Steel & Wire Company, Cleveland, Ohio. James A. Donahue, William McBride and one other man whose name we have not learned, were killed, and two others were seriously injured.

(174.)—A tube ruptured, on June 8, in a water-tube boiler in the Allegheny County Light Company's plant, Twelfth and Etna streets, Pittsburg, Pa. Martin Fahey was severely scalded.

(175.) — On June 10, the boiler of freight locomotive No. 635, of the New York, New Haven & Hartford railroad, exploded at Wollaston, Mass. Brakeman John C. McKay was seriously injured. Several cars of the train (which was headed for Brockton, and known as the "shoe freight") were wrecked.

(176.) — A slight explosion occurred, on June 10, at the McCoy Brick & Tile Company's plant, Augusta, Ga.

(177.) — On June 13 a tube failed in a water-tube boiler in the power house of the Pittsburg Railways Company, on Twentieth street, Pittsburg, Pa. Fireman Jacob Stark was scalded.

(178.)—A fifty horse-power boiler used for operating a pumping engine exploded, on June 16, at Traveskyn, two miles from Bridgeville, Pa. The boiler was thrown 400 feet.

(179.)—Two tubes collapsed, on June 16, in a boiler in E. E. Bain's Planing mill, at Greensboro, N. C.

(180.) — On June 17 a boiler exploded in Henley Fugate's sawmill, on Big Branch, ten or twelve miles from Jackson, Ky. Fireman Holt Fugate and a man named Wells were killed.

(181.) — A boiler belonging to J. B. McDonald, the subway contractor, exploded, on June 18, at 165th street and North River, New York City. Fireman James Morgan was injured so badly that he died during the following night, and Engineer Daniel Barry was injured quite seriously. John Amato, Edward Elmore, Edward Alteneser, Archibald Felton, and Ethel Stay received treatment in the J. Hood Wright hospital, and at least eight other persons received minor injuries. The property loss was estimated at $50,000.

(182.) — A flue failed, on June 18, on the steamer *Yates,* on Lake Keuka, at Penn Yan, N. Y.

(183.) — The boiler of a locomotive on the New York Central railroad exploded, on June 19, at St. Johnsville, N. Y. Fireman Robert Wilkins and Brakeman John Nellis were fearfully injured, and at last accounts both men were in a critical condition.

(184.)—On June 19 a boiler exploded in the Geddis & Haefele sawmill at Hazleton, Ind. Nobody was injured, but the mill was considerably damaged.

(185.) — A small boiler used in drilling a gas well on the farm of William Perry, five miles east of Alexandria, Ind., exploded on June 21. Parts of the boiler were thrown hundreds of yards, but nobody was injured.

(186.) — On June 21 the famous Twentieth Century Limited train on the Lake Shore railroad was wrecked at Mentor, Ohio, owing to the misplacement of a switch. The boiler of the locomotive drawing the train exploded and added to the wreckage. The escaping steam scalded many of the injured, and rendered the work of rescue very difficult.

(187.) — A slight boiler explosion occurred, on June 22, on a dredge boat owned by Fox & Smith, at Sioux City, Iowa.

(188.) — A boiler exploded, on June 22, in the Attalla-Curtis Lumber Company's mill, two miles from Attalla, Ala. William Rosson, Marion Maddox, James Watts, and J. A. Gash were killed, A. W. Smith was fatally injured, and R. M. Wood, A. W. Crabtree, and Bernard Works were injured severely, but not fatally. The mill was completely wrecked.

(189.)—Three tubes ruptured, on June 23, in a vertical boiler in M. J. Putman's market, at Dunlap, Iowa.

(190.) — The boiler of a logging locomotive belonging to the E. E. Jackson Lumber Company exploded, on June 23, at Riderville, near Selma, Ala. Engineer

R. P. Moore was instantly killed, Fireman Grant Peoples was fatally injured, and two other employes whose names we have not learned received injuries of lesser magnitude.

(191.) — On June 26 a tube burst in a water-tube boiler in the hat manufacturing plant of The John B. Stetson Company, Philadelphia, Pa. Nobody was injured.

(192.) — A boiler exploded, on June 27, in W. D. McDowell's sawmill, fifteen miles west of Hot Springs, Ark. W. D. McDowell was instantly killed, and his son, John McDowell, was fatally injured. D. Mathias and H. G. Muncrief were also injured, though less seriously. The mill was totally wrecked, and the machinery destroyed.

(193.)—On June 27 a tube pulled out of the drum of a water-tube boiler in the plant of the Inland Steel Company, at Indian Harbor, Ind. Fireman Michael Boyan was slightly injured.

(194.)—A boiler exploded, on June 28, in the Higgins Oil & Fuel Company's pumping station, at Batson, Tex. Fireman Ivy Brown was injured so badly that he died a few hours later. There was considerable property damage.

(195.) — A boiler exploded on June 29, on Ex-Congressman Isaac Watson Stephenson's steam yacht *Bonita,* on Green Bay, Lake Michigan, near Menominee, Mich. The fireman was badly and perhaps fatally burned, and several of the passengers received slight injuries.

JULY, 1905.

(196.)—The boiler of a locomotive attached to a freight train on the Canadian Pacific railroad exploded, on July 1, at Kincorth, near Maple Creek, Manitoba. Engineer Barrett, Fireman Pritchard, and Brakeman Smyth were badly injured.

(197.) — On July 2 a heating boiler exploded in the apartments of Mrs. L. L. Bowers, at Newtonville, Mass. Nobody was injured, but the property loss amounted to about $1,200.

(198.) — Four men were killed and seven injured, on July 3, by the explosion of a threshing machine boiler near Axton, Henry county, Va. It was reported, at last accounts, that several of the injured would die.

(199.)—On July 5 a tube ruptured, and six headers fractured, in a water-tube boiler in the plant of the Fairbanks Company, Springfield, Ohio.

(200.) — The boiler of a logging locomotive belonging to Olive, Sternenberg & Company exploded, on July 5, at Olive, Tex. A fragment of the boiler weighing 300 pounds was blown to a distance of nearly 1,000 feet from the original site of the boiler.

(201.) — A boiler exploded, on July 6, in the Richmond pop factory, at Richmond, Ky. Frank Dudley was killed.

(202.) — A boiler exploded, on July 7, in the Spiking mill, at Goldfield, Cal. J. H. Spiking and Taylor Bayles were fatally injured, and the mill was totally wrecked.

(203.) — A tube ruptured, on July 7, in a water-tube boiler in the Juniatte street plant of the Pittsburg Railways Company, Allegheny City, Pa. Fireman Jesse Caskins was scalded about the face and arms.

(204.) — On July 7 a boiler exploded in a sawmill at Beattyville, Lee county, Ky. Wesley Cornelius (the owner of the mill) was fatally injured.

(205.) — A tube exploded, on July 9, in a water-tube boiler in the power house of the Kokomo, Marion & Western Traction Company, at Kokomo, Ind.

(206.)—A boiler exploded, on July 10, in Couch's sawmill at Golightly, Madison county, Ala. Allen Hall, Frank Wallace, and Edward Beach were killed, and several other persons were injured. The mill was demolished.

(207.) — A slight boiler explosion occurred, on July 11, in the plant of the Willmar Milling Company, at Willmar, Minn.

(208.) — A boiler exploded, on July 12, in a laundry on Central avenue, San Francisco, Cal. Raphael Monrepose was very seriously injured, and Henry Bourie (owner of the laundry), Mrs. Henry Bourie, Ignatius Bourie, Peter Bourie, and Miss Mary Lauchere received lesser injuries. The building was wrecked.

(209.) — A blow-off pipe ruptured, on July 13, on a boiler belonging to Lewis Brothers, on Monroe street, Newark, N. J.

(210.) — On July 14 the boiler of George S. Ramsburg's traction engine exploded near Bethel Church, Frederick county, Md. William H. Baugher, Freeman Huyett, and Spencer Ramsburg were seriously injured.

(211.) — Joseph Severn was fatally injured, and Eugene Renaud was seriously injured, on July 14, by the explosion of a boiler in the pulp mills at Hawkesbury, Canada.

(212.) — By the explosion of a traction engine boiler at West Lincoln, Neb., on July 14, William Allison was injured so badly that he died a day or two later. Frederick A. Howard, Frank Kirkham, and Philip Thompson were also injured seriously.

(213.) — The boiler of an Atchison, Topeka & Santa Fé freight locomotive exploded, on July 15, at Kingman, Ariz. Engineer Frank C. Copeland and Fireman C. B. Bryant were killed, and the locomotive was completely wrecked.

(214.) — On July 16 a slight boiler explosion occurred in the plant of the Wichita Ice & Cold Storage Company, at Wichita, Kan.

(215.) — The boiler of a traction engine exploded, on July 16, six miles northeast of Bluff City, Kan. Daniel Tobias and John Huddleson were fatally injured, and Roy Wyckoff received lesser injuries.

(216.) — A tube exploded, on July 17, in a water-tube boiler in the power house of the Georgia Railway & Electric Company, at Atlanta, Ga.

(217.) — A boiler exploded, on July 18, in the plant of the Pine Bluff Light & Water Company, at Pine Bluff, Ark. Engineer E. M. Baker was seriously scalded.

(218.) — On July 18 a passenger train collided with a construction train, near Romeo, Ill., on the Atchison, Topeka & Santa Fé railroad. The boiler of the passenger locomotive exploded. One man was killed and another fatally injured; but these fatalities appear to have been due to the collision, rather than to the explosion of the boiler.

(219.) — The boiler of locomotive No. 534, of the Rock Island railroad, exploded, on July 20, near Bowie, I. T. Fireman Earl A. Brandon and Brakeman George Hall were scalded to death. (Five years ago, to a day, this same locomotive was in a head-on collision, which caused the death of three men, near Rush Springs, I. T.)

(220.) — The boiler of locomotive No. 790, of the Grand Trunk railway, exploded, on July 20, at Princeton, near Woodstock, Ont. Brakeman Robert Hutchison was killed, Fireman Duncan Martin received injuries from which, at last accounts, he was not expected to recover, and Engineer David Strickland was scalded slightly. The locomotive was wrecked.

(221.) — There was a slight boiler explosion, on July 21, in the plant of the Boston Forge Company, at East Boston, Mass.

(222.) — On July 21 a boiler exploded on the United States gunboat *Bennington*, in the harbor of San Diego, Cal. Sixty-two persons are known to have been killed, fourteen were injured very seriously, and twenty-six others were less seriously injured. A more detailed account of this terrible explosion will be given in the January issue of THE LOCOMOTIVE.

(223.)—A boiler exploded, on July 24, in the Norwich Silk Company's factory, at Thamesville, near Norwich, Conn. Engineer Joseph E. Hopkins was killed, and the property loss was about $1,500.

(224.) —A blow-off pipe burst, on July 25, in the Eureka Lumber Company's plant, at Washington, N. C. Fireman Battle Barnes was scalded.

(225.) — The boiler of a traction engine exploded, July 25, on Henry Rehe's farm, near Howesville, W. Va. Edward Greaser was killed, and a son of Mr. Rehe was severely injured.

(226.) — A boiler exploded, on July 26, in Chester Dumont's sawmill, seven miles east of Stanwood, Mich. Engineer George Foreman was instantly killed, and Hiram Hopkins received injuries from which it was thought he might not recover. Several other persons received minor injuries, and the mill was destroyed.

(227.) — On July 27 a tube burst in a water-tube boiler in the Helmbacher plant of the American Car & Foundry Company, at Madison, Ill. Fireman John Powell was injured.

(228.) — On July 27 a tube exploded in a water-tube boiler in the plant of the Virginia Portland Cement Company, at Frederick, Va. Hoyt Carr was scalded.

(229.) — A boiler exploded, on July 28, in the Kee & Chapel creamery at Batavia, Ill. The plant was considerably damaged, but nobody was present at the time.

(230.) — On July 29 a tube exploded in a water-tube boiler in the plant of the Carbonic Dioxide Company, Canal and Lumber streets, Chicago, Ill.

(231.) — A boiler exploded, on July 29, in S. K. Bybee's sawmill, three miles from Columbia, Ky. Otha Bybee, a son of the owner, was injured so badly that at last accounts it was considered doubtful if he could recover.

(232.) — On July 30 a boiler used for hoisting purposes exploded at mine No. 7, Higbee, Mo. The engine and boiler rooms were wrecked, but nobody was injured.

(233.) — A roundhouse and coal chute belonging to the Illinois Central railroad at Chicago, Ill., were damaged somewhat, on July 30, by the explosion of the boiler of a Wabash locomotive. We have not learned further particulars.

Boiler Explosions during 1904.

We present, herewith, our usual annual summary of boiler explosions, giving a tabulated statement of the number of explosions that have occurred in the United States during the year 1904, together with the number of persons killed and injured by them. We desire to say, once more, that it is by no means easy to make out accurate lists of boiler explosions, because the accounts that we receive are often unsatisfactory; but, as usual, we have spared no pains to make the present summary as nearly correct as possible. In preparing the detailed monthly lists upon which it is based (and which are published regularly in The Locomotive), it is our custom to obtain as many distinct accounts of each explosion as possible, and then to compare these different accounts diligently, in order that the general facts may be stated with some considerable degree of accuracy. We do not pretend that this summary includes *all* of the boiler explosions of 1904. In fact, it is likely that only a fraction of these explosions is here represented; for many accidents have doubtless occurred that were not considered by the newspapers to be sufficiently "newsy" to interest the general public, and many others have doubtless been reported in local papers that we do not see.

The total number of boiler explosions in 1904, according to the best information we have been able to obtain, was 391, which is 8 more than were recorded for 1903. There were 383 in 1903, 391 in 1902, 423 in 1901, and 373 in 1900. In several instances during the year 1904 two or more boilers exploded simultaneously. In every case of this sort we have counted each boiler separately in making out the summary, believing that by so doing we should represent the actual damage more accurately than we should if we simply recorded the number of separate occasions on which boilers have exploded. The difference in the figures, as given by these two methods, however, is trifling.

The number of persons killed in 1904 was 220, against 293 in 1903, 304 in 1902, 312 in 1901, and 268 in 1900; and the number of persons injured in 1904

Summary of Boiler Explosions for 1904.

Month.	Number of Explosions.	Persons Killed.	Persons Injured.	Total of Killed and Injured.
January,	48	23	46	69
February,	35	20	23	43
March,	34	12	22	34
April,	27	9	34	43
May,	19	17	31	48
June,	25	11	28	39
July,	27	8	18	26
August,	36	23	46	69
September,	20	21	28	49
October,	29	21	34	55
November,	37	25	40	65
December,	54	30	44	74
Totals,	391	220	394	614

was 394, against 522 in 1903, 529 in 1902, 646 in 1901, and 520 in 1900. We sincerely hope that the improvement here signalized may be permanent, though we fear, from the irregularity observable in the past, that the data afforded by the year 1904 will prove to be merely a temporary improvement, due to the vagaries of chance, and that the reports for future years will be as bad as heretofore.

We are well aware that it would greatly increase the interest of this annual summary to give some estimate of the total property loss from boiler explosions during the year. We are often asked about this point, and we should be glad to give the desired information if we could get it. Usually, however, it is very difficult to obtain reliable estimates of the loss resulting from a boiler explosion, unless the boiler is insured; and hence it is impossible to arrive at any trustworthy figures for the total destruction of property for the year.

THE Bureau of Manufactures, of the department of Commerce and Labor, Washington, D. C., has issued a circular intended to aid in the extension of the foreign trade of the United States. The Bureau proposes to establish a comprehensive card index containing information that will be of service to manufacturers and intending purchasers, and the circular referred to is intended to facilitate the preparation of this index. The idea strikes us as being a most excellent one, and all manufacturers are advised to procure a copy of the circular from the Bureau of Manufactures, and fill out the blanks. The trouble involved is slight, and it may lead to a considerable extension of business.

Inspectors' Reports.

On pages 229 and 230 we present a general summary, by defects, of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company, during the months of January, February, March, April, May, June, July, and August, 1905. We also give, below, a summary for these months, showing the number of visits of inspection made, the total number of boilers examined, the total number inspected internally, the number tested by hydrostatic pressure, and the number of boilers condemned.

YEAR 1905.	JANUARY.	FEBRUARY.	MARCH.	APRIL.
Number of visits of inspection, .	14,333	12,192	14,145	12,721
Total number of boilers examined,	26,995	23,370	25,513	23,280
Number inspected internally, .	8,191	7,026	8,675	10,567
Number of hydrostatic tests, .	725	654	957	1,006
Number of boilers condemned, .	51	39	73	93

YEAR 1905.	MAY.	JUNE.	JULY.	AUGUST.
Number of visits of inspection, .	12,923	13,089	13,020	12,090
Total number of boilers examined,	24,239	22,611	23,612	21,176
Number inspected internally, .	10,526	11,148	13,180	9,994
Number of hydrostatic tests, .	1,115	1,340	1,344	1,393
Number of boilers condemned, .	87	75	95	56

Inspectors' Reports for January, February, March, and April, 1905.

Nature of Defects.	January.		February.		March.		April.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,240	80	1,135	70	1,467	116	1,758	141
Cases of incrustat'n and scale,	2,940	94	2,497	79	3,111	99	3,723	105
Cases of internal grooving, .	181	18	202	6	222	26	287	21
Cases of internal corrosion, .	830	57	661	28	947	51	1,109	55
Cases of external corrosion, .	670	60	553	41	814	60	982	70
Defective braces and stays, .	162	38	148	28	178	55	179	32
Settings defective, . .	483	49	343	33	421	48	560	61
Furnaces out of shape, .	612	18	425	17	519	25	715	26
Fractured plates, . . .	298	62	253	44	333	59	352	74
Burned plates, . . .	395	64	379	59	461	54	442	53
Laminated plates, . .	80	6	42	3	62	11	86	11
Cases of defective riveting,	295	51	360	56	362	29	328	68
Defective heads, . . .	99	16	101	14	148	34	145	11
Leakage around tubes, .	897	80	746	61	1,016	154	1,013	129
Cases of defective tubes, .	156	37	70	22	301	57	351	78
Tubes too light, . . .	6	1	21	8	41	11	42	12
Leakage at joints, . .	571	36	405	24	573	50	538	30
Water-gauges defective, .	317	57	272	70	239	96	320	80
Blow-offs defective, . .	347	100	383	85	432	104	485	123
Cases of deficiency of water,	25	10	12	6	68	9	21	13
Safety-valves overloaded, .	142	49	95	22	127	41	96	24
Safety-valves defective, .	126	38	116	16	121	52	142	42
Pressure gauges defective, .	550	51	486	36	628	57	646	58
Without pressure gauges, .	14	14	22	22	16	16	41	41
Unclassified defects, . .	0	0	0	0	0	0	0	0
Totals, . . .	11,436	1,086	9,727	850	12,607	1,314	14,361	1,358

Inspectors' Reports for May, June, July, and August, 1905.

Nature of Defects.	May.		June.		July.		August.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,692	110	1,639	95	1,779	113	1,527	103
Cases of incrustat'n and scale,	3,855	129	3,587	75	4,086	96	2,919	88
Cases of internal grooving, .	314	24	250	19	286	38	247	22
Cases of internal corrosion, .	1,208	47	1,533	49	1,821	76	1,176	52
Cases of external corrosion, .	865	65	1,079	63	1,175	78	943	88
Defective braces and stays, .	178	42	222	56	186	52	159	42
Settings defective, . .	586	63	519	50	684	52	510	45
Furnaces out of shape, . .	747	36	791	22	714	25	636	15
Fractured plates, . . .	291	42	200	35	332	50	290	44
Burned plates, . . .	462	36	405	26	545	53	403	26
Laminated plates, . .	92	5	97	1	117	21	58	5
Cases of defective riveting, .	291	46	222	36	292	54	274	59
Defective heads, . . .	146	19	169	13	174	27	245	16
Leakage around tubes, . .	1,054	69	856	86	1,167	233	1,065	147
Cases of defective tubes, .	292	70	376	59	572	293	518	162
Tubes too light, . . .	59	16	37	6	59	7	89	42
Leakage at joints, . .	537	37	477	28	540	26	521	40
Water-gauges defective, .	312	81	256	73	252	71	230	49
Blow-offs defective, . .	428	106	385	69	424	101	373	103
Cases of deficiency of water,	23	6	16	4	27	12	20	9
Safety-valves overloaded, .	122	42	93	27	105	39	122	36
Safety-valves defective, .	127	27	138	31	91	20	95	31
Pressure gauges defective, .	650	38	595	25	782	53	627	34
Without pressure gauges, .	21	21	12	12	12	12	8	8
Unclassified defects, . .	6	3	1	1	0	0	0	0
Totals, ...	14,358	1,180	14,045	961	16,222	1,602	13,055	1,266

The Locomotive.

FOUNDED BY J. M. ALLEN, A.M., M.E.

HARTFORD, OCTOBER 15, 1905.

THE LOCOMOTIVE *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each. (*Any volume can be supplied.*)

Obituary.

MR. EUGENE GESLEY CHAMBERLIN.

We regret exceedingly to have to announce the death of Mr. Eugene Gesley Chamberlin, Assistant Manager in our Northwestern Department. He was born on November 24, 1848, at Northfield, Michigan, and was descended, on both sides of the family, from old New England ancestors. When very young he removed with his parents to Monroe, Michigan, where he received a common school education. His work with the Hartford Steam Boiler Inspection and Insurance Company began early in 1879, in our Boston office, where he remained until March, 1893, when he was transferred to the Chicago office, as Assistant Manager, a position which he has held since that date. His health began to fail perceptibly during the winter of 1903-04, from arterio-sclerosis. He was completely prostrated by a severe attack on April 3, 1904, from which, however, he partially recovered. A second similar attack followed on June 5, of the same year, and after that time he remained in a critical condition, until his death on September 1, 1905.

Mr. Chamberlin was a member of the First Unitarian Church of Chicago. He had a most kind and amiable nature, and was courteous, honorable, and gentlemanly in all his dealings, and faithful and efficient in the discharge of his duties. He will be greatly missed by all his many friends.

"The Needle's Eye."

Our genial and capable friend, Mr. F. R. Low, editor of *Power,* has an editorial on the *Bennington* disaster in the October issue of his paper, in the course of which he says: "There must be somebody in responsible charge of the steam apparatus and steam machinery who has been brought up on a diet of coal dust, boiler scale, iron rust, and lubricating oil, instead of dignity, gold lace, and differential calculus; somebody who will be more punctilious about his safety-valves blowing off than about the jackies saluting as he passes; somebody who knows the tortuous way through a 9 by 11 manhole, and among the braces and stays, and how to keep his head and breath and patience in a stifling back-connection, as well as the other fellow knows navigation and tactics and international etiquette." In a general way we approve of these sentiments, though we should not necessarily object to the man if he added pie to the rather severe bill of fare that is permitted above.

But we don't think that unfamiliarity with the intricacies of a 9 by 11 manhole ought to be fatal to his prospects. We have an inspector who is exactly six feet six inches in height, and he is a very good man. Of course we do not expect him to go through any manhole *cross-wise,* but the point is, that he is built laterally on a plan that is in harmony with his longitudinal dimension.

There is an old story about a king who made every traveler welcome, entertained him royally, and sent him to bed in the chamber of state, and all without a penny of expense to him. But there was only one bed for all comers. If the traveler happened to fit his bed, he was in luck; for if he was too long he was cut off to the proper length, and if he was too short, he was correspondingly stretched.

We suppose we could have an official Shylock to trim off the projecting curves and angles of such otherwise good inspectors as happened to be too stout to comply with the proposed specification, but we do not regard this plan with entire favor, because we do not wish to reduce our inspection force, even piecemeal. Perhaps Mr. Low had this difficulty in mind when he made out his bill of fare; for on a menu of the character that he outlines, we should imagine that the patient, like Cassius, would ultimately have a "lean and hungry" look, and be able to go through a 9x11 manhole, or most anything else. We are inclined to the belief that a better way would be, to follow the practice of the old king, and stretch the plethoric inspector until he calipered right. This would interest the theoretical mechanic, too, for we are not aware that the Poisson ratio of an inspector has ever yet been determined; and it would be a distinct addition to the theory of elasticity, if we could learn how much an inspector would contract in diameter, per foot of extension in length.

We guess that the best way of all would be, to have a drawing-plate made of just the right size, and then catch the inspector's heels with a stout pair of tongs, and draw him down to size. Some inspectors could hardly be drawn to size in one operation, but by repeated passes through a series of plates the thing could be done, especially if the subject were carefully annealed from time to time. The operation might make the inspector "hot", but that could be remedied by liberal applications of soapy water.

Low Water.

In a recent issue of a technical journal we read the following: "The Hartford Steam Boiler Inspection and Insurance Company records for 1904 show a total number of boiler defects of 154,282, out of which 20 per cent., or 29,630 cases, were directly or indirectly due to low water or to wide variations in water lines in boilers."

In looking over our records, as published in THE LOCOMOTIVE for April, 1905, to see how these figures were obtained, we find that the 29,630 defects said to be due directly or indirectly to low water, are apparently computed as follows:

Cases of low water,	290
Burned plates,	5,642
Blistered plates,	1,148
Fractured plates,	3,983
Cases of leakage at seams,	6,581
Cases of leakage at tube-ends,	11,986
Total,	29,630

Now, many of the defects here tabulated were certainly not due to low water. Consider, for example, the last one on the list. Low water is quite competent to produce leakage around the ends of the tubes at the back end of the boiler, but in most cases such leakage is due rather to the accumulation of scale on the back head. There may be plenty of water in the boiler, but the scale, by preventing the water from coming into contact with the tubes and the head, where they join, allows the metal at this point to become overheated, and leakage is the result. Similarly, burned plates are most commonly due to the deposit of scale upon the sheets, the water being thereby kept away from the plate, with the result that burning occurs even when three gauges of water are present in the boiler. Blisters and laminations in plates have no necessary connection with low water, but usually (and perhaps invariably) result from imperfections in the plates themselves. Leakage at seams, too, may be due to such a cause as the chilling action of cold feed water. The effect of cold feed water in straining a boiler shell is demonstrated experimentally in the leading article of The Locomotive for May, 1894. We would also refer to the article on this same subject on page 42 of the issue of The Locomotive for March, 1893.

We do not make these remarks for the purpose of criticising the journal in which the quoted figures were given, but merely in the interest of accuracy. There is a very common impression that low water is responsible for most of the ills that befall boilers, and, as our experience has shown that this is not the case, we wish to call attention to the fact that our records do not show what they are said to show, above. Low water is doubtless a serious thing, but there are many other serious things about steam boilers, too.

With this number we complete the second year of the issue of The Locomotive as a quarterly. The numbers published during 1904 were not bound up, as has been usual in the past, nor was any index or title page issued for that year. The eight numbers issued during 1904 and 1905 together constitute Volume 25 of The Locomotive and an index covering these two years is in preparation, and will be sent, free of charge, to those of our readers who preserve their copies for binding, and who make application for it at the Hartford office of the company. The eight numbers referred to will also be bound into one volume, shortly, which may be had at the usual price of one dollar, postage prepaid.

The *Youth's Companion,* of Boston, Mass., recently published a story based upon the leading article in the issue of The Locomotive for January, 1905. The story told of how a line of steam pipe was erected with bolts that were too short, and that the inspector who looked the job over objected to the short bolts, and required that they be taken out and replaced by others of proper length, on the ground that the short ones were distinctly dangerous. The workman who was to make the change did not put in new bolts, but merely screwed some stub ends into the nuts, so that the job would have the appearance of being safe, although no really essential change had been made in it. The inspector, upon visiting the plant subsequently, detected the fraud, and the work was then done over again, and properly. We illustrated this thing, and gave a full account of it; and it would have pleased us to have the *Companion* give us the honest credit for it, that we extend to that paper when we make abstracts from it, whether those abstracts are literal or not. But there were some features of the *Companion's* tale for which we should not want to be considered responsible. In the first place, the plant in which the job was done was *not* a "western" one. In the next place, the *Companion* tells about the dismissal of the rascally workman who did the thing, and then adds that he later came back to the contractor who had employed him, with a paper describing the Brockton explosion, saying that he had been dreaming of that explosion, and wondering if there was anywhere a piece of his own work that might cause such a terrible catastrophe. The story goes on that the contractor, properly impressed by the man's penitence, and satisfied that he would never shirk again, took him back to work.

We are of the impression that this last part of the story is made up out of whole cloth. At all events, we never heard of it before. It may make a good yarn for the instruction of children, but it rather shook the confidence that we had previously had in the reliability of the *Youth's Companion*.

WE do not need to say that the Hartford Steam Boiler Inspection and Insurance Company is very well known through the United States. We had a recent illustration of this fact, however, which may be worth narrating. Mr. Edward Sullivan represents this company in Kansas City, Mo., and a patron in Sterling, Kan., who knows him well but could not recall his last name at the time, sent him a telegram a short time ago, addressed simply to "Ed Hartford," of Kansas City. This telegram was delivered as promptly as though it were addressed fully and correctly.

THE widening use of tungsten and the consequent rapidly increasing demand have led to high and still rising prices, and to energetic prospecting in many parts of the world. The principal use of tungsten at the present time, according to the *Engineering and Mining Journal*, is in the production of what is called self-hardening steel. For this purpose it is added in the proportion of from 5 to 8 per cent. When used in tool steel the alloy retains its hardness even when heated to temperatures which would quickly destroy the temper of ordinary high-carbon steel. Tungsten steel may be used for armor plates. An alloy of 35 per cent. tungsten and 65 per cent. steel will make a shell for lead bullets of much higher penetrating power than ordinary lead. Metallic aluminum can be advantageously hardened with tungsten, its resistance to oxidation making it much superior to copper. A small percentage of tungsten will also greatly increase the carrying power of spring steel. The steel used in the manufacture of permanent magnets for electrical meters contains from five to six per cent. of tungsten. Tungsten steel is also used for the sounding plates of pianos. Among the minor uses, tungsten compounds are frequently employed to make vegetable tissues incombustible, and they enter into the composition of the fluorescent screens used in X-ray observations. Metallic tungsten has a specific gravity of 18.7; it is practically free from carbon, and may be welded and filed like iron. It is found in the market as a metal of from 95 to 99 per cent. purity, or alloyed with iron in the proportion of 37 per cent. and described as "ferro-tungsten." The world's yearly consumption at present amounts to something like 700 or 800 tons. The chief sources of tungsten are the minerals wolframite, hübnerite, and scheelite. Often the ore contains not more than 5 to 8 per cent. of metallic tungsten; and to be marketable it must be brought to an average of 50 to 70 per cent. of tungstenic acid, the unit basis of selling prices. — *Cassier's Magazine*.

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1905.

Capital Stock, ... $500,000.00.

ASSETS.

	Par Value.	Market Value.
Cash in office and in Bank,		$200,088.96
Premiums in course of collection (since Oct. 1, 1904),		173,296.65
Interest accrued on Mortgage Loans,		18,357.32
Loaned on Bond and Mortgage,		775,270.00
Real Estate,		16,390.00
State of Massachusetts Bonds,	$100,000.00	100,000.00
County, City, and Town Bonds,	372,000.00	389,700.00
Board of Education and School District Bonds,	46,500.00	48,500.00
Drainage and Irrigation Bonds,	7,000.00	7,000.00
Railroad Bonds,	1,111,000 00	1,238,940.00
Street Railway Bonds,	60,000.00	62,650.00
Miscellaneous Bonds,	55,500.00	56,905.00
National Bank Stocks,	41,800 00	57,100.00
Railroad Stocks,	176,900 00	235,247.00
Miscellaneous Stocks,	35,500.00	33,100.00
	$2,005,300.00	
Total Assets,		$3,412,544.93

LIABILITIES.

Re-insurance Reserve,		$1,811,665.96
Losses unadjusted,		55,833.25
Commissions and Brokerage,		34,679.33
Surplus,	$1,010,366.39	
Capital Stock,	500,000.00	
Surplus as regards Policy-holders,	**$1,510,366.39**	1,510,366.39
Total Liabilities,		$3,412,544.93

On December 31, 1904, the Hartford Steam Boiler Inspection and Insurance Company had **91,137** steam boilers under insurance.

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J. B. PIERCE, Secretary. L. F. MIDDLEBROOK, Asst. Sec'y.

C. S. Blake, Supervising General Agent.
E. J. Murphy, M.E., Consulting Engineer.

Board of Directors.

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CHARLES M. BEACH, of Beach & Co.
GEORGE BURNHAM, Baldwin Locomotive Wks. Philadelphia.
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